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Foreword

The papers on the following pages were presented and discussed at a workshop on “Modelling aspects of the inflation process and the monetary transmission mechanism in emerging market countries”, held at the BIS on 15-16 January 2001. It was the first time that the BIS had arranged a meeting of this kind and twelve central banks from emerging market countries had accepted to participate in the workshop with papers or as discussants. Four papers by the BIS staff are also included in this volume.

The workshop had three sessions on specific modelling aspects, with the first focusing on modelling the inflation process in emerging market countries; the second on estimating the impact of asset prices and the pass-through of exchange rate movements; and a third devoted to modelling the transmission mechanism. In a final session, participants discussed policy implications and areas of future work. Four main conclusions emerged from the papers and the discussion. First, lack of reliable data or of data series with sufficient length often force researchers to rely on small models rather than large, fully specified macro-models. Second, in virtually all countries, a major problem is finding a robust link between the output gap and the rate of inflation. Third, several papers found a marked decline in the pass-through of exchange rate changes into domestic prices, though some uncertainty remains as to the sustainability of the change. Fourth, several papers also found a surprisingly large influence of administered prices on overall inflation, raising concerns over the ability of central banks to tightly control inflation.

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What determines inflation in emerging market economies?

M S Mohanty and Marc Klau[1]

1. Introduction

Two major developments marked the monetary sector in emerging market economies (EMEs) in the 1990s. One was the steady decline in the inflation rate to low levels in the second half of the decade. The other was the growing preference for conducting monetary policy based on inflation targeting. For example, average inflation in 10 of the 14 EMEs discussed in this paper[2] declined to a single digit rate in the second half of the 1990s, compared to only four in the first half. By the end of 2000, over half had switched to direct targeting of inflation. This change has meant a significant shift in the emphasis given to price stability in the monetary policy framework in EMEs as well as in the approach to controlling inflation. To be sure, this has underlined the key role for the central banks in the determination of inflation.

To understand the role of monetary policy in EMEs, it is crucially important to know the factors which determine inflation in these economies. Often two, rather different, claims are made regarding the inflation process in EMEs. First, inflation is hard to predict because it is affected by several non-monetary factors, most notably frequent supply shocks. These shocks tend to complicate the monetary transmission mechanism by blurring the role of demand side factors in the inflation process. In addition, as these factors are not easy to control and not enough information is available, it is often difficult for the central bank to be sure about their exact impact on the general price level and to take account of them in formulating monetary policy. The other view is that non-monetary factors influence only the short-run path of inflation. In the long run, monetary variables determine the inflation rate. Therefore, it is argued, the standard output gap models should provide a reasonable explanation of the inflation dynamics in EMEs. This also explains why central banks should worry about the current and future path of aggregate demand in the economy.

The reality for EMEs may, however, lie somewhere between the two paradigms. Empirical studies have not resolved the debate surrounding the causes of inflation in developing economies, particularly when it is low. Research has, nevertheless, found that high inflation tends to be associated with monetisation of excessive fiscal deficits, aggravated by a high degree of indexation of wages and prices and frequent devaluation of the exchange rate. But with the inflation rate declining in recent years, a fresh look at the inflation process in EMEs is necessary to throw light on at least two important issues. First, what are the major factors behind the inflation process in EMEs? Second, what implications do these factors have for the conduct of monetary policy? The objective of this paper is to address these issues by analysing a quarterly model of inflation using more recent information. The paper follows an eclectic approach, where both demand and supply factors are seen to drive prices. However, the paper is not intended to be exhaustive in its examination of the factors that cause inflation in EMEs. In fact, depending on the country characteristics, there may be several other influences, which are either difficult to quantify or for which no satisfactory data are available.

The empirical results reveal that the conventional determinants of inflation, such as the output gap, excess money supply and wages, have a significant influence on inflation. However, their unique importance could not be established for all countries. Supply factors affect inflation in a large number

1 We are grateful to Palle S Andersen for his extremely valuable suggestions and comments at each stage of preparing this paper and to Stefan Gerlach for many useful and stimulating discussions on the inflation processes in EMEs. The errors that remain are solely ours. The views expressed in the paper are also our own and do not represent those of the Bank for International Settlements.

2 Brazil, Chile, the Czech Republic, Hungary, India, Korea, Malaysia, Mexico, Peru, the Philippines, Poland, South Africa, Taiwan (China) and Thailand.

of countries. Shocks to food prices emerge as the most common inflation determinant in almost all EMEs, followed by the exchange rate. In contrast, inflation and oil price shocks are only weakly associated. In some countries, monetary policy did not accommodate these shocks. Different degrees of adjustment of domestic oil prices to changes in international prices may have played an additional role in this outcome. An important implication of these findings is that to the extent that agricultural shocks and large unexpected movements in the exchange rate affect inflation and diminish the importance of demand management policy, they complicate the conduct of monetary policy and introduce considerable uncertainty regarding its impact on prices. The role of monetary policy is more transparent and its impact more effective when inflation is primarily driven by demand shocks and when demand changes can be accurately captured by indicators such as the output gap or monetary growth. In contrast, a significant influence of supply factors on prices raises issues about the appropriate target for policy. The dominance of agricultural shocks and exchange rate movements in the inflation process also highlights the need to liberalise agricultural trade to reduce the volatility of food prices, and to stabilise the exchange rate to promote price stability in EMEs.

The remainder of the paper is divided into four sections. Section 2 reviews price developments in 14 selected EMEs and discusses the main determinants of inflation. Section 3 develops the theoretical model, while Section 4 presents the empirical results. Policy implications are discussed in Section 5.

2. A review of trends and determinants of inflation in EMEs

Trends in the 1990s

Many EMEs have had a history of moderate to high inflation, typically associated with either expansionary fiscal and monetary policies and/or large depreciation of exchange rates.[3] Inflation rates in EMEs have been highly sensitive to various internal and external price shocks, particularly those arising from large changes in import and food prices. However, conditions changed over the 1990s and most EMEs managed to reduce their inflation rates considerably during the second half of the decade.

Table A1 in the annex shows the mean and standard deviation of the annual headline inflation rate in 14 EMEs during the 1970s, 1980s, and the first and second halves of the 1990s. What is evident from Table A1 is that inflation declined during the 1990s, the rate of decline being fastest during the second half. In the Asian economies, average inflation fell from a range of 5–15% in the 1970s to 2–8% in the second half of the 1990s, with most countries witnessing a gradual but slow rate of disinflation over this period. In Korea, mean inflation declined from 15% in the 1970s to only 4½% by the second half of the 1990s. This trend is broadly shared by Malaysia, Taiwan (China) and Thailand, where average inflation has not only stayed within a single digit range during the past three decades but to between 2 and 5% by the second half of 1990s. Compared to their Asian neighbours, India and the Philippines have experienced relatively higher inflation, which exceeded 8% and 10%, respectively, up to the mid-1990s, but then fell to below 8% in the latter half of that decade. The Asian crisis did not seem to pose a lasting problem on the inflation front. In the crisis-hit economies (Korea, Thailand, Malaysia and the Philippines), inflation did rise to high levels in 1998 but fell sharply in 1999 following the implementation of stabilisation programmes.[4]

Latin American countries have witnessed a much faster rate of disinflation. In Chile, average inflation declined from over 140% in the 1970s to about 6% during the second half of the 1990s. Chile's anti-inflation strategy has been helped by the implementation of a comprehensive structural reform programme to boost productivity, a conservative fiscal policy, a crawling exchange rate peg and an independent monetary policy. In Peru, inflation averaged 25% in the 1970s but then rose above 300%

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3 Following Dornbusch and Fischer (1993), we define a moderate and high rate of inflation as 15-30% and 30-100% annually, respectively, over at least three years.

4 In Indonesia, however, inflation declined only temporarily after the crisis. The recent burst of inflation there has been fuelled by rapid currency depreciation and rising fiscal deficits.

by the first half of the 1990s. However, helped by a stabilisation programme focused on reducing the fiscal deficit to a low level, abolishing wage indexation in the public sector and allowing the exchange rate to be market determined, Peru succeeded in reducing inflation to less than 4% in 1999.

Following several large devaluations of the currency and very high rates of growth of the money supply, Brazil recorded exceedingly high levels of inflation throughout the first half of the 1990s, even compared to the 1970s and the 1980s. However, a dramatic turnaround began in the second half of the 1990s and since 1997 the inflation rate has been in a range of 4–6%. This period coincided with the introduction of the Real Plan, implementation of major fiscal reform programmes and a tightening of monetary policy. The period also witnessed a significant overvaluation of the exchange rate, culminating in a large devaluation in early 1999. However, unlike previous episodes, the devaluation had only a moderate impact on the rate of inflation. In Mexico, inflation fell steadily to a single digit rate in 1993 and 1994. Following the crisis and a sharp devaluation of the currency, inflation rose again to over 30% in 1995 and 1996. However, helped by a stabilisation programme centred on reducing the fiscal deficit, stopping high wage inflation and allowing the exchange rate to move freely, Mexico succeeded in reducing inflation to a single digit rate by 2000.

A common aspect of the inflation process in the central European economies during the 1990s was the large-scale deregulation of prices following the transition to market economy. The average rate of inflation in Hungary rose from about 14% in the 1980s to over 25% in the first half of the 1990s, a period beset with two large devaluations, growing fiscal problems and large relative price shifts. Following a comprehensive fiscal stabilisation programme accompanied by monetary tightening and a switch to a preannounced crawling peg system in 1995, the inflation rate declined in the second half of the 1990s. In the Czech Republic, following a large devaluation and liberalisation of prices at the beginning of the 1990s, prices grew relatively fast during the first half of the decade. Between 1993 and 1997 the exchange rate peg played an important role in containing inflationary pressures. But in the face of large capital inflows and increases in wages far in excess of productivity growth, the currency came under pressure, resulting in a steep devaluation in May 1997 and subsequent abandonment of the exchange rate peg. The inflation rate rose to over 10% in 1998, but then fell to about 2% in 1999.

Poland experienced hyperinflation in the early part of the 1990s. Following a broad-based stabilisation programme including an exchange rate peg, Poland succeeded in arresting the rapid growth in prices. However, inflation stabilised within the range of 30–60%, reflecting pressures stemming from a crawling peg, backward-looking indexing of wages, high fiscal deficits, capital inflows and liberalisation of regulated prices. The subsequent stabilisation efforts, however, reduced the inflation rate to a single digit level by 1999.

South Africa experienced double digit inflation in the 1980s and the first half of the 1990s, reflecting high fiscal deficits, growing nominal rigidities in factor and product markets and a steady depreciation of the exchange rate. In 1993, inflation started to decline following the implementation of deeper structural reforms. Much of the improvement was concentrated in the years 1998 and 1999, when a greater degree of fiscal and monetary discipline was enforced.

Two distinct aspects of inflation in EMEs are clearly evident from the above discussion. First, different regions have witnessed different speeds of disinflation. In the Asian economies, inflation has fallen rather gradually over a long period and the volatility of inflation has been low. In the Latin American and central European economies, on the other hand, the recent decline in inflation has followed a period of rapid increase in prices. These countries have undergone a much sharper rate of disinflation and the volatility of inflation has remained high. Given the different experiences, an important question is how the inflation history affects the degree of inflation persistence. A second question is the extent to which any one or more factors were responsible for sustained increases or decreases in inflation. Fiscal policy in particular played a key role in the inflation process in many countries, while the influence of the exchange rate regime is more difficult to assess. A number of countries relied on a fixed exchange rate regime as their nominal anchor, but ultimately were unsuccessful in defending the peg. In others, disinflation has coincided with the introduction of a more flexible regime. One important aspect, which is not so clearly evident from the discussion so far, is the role that supply factors played in aggravating or dissipating price pressures in different countries. In what follows, a brief review of inflation determinants is presented to identify the transmission mechanism in the 14 economies.

Determinants of inflation

An important reason for sustained rates of high inflation in the EMEs is the vicious nexus between fiscal deficits, monetary growth and inflation (Montiel (1989), Dornbusch (1992) and Bruno (1993)). According to Burton and Fischer (1998), the average seigniorage revenue in the moderate-inflation economies was about 1.8% of GDP before stabilisation but declined to about 1.5% after inflation was reduced. This seigniorage revenue was associated with average fiscal deficit/GDP ratios and narrow money (M1) growth rates of 4% and 24%, respectively, before stabilisation and 0.3% and 12% after stabilisation.

However, differences in inflation performance cannot be attributed to differences in fiscal performance alone. The adaptability of fiscal systems to external shocks has been a contributing factor. For example, a low fiscal deficit and a relatively equal distribution of income (which facilitates sharper adjustment of fiscal deficits) in the East Asian economies are cited as important factors in their better inflation performance than the Latin American economies, which lack these conditions (IMF (1996)). A sound fiscal balance, though necessary, is not, however, a sufficient condition to rein in inflation if monetary policy remains loose and accommodates the private sector's excess demand for credit, as was the case in many East Asian countries before the 1997-98 crisis. Whatever the cause, excess demand arises if monetary growth remains higher than needed to support growth. A straightforward implication of this is that inflation will rise until real demand falls to the level consistent with potential output. Conversely, a sustained decline in inflation can be identified with a long-term improvement in the fiscal position and a lower rate of monetary growth that push actual output closer to potential. Changes in the output gap should, therefore, explain most of the policy-driven changes in inflation.

In contrast to the "fiscal" view of inflation, the "balance of payment" view emphasises the role of the exchange rate in the determination of domestic prices.[5] Conventional wisdom holds that countries that are prone to large external shocks should allow their exchange rate to move to correct the external disequilibrium. An important consequence of opting for a flexible exchange rate is that domestic prices are partly determined by the exchange rate. As a first-round effect, movements in the exchange rate directly affect inflation by changing the domestic currency price of imports. The second-round effect depends on how this initial shock is transmitted into other sectors through changes in costs and inflation expectations. Where maintaining domestic price stability takes precedence over external stability and the authorities opt for a fixed exchange rate regime, the exchange rate, of course, has no impact on inflation. In fact, the burden of adjustment to external shocks falls on fiscal policy.

Empirical evidence is, however, ambiguous on whether a fixed or a flexible exchange rate leads to lower inflation. Some cross-sectional studies show that inflation is lower under pegged exchange rate regimes than under flexible regimes (Edwards (1993) and Ghosh et al (1995)). But this result is typically true of fixed regimes that were not subjected to frequent adjustments. Others have attributed this result to lower rates of monetary growth in the fixed exchange regimes or what is called a "monetary disciplining effect" of the regime, and to the fact that a part of excess money growth may appear as a balance of payments deficit in the absence of an offsetting change in the exchange rate (Fielding and Bleaney (2000)). The latter effect is, however, only temporary since the external deficit will eventually require a correction. Ultimately, the inflationary impacts of a fixed exchange rate regime depend on the credibility of the regime, particularly in the context of an open capital account and financial imperfections such as a weak banking system (Kaminsky and Reinhart (1999)). Others argue that the inflationary consequences of the exchange rate depend on the nature of external shocks – temporary or permanent – and whether or not a real depreciation is warranted (Chang and Velasco (2000)). As Siklos (1996) concludes, countries with fixed regimes often experience higher, rather than lower, average inflation because the regimes are not credible. On the other hand, Quirk (1994) argues that differences attributed to the various exchange rate regimes tend to narrow once adjustments are made for the influence of other factors. The country experiences, nevertheless, show that, irrespective of regime, the exchange rate is an important determinant of inflation in a number of EMEs (Kamin and Klau (2001)).

A third important factor is the rate of wage inflation. The role of wages in inflation dynamics in EMEs has received attention from two major angles. One is that an exogenous wage shock can lead to cost-push inflation if the monetary authorities follow an accommodative policy. The other is that the

[5] See Montiel (1989) for a discussion on the two schools of thought.

backward-looking indexing mechanism, by which current wages follow past inflation, can give rise to strong persistence effects. Dornbusch and Fischer (1993) note two specific features of the indexation mechanism in the high- to moderate-inflation economies that could produce such effects. First, indexation encourages longer-term contracts, which make the inertia effect particularly strong. Second, the typical indexing formula tends to make real wages a negative function of inflation, implying that real wages and unemployment increase when the inflation rate is reduced. The resulting output cost may discourage authorities from engaging in a process of sustained disinflation. In addition, the wage indexation mechanism may play a role in the transmission of exchange rate movements to inflation, since the frequency with which wages are revised tends to increase when the inflationary pressures are driven by exchange rate depreciation (Leviathan and Piterman (1986)). This has been an important factor in the inflation episodes of some of the Latin American and transition economies, where devaluation-induced inflation has had higher persistence effects than inflation driven by domestic factors. Empirical studies have also confirmed the significant role of wages in the inflation dynamics in a number of EMEs (Montiel (1989) and Agénor and Hoffmaister (1997)).

A particularly important factor in the EMEs context is the role that relative prices play in the inflation process. In classical models of inflation, relative price changes do not affect aggregate inflation, since industry level price variations are expected to be mutually offsetting in nature; only aggregate demand changes have implications for the rate of inflation. However, the role of relative prices in inflation has received increasing attention since Ball and Mankiw (1994 and 1995) demonstrated that firms react differently to a large price shock than to a small price shock. Since firms face costs in adjusting prices they would react to a large shock by revising prices but ignore small shocks. Hence the impact of a relative price shock on inflation depends on its distribution: the more it is skewed to either side the greater the impact on the overall inflation. Apart from this, two factors may explain why relative prices play a relatively larger role in the inflation process in the EMEs.

First, certain relative price changes, particularly those arising from large supply shocks may have major macroeconomic implications (Fischer (1981)). The size of the overall price impact, even if the shock is only temporary, depends on how important the sector in question is for overall consumer inflation. For example, food and energy account for a relatively larger share of the consumer price index in the EMEs than in the industrialised economies. A sharp rise in prices of these commodities not only raise short run inflation, by virtue of their high weight in the consumer price index, but also can lead to a sustained rise in the inflation rate if it raises inflation expectations.[6] Second, to the extent that supply shocks are accommodated by monetary policy they give rise to demand-driven inflationary pressures.

An important source of relative price volatility in EMEs is administered prices. Despite their diminishing importance, revision or liberalisation of administered prices has had inflationary outcomes, in particular in transition economies. Whether or not administered prices can be a major source of inflation depends on the nature of price adjustments and the extent to which monetary policy remains neutral. If administered prices are revised periodically to restore their relative level, they may not affect average inflation (Phillips (1994)). Nonetheless, adjustment of administered prices can be inflationary. First, they may be accommodated by monetary policy. Second, as the experience of the transition economies has shown, price increases in administered sectors were not fully compensated by price decreases in the non-administered sectors. Hence, average prices rose in these economies (IMF (1996)). Moreover, price liberalisation has in many cases been spread over a long period of time, leading to continuing adjustment of relative prices and increases in inflation. Recent research has confirmed that relative prices did have a significant impact on inflation in the transition economies and that this impact was not necessarily temporary (Coorey et al (1998), Pujal and Griffiths (1998)).

Another factor is the extent to which inflation persists on its own through various mechanisms which link current inflation to past inflation. Inflation persistence stems from both backward-looking inflation expectations and indexation of wages and prices to past inflation. Thus, stopping high inflation has typically involved efforts to break the mechanisms that give inflation its own momentum (Sargent (1982)). While a low degree of persistence is highly desirable for the success of the disinflation process, it is not entirely clear if that would be the case once inflation has been stabilised at a low

[6] The inflation volatility arising from fluctuations in food prices may have a higher persistence effect if supply adjustments are constrained by domestic and international trade restrictions.

level. To the extent that low inflation and credible monetary and fiscal policies anchor inflation expectations better, they might lead to more persistent inflation, thus helping the central banks in their efforts to maintain price stability. In such an environment, a temporary shock has very little initial impact on the prospects of price stability. But the challenges for the central banks are considerable when low policy credibility leads to a high degree of persistence of inflation and high costs of disinflation.[7]

How far do the above factors explain the actual movement of inflation in various countries? Tables A2 to A8 present data on average values of potential determinants of inflation during the 1980s and the first half of the 1990s and annual trends during the second half of the 1990s. These indicators include annual percentage changes in broad money, output gaps and unemployment rates, as demand side factors, and growth rates of nominal wages, exchange rates, import prices and prices of food and oil components in the CPI index, as cost or supply side factors. There are, however, some important gaps in the data. Data on unemployment, wages and food and oil prices are not available for the entire sample period for all the EMEs. In particular, some data series for the transition economies only start in 1990. Second, as data on administered prices are not easily available, we exclude them from further analysis although they are an important determinant of inflation in many EMEs. The following trends are easily discernible from the tables:

– None of the indicators used to track the demand side picture of inflation appear to have moved closely with inflation (see Tables A2 to A4). Output gaps seem to be poorly related to inflation, particularly during the second half of the 1990s:[8] both variables moved in opposite directions in the first three years but in the same direction in the last two years. The correlation coefficient between these two variables during the 1990s was negative for only six countries and positive end reasonably high for only four (Table A9). The weak association is also evident from Graph 1;

– The growth of broad money is typically high in high-inflation economies. Nevertheless, except for Brazil and Peru, which experienced a contraction in money supply growth during the second half of the 1990s, it is not apparent that the recent decline in inflation has been associated with a significant reduction in monetary growth. In fact, the correlation coefficient between these two variables is negative for roughly half the countries in our sample;

– The correlation coefficient between the unemployment rate and inflation is negative in only five countries. However, there are signs of a closer relationship in the more recent period when, in several countries, higher unemployment coincided with declining inflation;

– Exchange rate changes and inflation appear to be closely linked. This is true for all regions although the degree of pass-through seems to be higher for the Latin American countries, where rapid disinflation has usually been accompanied by significant nominal appreciation of currencies. The correlation coefficient between inflation and changes in the exchange rate is positive in all but four countries, with particularly high values for Brazil, Hungary, Korea and Mexico;

– Wage inflation has been high in Latin American and transition economies as well as in South Africa. Typically, nominal wage growth has exceeded inflation during the 1990s. The notable exceptions are Hungary, the Philippines and Peru, where real wage growth has been negative. The correlation coefficient between nominal wage growth and inflation is positive and strong in the Latin American countries, but less so in other countries and actually negative in some cases;

– A large part of the movement in inflation seems to come from the two major components of the price index, food and oil prices. The changes in these two indices are, however, highly

7 Blanchard (1998) points out three essential features of successful disinflation: (i) the credibility of the monetary authority implying coherent fiscal and monetary policy, (ii) a wage setting process that is less tilted to nominal overhang and (iii) a flexible labour market enabling the authorities to enforce a real wage cut.

8 The estimates of the output gap are based on quarterly GDP data and are measured as the proportionate deviation of actual output from potential, with the latter calculated by applying the HP smoothing procedure to separate the trend and cyclical components of GDP. We also use alternative estimates of potential output to test the empirical relevance of this variable in forecasting inflation.

irregular, suggesting that they are largely determined by supply conditions (Table A7). The extent of supply side influences on inflation is evident from the high correlation between overall inflation and food price inflation. It needs, however, to be noted that since food prices constitute a large part of the consumer price index in all EMEs, a high degree of comovement of these two variables is to be expected. But to the extent that food prices are determined by exogenous factors, this provides a rough idea about the supply side influence on inflation in these economies. Surprisingly, oil prices seem to be a less important factor; in fact, the correlation is negative in six out of the 14 countries;

– The role of import prices in the recent disinflation episode is evident in many EMEs as import prices, including oil, have increased at a significantly lower rate than overall inflation (Table A8). Given the high correlation between import prices and the exchange rate, it is not clear which factor is the more important determinant of inflation, though the bilateral correlation coefficient in Table 9 points to the latter.

3. The model and the data

In this section, we turn to empirical estimates of inflation, using a common specification that accounts for both demand and supply side factors as discussed above. Following Gordon (1985), a general specification for inflation can be obtained by combining a wage equation with a markup price equation, along the lines of the standard augmented Phillips curve. The equation for unit labour costs can be expressed as a function of current and lagged inflation, the output gap,[9] the difference between actual and trend productivity growth and various supply shift factors:

$$\Delta w_t - \Phi_t^* = \alpha_1(L)\Delta p_t + \alpha_2(L)\hat{O}_t + \alpha_3(L)(\Phi_t^A - \Phi_t^*) + \sum_j \alpha_{4j}(L) z_{it}^w + \varepsilon_t^w \tag{1}$$

where w and p are natural logs of wages and prices, respectively, Φ^A and Φ^* are growth rates of actual and trend productivity, $\hat{O}$ is the output gap measured as the proportionate deviation of actual from potential output, z is a vector of variables representing supply shift factors and (L) is the lag operator.

A markup equation for the changes in prices can be expressed in a similar fashion:

$$\Delta p_t = \beta_1(L)(\Delta w_t - \Phi_t^*) + \beta_2(L)\hat{O}_t + \beta_3(L)(\Phi_t^A - \Phi_t^*) + \sum_i \beta_{4i}(L) z_{it}^p + \varepsilon_t^p \tag{2}$$

For simplicity the two supply shift factors for the labour and product markets are combined into one "*z*" vector. Moreover, assuming that wages do not depend on the current period inflation, the reduced form inflation equation, after denoting the complex set of lagged coefficients by $\gamma_i(L) = \beta_i(L)\alpha_i(L)$ and adding a constant, can be written as:

$$\Delta p_t = \gamma_0 + \gamma_1(L)\Delta p_{t-1} + \gamma_2(L)\hat{O}_t + \gamma_3(L)(\Phi_t^A - \Phi_t^*) + \sum_i \gamma_{4i}(L) z_{it} + \beta_1(L)\varepsilon_t^w + \varepsilon_t^p \tag{3}$$

In order to make the model operational for the EMEs, we make a few changes to the basic specification. First, since it is not easy to obtain reasonable and reliable estimates of productivity growth, we exclude this term from the empirical version of the equation.[10] Second, although equation (3) rules out a direct role of wages by assuming the same set of determinants for unit labour cost as for the markup price specification, we introduced nominal wages into the model where data were available. This was based on the consideration that indexation plays an important role in the inflation process in many EMEs.

[9] Because data on unemployment rate are not available for all countries, we have used the output gap as a proxy for labour market conditions.

[10] Evidence suggests that the rise in total factor productivity has played a role in the growth experience of several EMEs, and has worked its way through to the final consumer by way of lower product prices. However, data for long time spans are not yet available to enable empirical testing of this hypothesis.

Third, in most inflation models for industrialised countries, demand indicators are represented by one single variable (the output gap) while monetary variables do not directly enter into the model. The underlying rationale is that the transmission of monetary policy takes place through changes in aggregate demand and there exists a strong link between the interest rate and demand in these economies. This relationship is quite central to the monetary transmission mechanism and looks plausible for developing economies as well. There are, however, important differences between the two cases. One is that estimates of the output gap for developing economies are not very precise and, therefore, may not fully capture the demand dynamics. In such a case, some measure of excess money growth along with the output gap could help measure demand developments better. Another is that, given the relatively underdeveloped state of financial markets and the weak relationship between the interest rate and inflation, money supply growth could be an important indicator of future demand growth and hence inflation expectations.

Two different approaches are available for directly including monetary variables in addition to the output gap. One is proposed by Gordon (1985), and links current period output growth to excess money growth and actual velocity growth by the following two identities:

$\hat{O}_t \equiv \hat{O}_{t-1} + \Delta\hat{y} - \Delta p_t$ and $\Delta\hat{y}_t \equiv \Delta m_t + \Delta v_t$

where $\Delta\hat{y}$ and Δm and Δv are the growth rates of nominal GDP in excess of the growth of potential GDP, excess money growth and actual velocity growth, respectively. Making use of these two identities and assuming further that inflation depends not only on the current period output gap but also on the change in the gap, the inflation model in equation (3) can be written in terms of both the output gap and monetary variables (see Gordon (1985) for details of the derivation). The other approach is to let the money gap appear as an additional variable on the strength of its being an indicator of inflation expectations (Coe and McDermott (1997)). We follow the second approach and specify the money gap in two different ways for two different groups of countries. For countries where the money demand function appears to be stable, we use a partial adjustment framework specified as:

$\hat{m}_t = m_t^{\mathrm{s}} - m_t^{\mathrm{d}}$ and $m_t^{\mathrm{d}} = \upsilon_0 + \upsilon_1 y_t - \upsilon_2 i_t + \upsilon_3 m_{t-1}^{\mathrm{d}}$

where m^{d} and m^{s} are the natural log of demand for and supply of broad money, respectively, y is the log of real GDP and i is the nominal short-term interest rate. For countries for which we did not get a stable money demand function or which have long ago moved away from monetary targeting, we constructed a real money gap variable, measured as the proportionate deviation of the actual real money supply from its trend value, obtained through a simple time trend equation:

$\hat{m}_t = m_t - m_t^{\mathrm{TR}}$

We chose four supply side variables: the rate of change in the exchange rate (Δe_t), and shocks to import prices ($\Delta mp_t - \Delta p_{t-1}$), food prices ($\Delta fp_t - \Delta p_{t-1}$), and oil prices ($\Delta op_t - \Delta p_{t-1}$). As is evident from the notation, a price shock is defined as the deviation of percentage changes in that variable from the previous period inflation rate. In defining the shocks in this way, the model overcomes the potential problems of regressing the inflation rate on its components. Since changes in the exchange rate and import prices are closely related, we use them alternately. The final version of the model for estimation is thus:

$$\begin{aligned}\Delta p_t = \varphi_0 + \varphi_1(L)\Delta p_{t-1} + \varphi_2(L)\hat{O}_t + \varphi_3(L)\hat{m}_t + \varphi_4(L)\Delta e_t + \varphi_5(L)\Delta w_t + \varphi_6(L)(\Delta mp_t - \Delta p_{t-1}) \\ + \varphi_7(L)(\Delta fp_t - \Delta p_{t-1}) + \varphi_8(L)(\Delta op_t - \Delta p_{t-1}) + \varepsilon_t'\end{aligned} \tag{4}$$

The first three terms (including the constant) are the same as in equation (3), the fourth and fifth terms are additional variables representing excess money supply and exchange rate changes, and the set of "*z*" variables are replaced by the three price shock variables, with *mp*, *fp* and *op* being the natural log of import prices, food prices and oil prices, respectively. All parameters are expected to be positive.

The data

All data used in the model, except the output gap and excess money supply, are quarterly changes in the variables unless otherwise stated. Given the data limitations, we restricted the sample period to the 1990s or even shorter for some countries. Nevertheless, wherever possible, the sample period is extended back to the 1980s. Inflation is measured as the quarterly percentage change in consumer prices, except in the case of India, where it refers to wholesale prices. While food and oil prices are a part of the overall price index, import prices refer to the unit value index for imports. Money supply data refer to either M2 or M3, while quarterly changes in wages are measured as the percentage change in the emoluments per person employed. As an indicator of the exchange rate, we used the bilateral nominal exchange rate against the US dollar.

A key variable in the model is the output gap, which measures the proportionate deviation of actual output from potential output. Potential output is an unobservable variable and needs to be estimated. Broadly, two approaches are followed in the literature (see Barrell and Sefton (1995), De Masi (1997) and Cerra and Saxena (2000) for recent reviews of methods). One is the production function approach, where potential output is derived from an estimated production function with labour and capital measured at their full employment level and total factor productivity at its trend level. While this method has the advantage of explicitly identifying the sources of output growth and is most commonly used for estimating potential output for the industrialised economies, its relevance for developing economies is not so obvious given data limitations on factor inputs. The other approach is to adopt a statistical detrending method that separates actual output into trend and cyclical components. The trend component is then assumed to represent potential output.

A commonly used smoothing procedure is the Hodrick-Prescott (HP) filter, which minimises a combination of the gap between actual and trend output and the rate of change in trend output over the sample period:

$$\text{Min}\sum_{t=0}^{T}\left(y_t - y_t^*\right)^2 + \lambda\sum_{t=2}^{T-1}[(y_{t+1}^* - y_t^*) - (y_t^* - y_{t-1}^*)]^2,$$

where λ is the smoothing parameter. The limitations of the HP filter are well known, the two most important ones being that the estimated trend is sensitive to the chosen value of the smoothing parameter and that it suffers from an end-sample bias (Harvey and Jaeger (1993)). In the context of EMEs, one further limitation of any data smoothing technique is that it may not capture the impact of rapid structural changes and the large supply side influences on trend output. Nevertheless, the HP filter is a commonly used method for estimating potential output in developing countries. For example, most recent studies which attempt to estimate the output gap in the Asian and Latin American economies rely on this technique and adopt different approaches to reduce the problems arising from the choice of smoothing parameter (Coe and McDermott (1997), Roldos (1997) and IMF (1996)). To date, very few attempts have been made to measure potential output in the central European transition economies. This is partly because of the limited time points that separate the planned and the market regimes and partly because the transition process itself has rendered measurement of output difficult in these economies.[11]

We estimated the output gap by applying the HP smoothing procedure to quarterly GDP data drawn from national sources. Since choosing any particular value of λ implies putting an arbitrary restriction on the smoothed trend line, we follow an iterative procedure by which, starting from an initial value (1,600 as the standard value for quarterly data), we compute the trend line for successively lower and higher values of λ and choose the one that does not significantly alter the trend line any further. Although the procedure is simple and relies considerably on judgment, it provides an optimal value of λ based on the specific data characteristic for each country. Since the quarterly GDP data for EMEs suffer from larger measurement errors than annual data, we computed two alternative estimates of potential output based on annual GDP data. As a first alternative, potential output is estimated from annual GDP data using a simple time trend; quarterly gaps are then computed by applying the Ginsburgh interpolation technique. In the second alternative, a similar estimate is obtained by applying a linear interpolation technique. The three alternative estimates of potential output are used in the inflation equation to get a feel for the margins of error and to see if the coefficients on the output gap vary significantly across the three definitions.

[11] For example, Gavrilenkov and Koen (1995) discuss various problems associated with output measurement in the transition economies, using the evidence for the Russian economy. While output in these economies was overstated during the pre-transition period because of the incentives for overreporting, it is likely to have been underreported in the post-transition period as several new activities escaped official statistics. To overcome these difficulties, IMF (1996) recently estimated the long-term growth rates for the transition economies based on the growth experiences of other parts of the world.

4. The results

The unconstrained model

We now turn to the model in equation (4). We estimated two versions, one without constraints on the coefficients and the other with the constraint that the coefficients on the nominal variables add up to 1. The model was estimated with different combinations of variables and for different lags. In order to save some degrees of freedom, given our limited sample period, we omitted those variables which turned out to be highly insignificant from the final regression. The preferred unconstrained version of the model for each country is presented in Table 1, while the table below provides a summary of the results.

Summary of Table 1

Sum of the coefficients of the determinants of inflation in the unconstrained model

	C	$\hat{o}$	$\hat{m}$	Δe	Δw	$\Delta fp_t - \Delta p_{t-1}$	$\Delta mp_t - \Delta p_{t-1}$	$\Delta op_t - \Delta p_{t-1}$	$(L)\Delta p$
India	0.009	0.720	0.230	0.197		0.077			0.237
Korea	0.023	0.066		0.053	0.047	0.151			0.524
Malaysia	0.002	0.003				0.203			0.654
Philippines	0.005	– 0.131	0.055			0.398	0.050	0.079	0.684
Taiwan	0.003	0.315		0.054	0.081	0.164			0.199
Thailand	0.005	0.063		0.025		0.287		0.084	0.453
Brazil	– 0.004	0.455	0.036			0.493		0.122	1.020
Chile	– 0.005	0.082		0.084	0.579	0.040			0.317
Mexico	0.001	– 0.124	0.089	0.082	0.410	0.465			0.415
Peru	– 0.005	0.429		0.096		0.280			1.034
Czech Rep.	0.011	– 0.012		0.132		0.714			0.735
Hungary	0.011	– 0.382				0.305	0.294	0.086	0.783
Poland	– 0.002	0.284	0.001		0.304	0.268			0.886
South Africa	0.000	0.106	0.029			0.170		0.030	0.943

Robustness and stability checks

As may be observed from Table 1, the fraction of variance of inflation explained by the model ranges from 0.5 to 0.9. The equations for individual countries pass the traditional robustness checks. The Breusch-Godfrey test statistics (BG-LM) for up to the fourth-order lag are normally below the critical value (5% level of significance), ruling out the presence of higher order serial correlation in the model. The White tests on residuals, however, displayed some evidence of heteroskedasticity, implying that ordinary least squares estimates are not efficient. The heteroskedasticity bias was corrected by constructing a heteroskedasticity-consistent covariance matrix of the form suggested by White (1980), when the type of heteroskedasticity is unknown.

Although the model captured the inflation dynamics quite well for most countries, it cannot be excluded that the parameter values are unstable and/or that the estimated relationships have been subject to structural changes during the period under review. As a first step in exploring this issue, Chow breakpoint tests were computed on each country's mid-sample point, since the date of a break, if there is any, is unknown. For three countries, Brazil, the Czech Republic and Mexico, there is evidence of shifts in the estimated equations (see Table 3). Indeed, these countries went through major structural reform programmes in the course of the 1990s, which could have implied important changes to the relationship between inflation and its determinants. In a second stability test - a one-step forecast test - the inflation equations were re-estimated recursively and the plots of the residuals were explored without revealing obvious in-sample parameter instability for most countries (see the upper portion of the plot in Graphs 2a, b and c). With residuals outside the standard error bands, Korea and South Africa show some instability towards the end of the 1990s. The lower part of the plot shows the probability values for those sample points where the hypothesis of parameter constancy would be rejected at different significance levels. Looking at the 1990s, most countries reveal a high degree of stability in their inflation behaviour. The central European countries display some instability, which again might be attributable to the structural changes.

The in-sample forecasting ability of the estimated inflation equations was also examined and the results are reported in Table 3. The low values of the root mean squared error and the mean absolute error in both the constrained and the unconstrained version would suggest that the specified equations have a good forecasting ability. According to Theil's inequality coefficient, it appears that the equations have a better forecasting ability for the Latin American and central European countries than for the Asian countries.

The in-sample test, however, throws little light on whether the inflation processes changed after the estimation period. To explore this issue, the models were used to construct some out-of-sample forecasts for the countries for which more than 10 years of observations were available. The forecasts are carried out for the period 1997:2 to 1999:3 and compared with the actual values for six selected countries (see Graph 3). The estimated inflation relationship seems to have a good forecasting ability for Taiwan, but less so for Chile and Malaysia. Although the model is able to predict the turning points of inflation in all but one country (South Africa), it seems to overestimate inflation in Korea, Malaysia and Taiwan and underestimate it in Mexico. In the case of South Africa, the unpredicted sharp increase in inflation in the third quarter of 1998 was due to the devaluation of the rand. In contrast, the response of inflation in Korea to the sharp depreciation during the first quarter of 1998 was much weaker than estimated by the model.

Turning to the parameter values of the inflation equations for individual countries, the role of demand factors is not clearly established in all cases. Conversely, the supply factors are invariably significant, both statistically and economically.

The degree of inflation persistence, as measured by the sum of the coefficients on lagged inflation,[12] ranges from 0.2 (Taiwan) to about 1 (Brazil, Peru and South Africa) and tends to be positively correlated with the average rate of inflation over the sample period.[13] This result is consistent with recent findings in the literature (see for instance Taylor (2000)) that inflation persistence as well as the pass-through of cost increases tend to be lower in a low-inflation environment. It also means that the persistence coefficients shown in Table 2 may not be valid for those countries (mostly in Latin America and central Europe) that have only recently managed to reduce their inflation to a single digit rate. However, because of the short sample period we were unable to test this hypothesis.

Taken at face value, the persistence coefficients imply that reducing inflation is much more costly (in terms of lost output) in countries such as Brazil, Peru and South Africa than for instance in Chile, India and Taiwan.

Turning next to the output gap, we were able to find significant coefficients for all countries in the sample. However, the coefficients and their significance differ widely across the 14 countries and in the three alternative measures of the output gap mentioned earlier. With respect to the cross-country variation, the "best fit" estimates in Table 2 show the expected positive coefficient on the gap level for ten countries. For Hungary, inflation appears to be a negative function of the gap level[14] and for three countries inflation seems to depend negatively on *changes* in the gap. The three significant coefficients for Mexico essentially imply that changes in the gap have only a transitory effect on inflation.

Regarding the three methods of estimation (Table 4), several points are worth noting. First, the "best fit" coefficients are about equally split between the HP filter and the annual trend combined with the Ginsburgh interpolation, while the linear interpolation worked less well. Second, for only one country (Korea) did all three methods produce significant coefficients. Third, the sensitivity of inflation to the

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12 Since the shock variables in the model also included lagged inflation, the persistence coefficients may be biased depending on the size and sign of the coefficients of the shock variables.

13 A cross-country regression between lagged inflation coefficients and average inflation rates produced the following result: $\Sigma\, \varphi_1(L)\pi_{t-1}^{*} = 0.266\ (1.61) + 0.143\ (2.34)\ (\pi^{A})$, where $\varphi_1(L)\pi_{t-1}^{*}$ is the sum of the estimated coefficients of lagged inflation and π^{A} is the average inflation rate for the sample period. Figures in brackets are t-statistics.

14 The negative coefficients with respect to either the gap or changes in the gap would imply that firms reduce their markups in periods of stronger demand. This is not implausible, though the consensus view seems to be that inflation responds positively to the level of or changes in the gap.

output gap is highly dependent on the measure used. This may be due in part to relatively large measurement errors for the quarterly output data (which would tend to bias the coefficients downwards), whereas the sensitivity to the interpolation method is harder to explain. Fourth, the annual trend combined with the Ginsburgh interpolation seems to suit better for the Asian countries,[15] whereas the HP filter seems preferable for most of the other countries in the sample.

Money supply often only has a significant impact for six countries. This is perhaps to be expected for countries like India, the Philippines and South Africa, where money supply is given a relatively greater importance in the conduct of monetary policy and where recent evidence confirms the existence of a stable money demand function.[16] In Latin America too, excess money supply appears to be a major determinant of inflation. Important exceptions are Korea and Peru, where, contrary to expectations and findings in other studies, money supply did not have a significant influence on inflation. Similarly, in most transition economies, money does not seem to play a direct role in the inflation process.[17] It also appears that in countries with low inflation (for example, Chile, Malaysia, Taiwan and Thailand),[18] money does not have a direct impact on inflation.

Among the supply factors, it is evident that wages are a major source of inflation in Chile, Korea, Mexico, Poland and Taiwan. The insignificance of wages in other countries may stem from the lack of proper data on unit labour costs and the fact that gaps in the wage data are particularly severe in countries where the official data do not accurately capture wage developments in the informal and small-scale sectors.[19]

As seen from Table 1, the exchange rate or import price shocks appear as significant determinants of inflation in 10 of the 14 countries.[20] The countries for which we do not find a significant relationship fall into two groups, those with a relatively high rate of depreciation (Brazil, Hungary and South Africa) and those with a low or moderate rate of depreciation (Malaysia). For the first group, most changes in the exchange rate may already have been anticipated and hence reflected in the lagged inflation term. To the extent that the anticipations were correct, little, if any, of the price changes would be explained by changes in the exchange rate. Malaysia, by contrast, maintained a relatively fixed exchange rate during the period preceding the Asian crisis, which might explain the absence of a significant influence on inflation. These results seem consistent with the findings of other studies that only large and unexpected changes in the exchange rate have an impact on inflation (Swagel and Loungani (1996)).

A final issue is how far inflation can be attributed to oil and food price shocks. The results are interesting. First, except in five countries oil prices do not seem to affect the overall inflation rate.[21] The different responses could be due to the differences in the degree to which oil price shocks are accommodated by monetary policy. Moreover, the response of inflation to oil prices depends on how domestic oil prices move with the international prices. The fact that in many countries oil prices are still administered and price revisions are staggered could imply that domestic oil prices are only slowly

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15 See, for example, Coe and McDermott (1997) and IMF (1996), for similar results from annual data. However, Swagel and Loungani (1996) show that for the developing countries as a group there is little evidence that the output gap has major effects on inflation.

16 See Reserve Bank of India (1998) and Gerlach (2000) for recent evidence on the stability of the money demand function in India, Arora (1999) for the Philippines and Jonsson (1999) for South Africa.

17 Studies based on panel regression in the context of transition economies, however, yield different results. For example, Coorey et al (1998) reported a positive and strong impact of broad money growth on inflation in a pooled sample of 21 countries, which included transition economies in Europe, the Baltic countries, and the Commonwealth of Independent States (CIS).

18 A recent study (Dekle and Pradhan (1997)) on the money demand function in the ASEAN countries showed that the real broad money demand function is unstable in Thailand, but not in Malaysia. The study, however, is based on the sample period 1975-95 and thus does not capture the potential changes to the money demand function following the Asian crisis.

19 In a few cases, the impact of wages on inflation could not be tested because of the lack of data on wages.

20 Given the high degree of correlation between the exchange rate and import prices, the two variables have been used alternately to represent the same phenomenon. Nevertheless, except in the Philippines and Hungary, the exchange rate seems to dominate import prices as a determinant of inflation.

21 This finding is broadly consistent with those of other studies (see Swagel and Loungani (1996)) and IMF (1996)) that oil prices do not directly account for a significant part of global inflation.

restored to their equilibrium value with no net impact on the long-run rate of inflation, unless accompanied by monetary accommodation.

What is common to all EMEs is the critical role that food prices play in the inflation process. In most countries, food price shocks emerge as a dominant determinant of inflation (except in India, where it is only weakly significant). The coefficient is significant at the 99% confidence level in 13 of the 14 countries, with the magnitude of the impact ranging between 0.2 and 0.7. To further illustrate the relative importance of food prices and other determinants, Table 5 reports the contribution of each determinant to inflation during the sample period. There are two ways of measuring this contribution. The first focuses on the volatility of inflation, with the contribution of each determinant captured by the β-coefficient, calculated as the ratio of the standard deviation of each determinant times its coefficient to the standard deviation of inflation (Ezekiel and Fox (1967)).[22] A second way to assess the relative importance of each determinant is to evaluate its contribution to the mean value of inflation (δ). This is measured as the ratio of the mean of the determinant times its coefficient to the mean rate of inflation.

Several points are worth noting from Table 5. First, the role of demand factors in the inflation process seems to be weak. The contribution of the output gap to inflation volatility is high in only some countries and its contribution to average inflation is negligible or nil in a majority of countries. Similarly, excess money supply contributes to the volatility as well as to the average inflation rate in only some countries. Second, wages explained a large component of inflation and its volatility wherever they emerged as a significant determinant (Chile, Mexico and Taiwan). Third, the exchange rate is a major contributor to inflation volatility in many countries, while its contribution to average inflation is more modest.

Fourth, the supply shock variables, particularly food price shocks, have contributed significantly to inflation volatility in all countries. However, being a shock variable in our model, the contribution of food price shocks to average inflation is understandably low. Nevertheless, favourable food price shocks seem to have played a role in the disinflation process. Oil shocks have contributed significantly to inflation volatility in some countries (Hungary, South Africa and Thailand), while import prices did so in only two countries (Hungary and the Philippines). Finally, inflation persistence explains a large proportion of both the variation and the average inflation in all countries.

Graph 4 shows the annual contribution of the food price shocks to inflation volatility in the 14 EMEs during the 1990s. In a majority of countries, they stand out as a dominant source of inflation volatility.

The constrained model

Another approach frequently followed in the literature is to sum the coefficients on the nominal variables in the price equation (4) to one (Stock and Watson (1999) and Andersen and Wascher (2000)). For most countries, the ADF test suggested that inflation is an I(1) variable, in which case a constrained version is a more appropriate specification of the inflation process. We estimated the constrained version using the specification shown in (5) and conducted a Wald test to verify whether the constraint is accepted:

$$\begin{aligned}\Delta\Delta p_t &= \Psi_0 + \Psi_1(L)(\Delta p_{t-2} - \Delta p_{t-1}) + \Psi_2(L)\hat{O}_t + \Psi_3(L)\hat{m}_t + \Psi_4(L)(\Delta e_t - p\Delta_{t-1}) + \Psi_5(L)(\Delta w_t - \Delta p_{t-1}) \\ &+ \Psi_6(L)(\Delta mp_t - \Delta p_{t-1}) + \Psi_7(L)(\Delta fp_t - \Delta p_{t-1}) + \Psi_8(L)(\Delta op_t - \Delta p_{t-1}) + \nu_t\end{aligned} \tag{5}$$

and $\Psi_1 + \Psi_4 + \Psi_5 = 1$

The results of the constrained model are presented in Table 6 and the coefficients of the model are summarised in the table below.

As may be seen from the last column of Table 6, the homogeneity constraint is rejected for only four countries (Hungary, the Philippines, Taiwan and Thailand). Moreover, the explanatory power of the individual equations underwent only marginal changes, except in India, where it improved. One important indicator of the relative performance of the constrained model is given by the within-sample

[22] In other words, β-coefficients correspond to the regression coefficients when the variables are measured in units of their standard deviation.

forecast errors. The root mean squared errors are consistently lower in the constrained model than in the unconstrained model (Table 3). The superior performance of the constrained model for some countries does not seem to be all that unique for the emerging market economies as a similar finding was reported by Stock and Watson (1999) for the US economy and by Andersen and Wascher (2000) for selected industrialised economies. All in all, this suggests that a constrained model is better suited to producing inflation forecasts than the unconstrained model.

It is also relevant to note that the constrained model validates most findings of the unconstrained model. Although the impact and significance of the output gap declined in some instances, the sign of the relevant coefficients remained unchanged in almost all cases. The constrained model also reinforces the findings of the unconstrained model with respect to the roles of excess money supply, the exchange rate and wages in the inflation process. In addition, the shock variables are highly significant in the constrained model. While oil and import price shocks affect both the level and the change in the inflation rate in only a limited number of countries, the impact of food price shocks is positive and large. The coefficient of food price shocks remained more or less unaltered in virtually all cases, the only exception being India, where it turned out to be significant and almost double the value found in the unconstrained model.

Summary of Table 6

Summary of the coefficients of the determinants of inflation in the constrained model

	C	$\hat{o}$	$\hat{m}$	$\Delta e_t - \Delta p_{t-1}$	$\Delta w_t - \Delta p_{t-1}$	$\Delta fp_t - \Delta p_{t-1}$	$\Delta mp_t - \Delta pt_{-1}$	$\Delta op_t - \Delta p_{t-1}$	$(L)\Delta\Delta p_{t-1}$
India	0.005	0.680	0.212	0.172		0.569			
Korea	0.015	0.065		0.065	0.054	0.158			0.370
Malaysia	– 0.001	0.015				0.213			0.390
Philippines	0.001	– 0.131	0.024			0.485	0.075	0.066	
Taiwan	– 0.001	0.161		0.139	0.096	0.223			
Thailand	– 0.001	0.006		0.003		0.367		0.103	
Brazil	0.001	0.317	0.031			0.512		0.099	0.464
Chile	– 0.005	0.080		0.090	0.560	0.040			0.286
Mexico	– 0.001	0.188	0.092	0.079	0.401	0.490			0.262
Peru	0.000	0.094		0.058		0.283			
Czech Rep	0.007	0.014		0.128		0.760			– 0.083
Hungary	– 0.001	– 0.316				0.266	0.392	0.191	0.015
Poland	– 0.002	0.172	0.001		0.199	0.276			0.372
South Africa	– 0.001	0.106	0.031			0.172		0.031	0.359

5. Policy implications and conclusion

The paper provides evidence on the inflation process in EMEs in several directions. First, the output gap is a significant determinant of inflation in all countries, though the precise influence is difficult to establish. From the different measures of the output gap developed in the paper, only Korea obtains a statistically significant impact under all three measures. Moreover, in the constrained model the significance of the output gap declines in a number of cases. Excess money supply, another demand side indicator, was related to inflation in only some countries. This finding supports the argument that money supply may have lost relevance for predicting inflation under the impact of financial liberalisation and innovation.

Second, inflation persistence is rather high in many countries. To the extent that high inflation persistence reflects backward-looking wage and price expectations, it makes it more costly for countries to reduce inflation. But once inflation has been stabilised at a low level, a high degree of persistence could be helpful to central banks to firmly anchor inflation expectations in the economy.

Third, supply side factors seem to play more than a passing role in the inflation process. The exchange rate or import prices turned out to be a significant and important determinant of inflation and this result appears to be robust across alternative specifications. In recent years, two factors have heightened the influence of the exchange rate on prices: the growing trade openness of economies and the move towards more flexible exchange rate regimes. Both factors imply a larger influence of exchange rate changes on domestic prices. At the same time, the general reduction in inflation is likely to have reduced the pricing power of firms and the degree of pass-through of exchange rate changes into inflation.[23] Our results do seem to validate the findings of other studies that greater volatility in the exchange rate is associated with higher volatility of inflation. It does not, however, follow that a "fix" policy is preferable to a "flexible" policy since the former regime is particularly problematic in countries with open capital accounts and imperfect financial systems. The growing influence of the exchange rate on inflation nevertheless creates a need to reconcile the external and domestic objectives of monetary policy. In practice, most developing countries seem to balance these objectives by adopting a "limited float" policy and implementing it by intervening in the exchange market.[24]

Fourth, an important finding of the paper relates to the role of food prices in inflation. Food prices turned out to be highly significant in the inflation equation for all countries and across all specifications.[25] It also turned out to be a dominant determinant of the variability of inflation. The reasons are quite obvious. Not only do food prices have a much larger weight in the consumer price index in the EMEs than in the industrialised economies, but they also tend to be highly volatile due to the influence of weather conditions and restrictions placed on agricultural trade. The implications of this for monetary policy are well known. Since food prices are heavily influenced by exogenous factors, they are bound to cause a large divergence between the underlying and headline inflation rates, which could distort monetary conditions if monetary policy were to focus only on the former. Put in the current context, a large part of the recent reduction in inflation in EMEs has stemmed from a sharp deceleration in food prices, thus keeping underlying inflation higher. If monetary conditions were tightened to reduce the underlying rate, the ex post real interest rate would rise to a level that might have implications for output growth. This is a typical problem associated with targeting a core measure of inflation when it diverges significantly from headline inflation.

Lastly, the influence of oil prices seems to differ across countries. This could be related to different responses to oil price shocks, particularly with regard to the degree of monetary accommodation or to rigidities in the adjustment of domestic oil prices.

To conclude, two major facts are evident from the present analysis. One is that a large component of price movements in EMEs is driven by supply factors, including large changes in the exchange rate/import prices and agricultural shocks. Central banks can certainly contribute to stabilising exchange rate expectations by firmly committing to an inflation target and by promoting transparency and accountability of their operations. However, large and unexpected movements in the exchange rate and frequent food price shocks are bound to occur and challenge the ability of central banks to achieve their inflation target. The dominance of agricultural shocks in the inflation process also highlights the need for deeper structural reforms such as removing agricultural trade restrictions. To the extent that large unexpected movements in the exchange rate are associated with fragility in the external and financial sectors, promoting price stability might also necessitate reducing these vulnerabilities. Second, the weak performance of traditional demand variables in the inflation equation raises another challenge to the conduct of a forward-looking monetary policy. In some cases, however, this may not indicate that demand factors are less relevant in the determination of inflation but rather point to difficulties associated with measuring potential output.

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[23] Unfortunately, the sample period is too short to test these alternative hypotheses.

[24] For example, Reinhart (2000) argues that the observed exchange rate variability is much less in the emerging market economies than in "committed floaters" such as the United States, Australia and Japan. She attributes the low relative exchange rate variability to the deliberate result of policy actions by the emerging market economies to stabilise the exchange rate by trading it off against higher reserve and interest rate volatility.

[25] For a more robust result, it is perhaps important to test whether food price shocks are endogenous to the overall inflation process. Unfortunately, we could not test this hypothesis (Hausman test) due to the lack of instruments which are highly correlated with food prices but not with overall prices. However, it seems plausible that most changes in food prices are induced by exogenous supply factors, such as the weather.

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Table 1

Unconstrained inflation equation for selected emerging market economies

Country and sample period	const	*gap*	gap_{t-1}	gap_{t-2}	*ems*	ems_{t-1}	Δe	Δe_{t-1}	Δe_{t-2}	Δw	*fshock*	*oshock*	*mshock*	Δcpi_{t-1}	Δcpi_{t-2}	Δcpi_{t-3}	Δcpi_{t-4}	R^2	BG-LM
India	0.009		0.720**			0.230	0.116		0.081		0.077			0.237				0.55	0.78
(90:2 - 99:4)	(3.18)		(2.16)			(5.26)	(2.21)		(3.39)		(1.66)			(1.93)					
Korea	0.023	0.066*					0.053			0.047	0.151			0.425	– 0.170	0.269		0.72	0.37
(85:2 - 99:4)	(4.96)	(2.24)					(4.55)			(2.31)	(5.94)			(6.95)	(– 2.35)	(2.76)			
Malaysia	0.002	– 0.078*	0.081*								0.203			0.423			0.231	0.55	2.11
(88:2 - 99:4)	(1.47)	(– 2.65)	(2.71)								(5.11)			(3.90)			(2.29)		
Philippines	0.005	– 1.580**	1.449**			0.055					0.398	0.079	0.050	0.684				0.83	2.52
(90:3 - 99:4)	(2.49)	(– 2.75)	(2.46)			(2.82)					(8.10)	(2.70)	(3.67)	(6.21)					
Taiwan	0.003	0.315**						0.054		0.081	0.164			0.199				0.59	3.97
(81:1 - 99:4)	(3.44)	(2.61)						(2.16)		(5.42)	(9.82)			(2.81)					
Thailand	0.005	0.063**						0.025			0.287	0.086		0.453				0.66	6.96
(90:2 - 99:4)	(4.13)	(2.29)						(2.26)			(8.14)	(3.41)		(4.51)					
Brazil	– 0.004		0.455*		0.036						0.493	0.122		1.217	– 0.330	0.133		0.99	0.57
(91:1 - 99:4)	(– 0.78)		(1.91)		(2.14)						(7.23)	(2.03)		(41.06)	(– 8.01)	(5.09)			
Chile	– 0.005			0.082*					0.084	0.597	0.040					0.317		0.92	0.67
(89:3 - 99:4)	(– 3.61)			(2.40)					(2.53)	(20.62)	(5.58)					(7.68)			
Mexico	0.001	2.272**	– 4.818**	2.422**		0.089		0.082		0.410	0.465			0.457		– 0.147	0.150	0.98	2.13
(86:2 - 99:3)	(0.50)	(1.99)	(– 2.29)	(1.94)		(2.93)		(4.43)		(6.44)	(8.23)			(5.46)		(– 2.88)	(5.54)		
Peru	– 0.005		0.429**						0.096		0.280			1.034				0.98	0.62
(92:1 - 99:4)	(– 1.27)		(1.83)						(2.28)		(5.88)			(10.89)					
Czech Republic	0.011	– 0.595*	0.583*					0.132			0.714			0.851	– 0.116			0.87	4.43
(90:4 - 99:4)	(2.08)	(– 2.07)	(2.09)					(2.43)			(8.55)			(6.44)	(– 2.36)				
Hungary	0.011	– 0.382									0.305	0.294	0.086	1.005	– 0.222			0.90	0.54
(93:1 - 99:4)	(2.64)	(– 2.56)									(5.56)	(2.12)	(4.32)	(15.34)	(– 3.51)				
Poland	– 0.009		0.284*			0.001				0.304	0.268			0.487			0.399	0.92	1.41
(94:2 - 99:4)	(– 1.98)		(2.20)			(3.60)				(2.86)	(4.99)			(4.92)			(4.99)		
South Africa	0.000		0.106*			0.029					0.170	0.030		0.613		0.330		0.69	0.16
(81:1 - 99:4)	(0.07)		(2.42)			(1.83)					(4.99)	(2.33)		(7.33)		(3.89)			

Abbreviations: Δcpi = change in log of consumer prices (for India, wholesale price); *gap* = output gap (* HP filter, ** Ginsburgh, *** trend); *ems* = excess money supply; Δe = change in log of nominal exchange rate (local currency/US dollar); Δw = change in log of wage rate; *fshock* = food price shock (change in log of food price minus lagged change in log of consumer price); *oshock* = oil price shock (change in log of oil price minus lagged change in log of consumer price); *mshock* = import price shock (change in log of import price minus lagged change in log of consumer price); BG-LM = Breusch-Godfrey Serial Correlation LM test; the F-statistics are given.

Note: t-statistics in parentheses.

Table 2

In-sample Chow breakpoint stability test

	India	Korea	Malaysia	Philippines	Taiwan	Thailand	South Africa
F-statistic	0.34	0.58	1.08	0.41	0.90	0.43	1.65
	Brazil	**Chile**	**Mexico**	**Peru**	**Czech Republic**	**Hungary**	**Poland**
F-statistic	10.24*	1.75	2.48	0.23	7.40*	2.27	1.58

Note: The chow breakpoint tests have been done on the respective mid–sample point. * indicates that the null hypothesis of no structural break has been rejected.

Table 3

Inflation equation: within-sample forecasts[1]

	Unconstrained version				Constrained version			
	Mean dependent variable	Root mean squared error	Mean absolute error	Theil inequality coefficient	Mean dependent variable	Root mean squared error	Mean absolute error	Theil inequality coefficient
India	0.020	0.008	0.006	0.171	0.000	0.008	0.007	0.274
Korea	0.013	0.005	0.004	0.175	0.000	0.006	0.005	0.268
Malaysia	0.009	0.003	0.003	0.178	0.000	0.004	0.004	0.393
Philippines	0.021	0.005	0.004	0.102	– 0.000	0.006	0.004	0.209
Taiwan	0.006	0.006	0.005	0.274	– 0.001	0.009	0.007	0.357
Thailand	0.012	0.004	0.003	0.147	– 0.000	0.006	0.005	0.355
Brazil	0.290	0.046	0.039	0.050	– 0.011	0.021	0.018	0.073
Chile	0.027	0.005	0.004	0.083	– 0.001	0.008	0.007	0.265
Mexico	0.072	0.014	0.010	0.068	– 0.003	0.015	0.012	0.178
Peru	0.054	0.011	0.008	0.068	– 0.011	0.008	0.006	0.102
Czech Republic	0.032	0.016	0.013	0.138	– 0.003	0.017	0.014	0.141
Hungary	0.042	0.009	0.008	0.097	– 0.002	0.007	0.006	0.133
Poland	0.029	0.006	0.005	0.063	– 0.002	0.010	0.008	0.253
South Africa	0.028	0.011	0.010	0.217	– 0.001	0.007	0.005	0.122

[1] Dynamic simulations.

Table 4

Test on output gaps with different measures of gaps

	HP filter methodology[1]			Ginsburgh interpolation[2]			Time trend methodology[3]		
	gap t	***gap t*-1**	***gap t*-2**	***gap t***	***gap t*-1**	***gap t*-2**	***gap t***	***gap t*-1**	***gap t*-2**
India		0.0578 (0.81)			0.7198 (2.16)			0.2082 (2.47)	
Korea	0.0658 (2.24)			0.2369 (3.24)			0.0775 (3.17)		
Malaysia	– 0.0781 (– 2.65)	0.0814 (2.71)		– 0.1568 (– 1.11)	0.1816 (1.19)		– 0.0144 (– 0.37)	0.0229 (0.54)	
Philippines	– 0.0327 (– 0.45)	0.0747 (0.99)		– 1.5802 (– 2.75)	1.4493 (2.46)		– 0.4266 (– 2.54)	0.4446 (2.75)	
Taiwan	0.0394 (0.70)			0.3147 (2.61)			0.0960 (2.86)		
Thailand	0.0170 (1.03)			0.0630 (2.17)			0.0206 (2.29)		
Brazil		0.4546 (1.91)			0.5878 (0.75)			0.0967 (0.33)	
Chile			0.0817 (2.40)			0.0229 (0.37)			– 0.0083 (– 0.33)
Mexico	– 0.1245 (– 1.27)	– 0.1863 (– 1.54)	0.0714 (0.70)	2.2719 (1.99)	– 4.82 (– 2.29)	2.42 (1.94)	0.0595 (0.24)	– 0.6921 (– 1.89)	0.5727 (2.85)
Peru		0.0842 (1.43)			0.4294 (1.83)			0.0868 (1.48)	
Czech Republic	– 0.5949 (– 2.07)	0.5830 (2.09)		– 1.9000 (– 1.66)	1.8964 (1.74)		– 0.1047 (– 0.23)	0.1518 (0.33)	
Hungary	– 0.3822 (– 2.56)			– 0.1038 (– 0.66)			– 0.0308 (– 0.66)		
Poland	0.2836 (2.20)			0.3339 (0.88)			0.0810 (0.80)		
South Africa	0.1063 (1.79)			0.2179 (1.25)			0.0465 (1.03)		

[1] Based on quarterly real GDP data, using an HP filter for the calculation of the potential real GDP. [2] Based on annual real GDP data, using a time trend approach for the calculation of the potential real GDP and a Ginsburgh interpolation technique in order to get quarterly data. [3] Based on annual real GDP data, using a time trend approach for the calculation of the potential real GDP and a linear interpolation technique to obtain quarterly data.

Table 5

Contribution of various factors to inflation

	Output gap		Excess money		Exchange rate		Wages		Food price shock		Oil price shock		Import price shock		Lagged inflation	
	β	δ	β	δ	β	δ	β	δ	β	δ	β	δ	β	δ	β	δ
India	0.27	– 0.03	0.64	0.07	0.33	0.12			0.24	0.02					0.24	0.24
Korea	0.17	– 0.01			0.32	0.02	0.16	0.11	0.53	0.03					0.17	0.17
Malaysia	0.01	– 0.00							0.65	0.08					0.33	0.32
Philippines	– 0.03	– 0.00	0.25	0.13					0.12	– 0.02	0.04	– 0.00	0.05	– 0.01	0.67	0.70
Taiwan	0.26	– 0.08			0.15	–0.02	0.43	0.28	0.84	– 0.01					0.23	0.22
Thailand	0.16	0.04			0.19	0.02			0.64	0.04	0.29	0.01			0.45	0.46
Brazil	0.03	– 0.01	0.03	– 0.02					0.30	– 0.02					0.34	0.37
Chile	0.10	0.01			0.12	0.05	0.70	0.79	0.29	0.00					0.31	0.35
Mexico	– 0.00	0.00	0.08	0.01	0.12	0.07	0.38	0.42	0.32	– 0.03					0.16	0.16
Peru	0.12	– 0.03			0.19	0.13			0.23	– 0.10					1.47	1.25
Czech Republic	– 0.00	0.00			0.21	0.08			1.07	– 0.26					0.37	0.40
Hungary	– 0.21	0.00							0.57	– 0.02	0.16	– 0.00	0.43	– 0.04	0.38	0.41
Poland	0.17	0.03	0.38	– 0.08			0.28	0.38	2.51	– 0.46					0.51	0.52
South Africa	0.16	0.00	0.12	– 0.00					0.34	0.01	0.17	– 0.01			0.45	0.49

Note: β is the contribution to the volatility of inflation, defined as the ratio of the standard deviation of the respective factor times its estimated coefficient and the standard deviation of the dependent variable. δ is the average contribution to inflation, defined as the ratio of the mean of the respective factor times its estimated coefficient and the mean of the dependent variable.

Table 6

Inflation equation for selected emerging market economies (constrained version)

Country and sample period	const	*gap*	*gap* $_{t-1}$	*gap* $_{t-2}$	*ems*	*ems* $_{t-1}$	$\Delta e - \Delta cpi_{t-1}$	$\Delta e_{t-1} - \Delta cpi_{t-1}$	$\Delta e_{t-2} - \Delta cpi_{t-1}$	$\Delta w - \Delta cpi_{t-1}$	*fshock*	*oshock*	*mshock*	$\Delta cpi_{t-2} - \Delta cpi_{t-1}$	$\Delta cpi_{t-3} - \Delta cpi_{t-1}$	$\Delta cpi_{t-4} - \Delta cpi_{t-1}$	R^2	F (Wald test)
India (90:2 - 99:4)	0.005 (2.65)		0.680** (1.95)			0.212 (4.73)	0.108 (2.18)		0.064 (3.99)		0.569 (5.98)						0.70	3.60
Korea (85:2 - 99:4)	0.015 (4.50)	0.065* (2.03)					0.065 (5.90)			0.054 (2.77)	0.158 (6.09)			– 0.089 (– 1.17)	0.337 (3.23)	0.122 (1.02)	0.80	7.08
Malaysia (88:2 - 99:4)	– 0.001 (– 1.34)	– 0.069* (– 2.50)	0.084 (2.63)								0.213 (5.06)					0.390 (5.88)	0.72	4.59
Philippines (90:3 - 99:4)	0.001 (0.73)	– 0.872** (– 1.36)	0.741** (1.15)			0.024 (1.13)					0.485 (8.47)	0.066 (4.35)	0.075 (2.85)				0.82	7.62
Taiwan (81:1 - 99:4)	– 0.001 (– 0.57)	0.161** (1.07)						0.139 (3.34)		0.096 (4.77)	0.223 (9.64)						0.63	75.91
Thailand (90:2 - 99:4)	– 0.001 (– 0.78)	0.006** (0.14)						0.003 (0.15)			0.367 (9.29)	0.103 (2.92)					0.56	23.06
Brazil (91:1 - 99:4)	0.001 (0.15)		0.317* (1.61)		0.031 (1.75)						0.512 (8.05)	0.099 (1.79)		0.335 (7.16)	0.129 (4.72)		0.98	1.88
Chile (89:3-99:4)	– 0.005 (– 4.34)			0.080* (2.41)					0.09 (3.08)	0.56 (9.66)	0.04 (5.92)				0.286 (4.53)		0.88	– 0.60
Mexico (86:2-99:3)	– 0.001 (– 0.78)	2.823** (2.58)	– 5.462** (– 2.61)	2.827** (2.28)		0.092 (2.74)		0.079 (3.91)		0.401 (5.83)	0.490 (8.48)				– 0.139 (– 2.76)	0.401 (5.83)	0.94	1.94
Peru (92:1-99:4)	0.000 (0.07)		0.094** (0.85)						0.058 (1.21)		0.283 (6.01)						0.95	5.19
Czech Republic (90:3-99:4)	0.007 (2.34)	– 0.391 (– 1.85)	0.405 (2.13)					0.128 (2.41)			0.760 (13.04)			– 0.083 (– 1.53)			0.92	0.81
Hungary (93:1 – 99:4)	– 0.001 (– 2.41)	– 0.316* (– 1.82)									0.266 (3.72)	0.191 (2.82)	0.392 (4.00)	0.015 (0.21)			0.85	26.07
Poland (94:2 – 99:4)	– 0.002 (– 0.92)		0.172* (1.46)			0.001 (3.44)				0.199 (2.16)	0.276 (4.89)					0.372 (4.49)	0.90	3.18
South Africa (81:1–99:4)	– 0.001 (– 1.95)		0.106 (2.42)			0.031 (1.94)					0.172 (5.09)	0.031 (2.47)			0.359 (5.00)		0.64	0.45

Abbreviations: Δcpi = change in log of consumer prices (for India, wholesale price); *gap* = output gap (* HP filter, ** Ginsburgh, *** trend); *ems* = excess money supply; Δe = change in log of nominal exchange rate (local currency/US dollar); Δw = change in log of wage rate; *fshock* = food price shock (change in log of food price minus lagged change in log of consumer price); *oshock* = oil price shock (change in log of oil price minus lagged change in log of consumer price); *mshock* = import price shock (change in log of import price minus lagged change in log of consumer price); Wald test = Wald test on the coefficients, critical values of F with 30 degrees of freedom are 7.56 (1% significance level) and 3.70 (5% significance level).

Note: *t*-statistics in parentheses.

Table A1

Inflation rates in emerging economies[1]

	1970s		1980s		1990-94		1995-99	
	Yearly average	Standard deviation	Yearly average	Standard deviation	Yearly average	Standard deviation	Yearly average	Standard deviation
India	8.3	8.8	8.1	4.9	10.5	2.4	6.2	2.2
Korea	15.0	6.4	8.1	9.1	7.0	1.9	4.4	2.4
Malaysia	5.4	4.9	3.6	3.0	3.8	0.8	3.5	1.1
Philippines	14.5	8.5	14.4	13.9	11.6	4.7	7.6	1.8
Taiwan	8.9	13.6	4.4	7.0	3.8	0.6	1.9	1.4
Thailand	7.8	7.3	5.7	5.9	4.8	1.1	5.1	2.9
Brazil	44.9	6.0	226.0	383.5	1,425.9	1,044.9	17.2	26.5
Chile	144.4	177.7	21.2	7.4	17.4	6.2	6.0	1.9
Mexico	14.6	7.9	65.1	38.7	16.1	8.3	24.2	9.5
Peru	24.9	22.1	193.6	1,041.2	315.1	3,287.6	8.3	3.3
Czech Republic	..	..	..	..	13.9	21.9	7.8	3.3
Hungary	..	..	13.8	6.9	25.4	6.2	18.7	7.3
Poland	..	..	..	..	45.7	244.3	16.2	8.0
South Africa	9.6	3.2	14.6	2.1	12.4	2.9	7.3	1.4
United States	7.1	2.7	5.5	3.6	3.6	1.2	2.4	0.5
Japan	9.0	5.7	2.5	2.3	2.0	1.1	0.4	0.8
Germany	4.9	1.5	2.9	2.2	3.7	1.0	1.3	0.5

[1] Consumer price inflation (for India, wholesale price).

Table A2

Demand pressure indicator: output gap[1]

	Average 1980-89	Average 1990-94	1995	1996	1997	1998	1999
India	– 0.0	– 0.5	0.4	1.3	– 0.1	– 0.1	0.3
Korea	– 0.0	– 0.5	1.5	3.0	3.9	– 6.1	– 0.4
Malaysia	1.1	– 1.3	0.5	3.8	6.6	– 4.7	– 2.5
Philippines	– 0.1	– 0.4	– 0.6	1.3	3.2	0.0	– 1.8
Taiwan	0.1	– 0.2	– 0.1	– 0.4	0.5	– 0.3	– 0.3
Thailand	..	– 3.0	3.0	6.4	3.7	– 6.6	– 1.7
Brazil	0.5	– 1.7	1.5	1.2	1.9	– 0.4	– 1.4
Chile	0.1	– 1.0	0.5	1.2	2.9	1.8	– 3.0
Mexico	– 0.3	1.7	– 4.9	– 2.8	0.1	0.6	– 0.1
Peru	0.8	– 2.9	3.8	0.5	2.6	– 1.1	– 1.3
Czech Republic	..	– 1.2	1.5	4.4	2.0	– 0.9	– 1.5
Hungary	..	0.8	– 0.2	– 1.9	– 0.8	0.3	1.0
Poland	2.1	– 3.1	0.8	0.9	1.6	0.8	– 0.5
South Africa	0.1	– 0.7	0.4	1.4	1.0	– 0.8	– 0.2

[1] Output gaps are estimated using HP filter methodology; data are in percentages.

Table A3

Demand pressure indicator: broad money[1]

(annual percentage change)

	Average 1980-89	Average 1990-94	1995	1996	1997	1998	1999
India	17	17	11	19	18	18	14
Korea	19	18	16	16	14	27	27
Malaysia	12	18	21	24	17	– 1	17
Philippines	21	21	24	23	26	9	16
Taiwan	..	17	10	8	4	9	8
Thailand	19	19	17	13	16	10	2
Brazil	281	1,089	48	56	21	24	38
Chile	35	31	27	25	22	12	11
Mexico	71	29	21	33	28	22	23
Peru	180	294	29	37	31	17	14
Czech Republic	..	21	19	8	10	5	8
Hungary	..	13	18	21	24	15	16
Poland	..	37	35	31	29	25	19
South Africa	21	13	14	16	19	14	14

[1] End-of-year data.

Table A4

Demand pressure indicator: unemployment rate[1]

	Average 1990-94	1995	1996	1997	1998	1999
Korea	2	2	2	3	7	6
Malaysia	4	3	3	2	3	3
Philippines	9	10	9	9	10	10
Taiwan	2	2	3	3	3	3
Thailand	3	2	2	2	4	4
Brazil	5	5	5	6	8	7
Chile	6	5	6	6	6	10
Mexico	3	6	5	3	3	2
Peru	0	8	8	8	8	9
Czech Republic	3	3	3	4	6	9
Hungary	8	11	11	11	9	6
Poland	12	15	14	11	10	12

[1] Yearly average in percentages.

Table A5

Cost pressure indicator: exchange rate[1]

(annual percentage change)

	Average 1980-89	Average 1990-94	1995	1996	1997	1998	1999
India	– 7	12	– 3	– 8	– 2	– 12	– 4
Korea	– 3	– 4	4	– 4	– 15	– 32	18
Malaysia	– 2	1	5	– 0	– 11	– 28	3
Philippines	– 10	– 4	3	– 2	– 11	– 28	5
Taiwan	3	– 0	– 0	– 4	– 4	– 14	4
Thailand	– 2	0	1	– 2	– 19	– 24	9
Brazil	– 69	– 93	– 30	– 9	– 7	– 7	– 36
Chile	– 18	– 9	6	– 4	– 2	– 9	– 10
Mexico	– 37	– 6	– 47	– 16	– 4	– 13	– 4
Peru	– 61	– 74	– 3	– 8	– 8	– 9	– 13
Czech Republic	– 1	– 12	8	– 2	– 14	– 2	– 7
Hungary	– 5	– 11	– 16	– 18	– 18	– 13	– 10
Poland	– 34	– 42	– 6	– 10	– 8	– 6	– 12
South Africa	– 11	– 6	– 2	– 16	– 7	– 17	– 10

[1] A decline indicates a depreciation of the domestic currency.

Table A6

Cost pressure indicator: nominal wages[1]

	Average 1990-94	1995	1996	1997	1998	1999
Korea	16	10	12	5	– 3	16
Malaysia	6	9	11	10	2	7
Philippines	6	2	12	15	6	7
Taiwan	9	3	5	4	1	6
Thailand	16	10	7	12	7	– 1
Brazil	1,453	72	20	6		
Chile	..	13	14	9	8	6
Mexico	23	16	20	20	18	16
Peru	– 10	2	3	76	11	– 3
Czech Republic	15	17	17	13	11	6
Hungary	22	20	23	22	15	11
Poland	..	33	27	21	16	10
South Africa	16	12	11	11	14	7

[1] Annual percentage change of yearly averages.

Table A7

Cost pressure indicators: food and oil price components[1]

		Average 1990-94	1995	1996	1997	1998	1999
India	*Food*	11.9	6.5	12.2	4.7	12.7	5.0
	Oil	12.6	1.6	12.9	13.2	4.4	4.4
Korea	*Food*	8.3	2.9	1.5	4.2	6.0	7.0
	Oil	5.9	4.4	14.3	30.2	21.6	4.4
Malaysia	*Food*	4.6	4.8	5.9	4.0	9.4	4.2
	Oil	2.0	– 5.6	5.0	3.1	4.8	5.1
Philippines	*Food*	8.7	10.4	9.7	3.6	9.6	4.0
	Oil	9.1	4.5	7.9	9.2	3.7	10.6
Taiwan	*Food*	4.5	4.3	3.7	– 0.8	4.6	– 1.6
	Oil	1.8	4.7	0.4	7.6	– 2.4	– 1.8
Thailand	*Food*	5.2	8.1	8.4	7.1	9.5	– 1.5
	Oil	2.4	4.9	1.8	11.6	16.8	0.6
Brazil	*Food*	1,090.2	34.7	4.8	1.0	4.0	5.0
	Oil	1,011.8	21.5	25.8	21.2	1.6	22.2
Chile	*Food*	15.9	20.7	– 1.9	20.9	– 0.2	– 10.7
	Oil	13.5	8.5	15.3	7.4	– 0.6	7.8
Mexico	*Food*	12.7	44.4	39.5	18.0	17.0	13.8
	Oil	19.7	50.0	30.8	21.0	18.3	23.3
Peru	*Food*	41.1	7.2	12.0	6.0	8.7	– 3.3
	Oil	44.1	7.8	12.1	6.3	– 2.8	12.3
Czech Republic	*Food*	19.6	9.7	8.2	4.8	3.7	– 3.5
	Oil	..	– 0.4	6.0	7.5	– 2.3	8.7
Hungary	*Food*	22.4	29.8	17.2	18.2	12.8	3.1
	Oil	14.5	21.3	25.1	18.1	8.2	21.8
Poland	*Food*	37.1	25.7	17.9	11.7	6.3	2.1
	Oil	38.0	11.2	18.7	17.7	9.3	29.6
South Africa	*Food*	16.0	7.7	6.5	9.6	6.2	4.8
	Oil	9.0	4.3	12.7	5.7	5.3	15.3

[1] Annual percentage changes.

Table A8

Cost pressure indicator: import prices [1]

	Average 1990-94	1995	1996	1997	1998	1999
India	1.2	10.7	44.3	– 10.6	– 13.9	
Korea	– 0.7	9.0	– 0.4	– 9.3	– 17.8	– 3.1
Malaysia	1.6	– 0.7	0.0	15.3	16.2	– 0.5
Philippines	– 1.4	1.3	4.5	2.4	3.3	– 7.0
Taiwan	1.6	11.9	– 1.0	1.1	0.3	2.6
Thailand	– 1.4	12.7	12.4	24.4	11.0	– 8.6
Brazil	– 3.4	2.3	– 9.7	6.5	– 5.3	0.3
Chile	– 1.6	8.4	0.3	– 4.3	– 5.1	– 3.6
Mexico	1.5	5.4	0.1	0.7	– 1.0	– 0.6
Peru	1.6	6.5	3.3	– 3.7	– 4.5	2.3
Czech Republic	0.7	0.9	0.3	2.0	– 3.6	1.1
Hungary	19.7	31.1	21.0	13.6	11.4	5.5
Poland	20.9	18.4	13.9	11.9	3.0	7.4
South Africa	1.4	6.1	– 8.1	– 0.9	– 7.7	– 4.5

[1] Annual percentage changes.

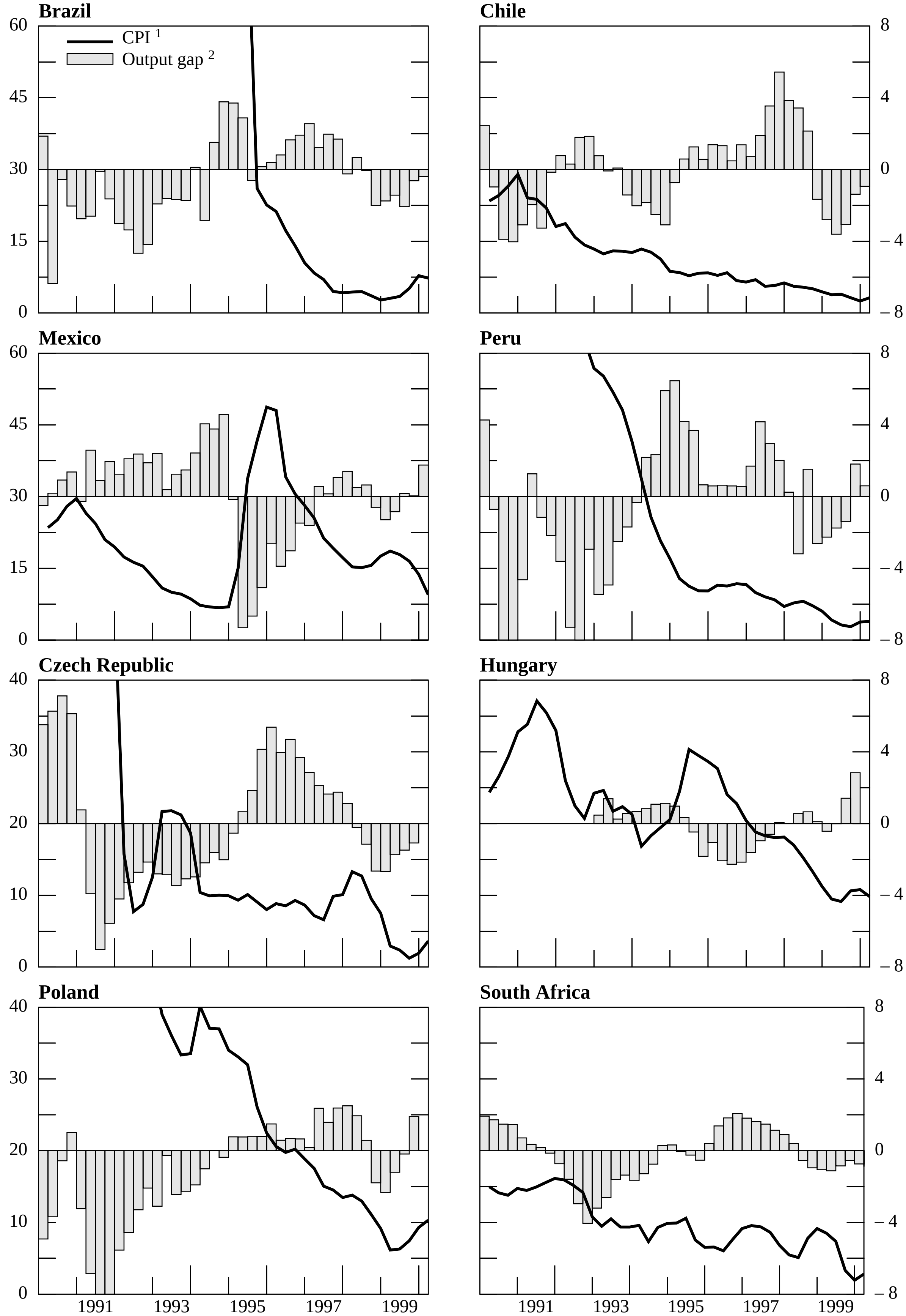
Table A9

Correlation with consumer price inflation

	Food price inflation	Oil price inflation	Import price inflation	Exchange rate depreciation	Output gap	Broad money expansion	Wage increase	Unemployment rate
India	0.61	0.07	0.12	0.09	– 0.10	– 0.51	..	..
Korea	0.50	– 0.06	– 0.12	0.47	0.15	– 0.45	0.06	– 0.20
Malaysia	0.71	– 0.11	– 0.10	0.22	– 0.13	– 0.26	– 0.40	0.21
Philippines	0.77	– 0.40	– 0.28	0.01	0.05	– 0.40	– 0.09	0.12
Taiwan	0.60	0.20	– 0.08	– 0.29	0.26	0.11	0.09	– 0.23
Thailand	0.71	0.33	0.42	0.36	0.43	0.27	..	– 0.29
Brazil	0.97	0.95	– 0.09	0.99	– 0.71	0.96	0.84	0.12
Chile	0.54	0.42	0.16	0.19	– 0.30	0.40	0.84	– 0.29
Mexico	0.96	0.64	0.30	0.66	– 0.46	0.75	0.88	0.26
Peru	0.71	– 0.05	– 0.04	– 0.28	0.36	0.31	– 0.05	0.19
Czech Republic	0.42	– 0.01	0.22	0.16	0.34	– 0.29	0.30	– 0.45
Hungary	0.78	0.34	0.76	0.48	– 0.19	– 0.56	0.10	0.40
Poland	0.84	– 0.20	0.36	– 0.02	0.02	0.23	0.70	0.73
South Africa	0.53	0.11	0.23	– 0.10	0.06	0.04	0.04	..

Graph 1

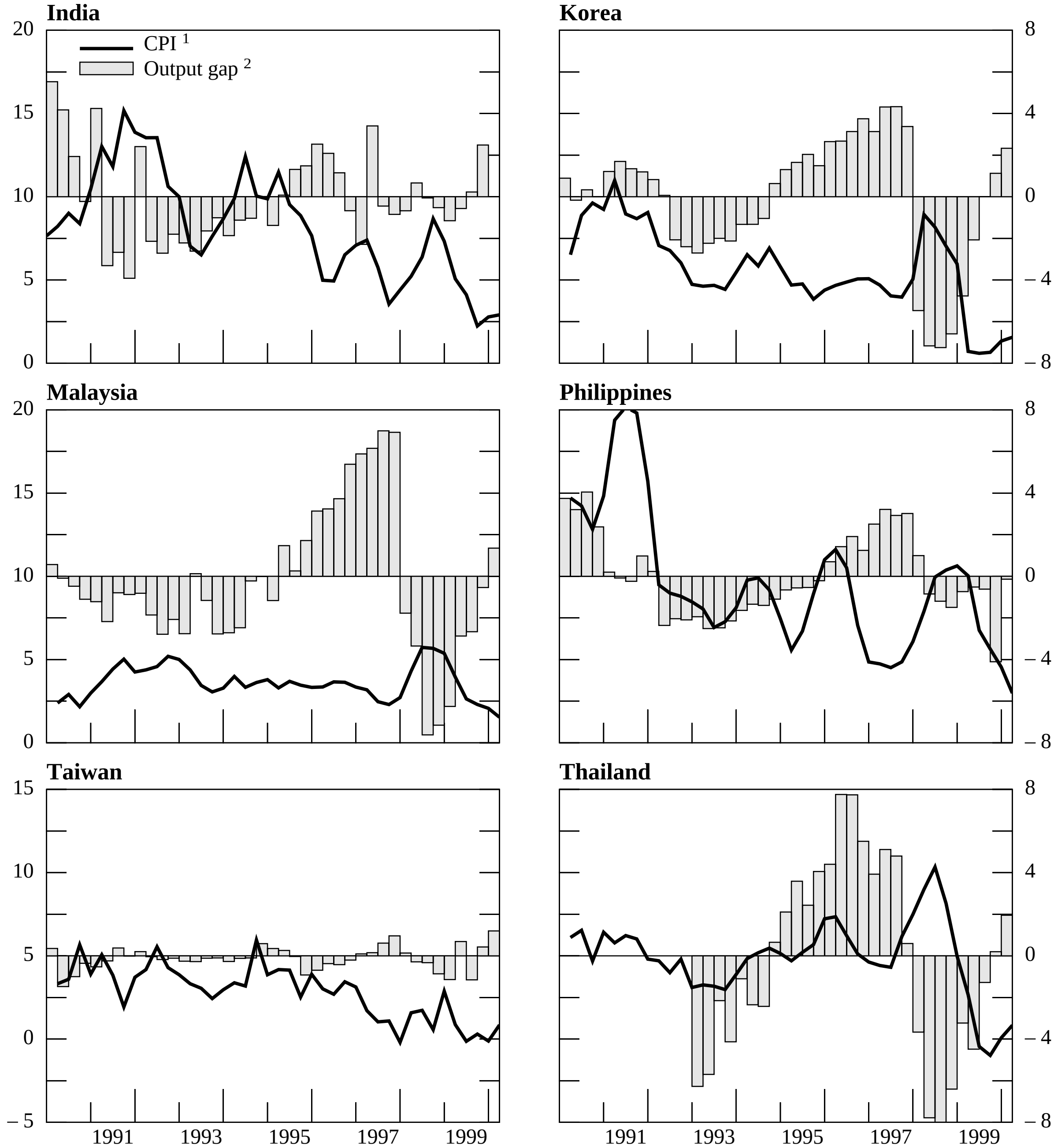
Inflation and output gaps



[1] Annual percentage change in consumer price index; left hand scale. [2] Right hand scale.

Graph 1a

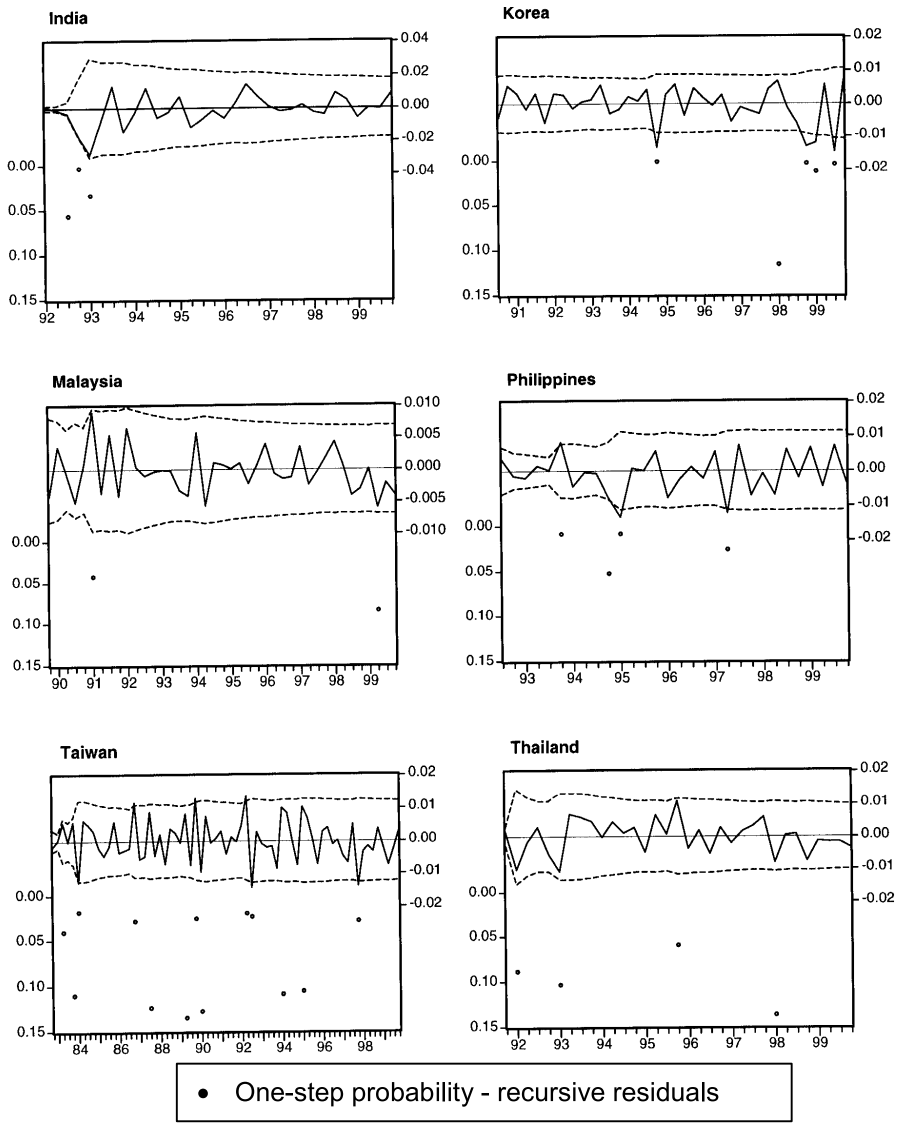
Inflation and output gaps



[1] Annual percentage change in consumer price index (for India wholesale price index); left hand scale. [2] Right hand scale.

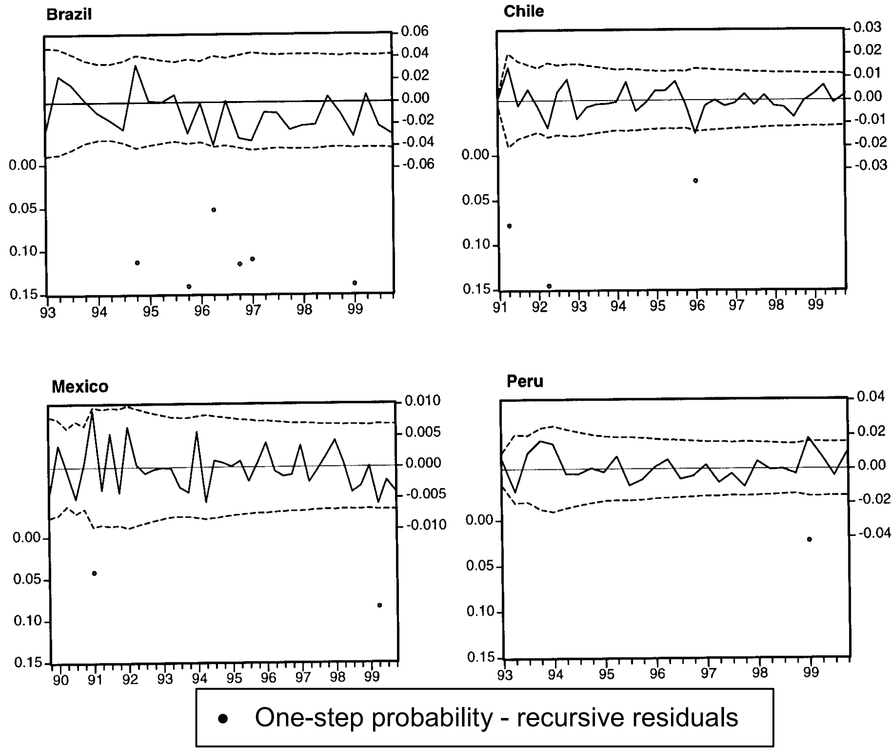
Graph 2a

Recursive estimation: one-step



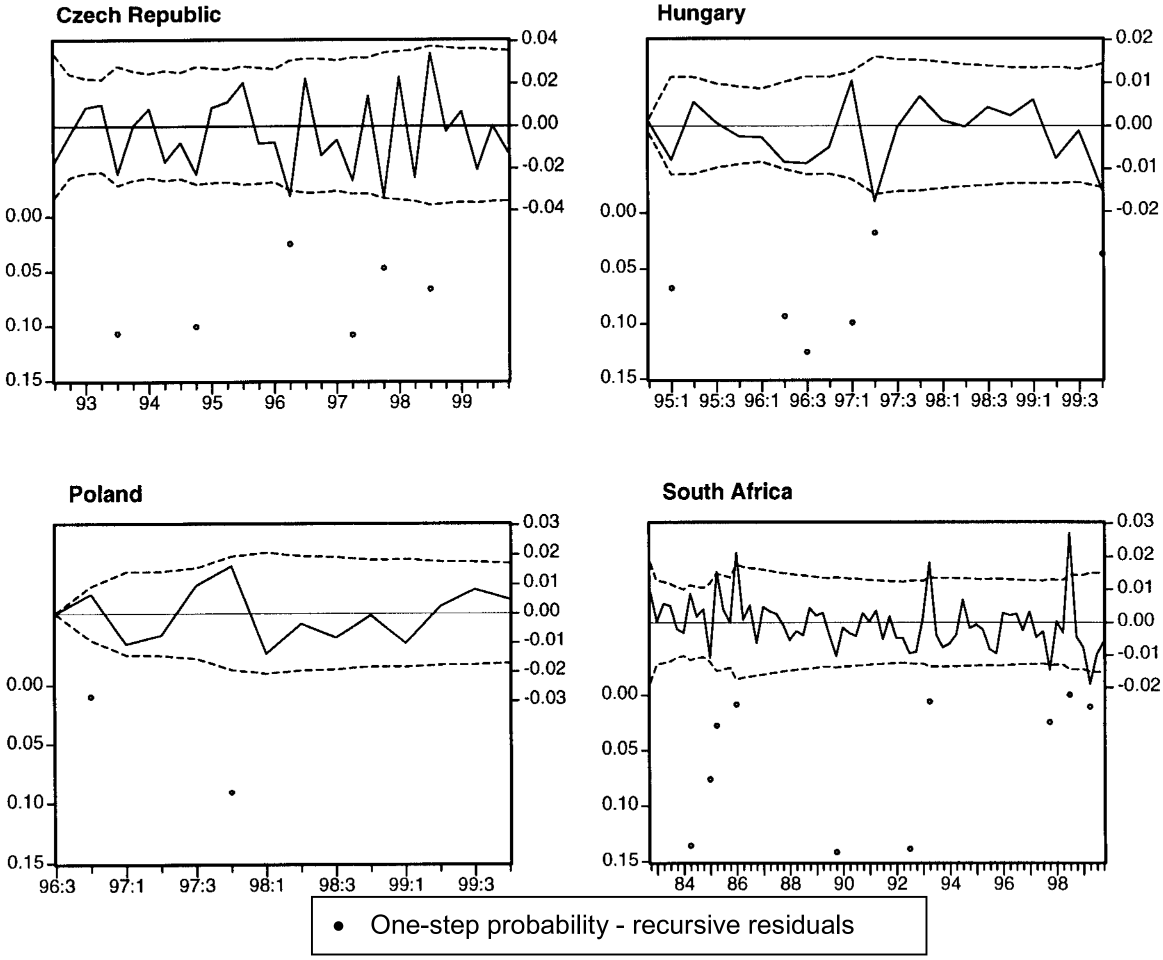
Graph 2b

Recursive estimation: one-step forecast test



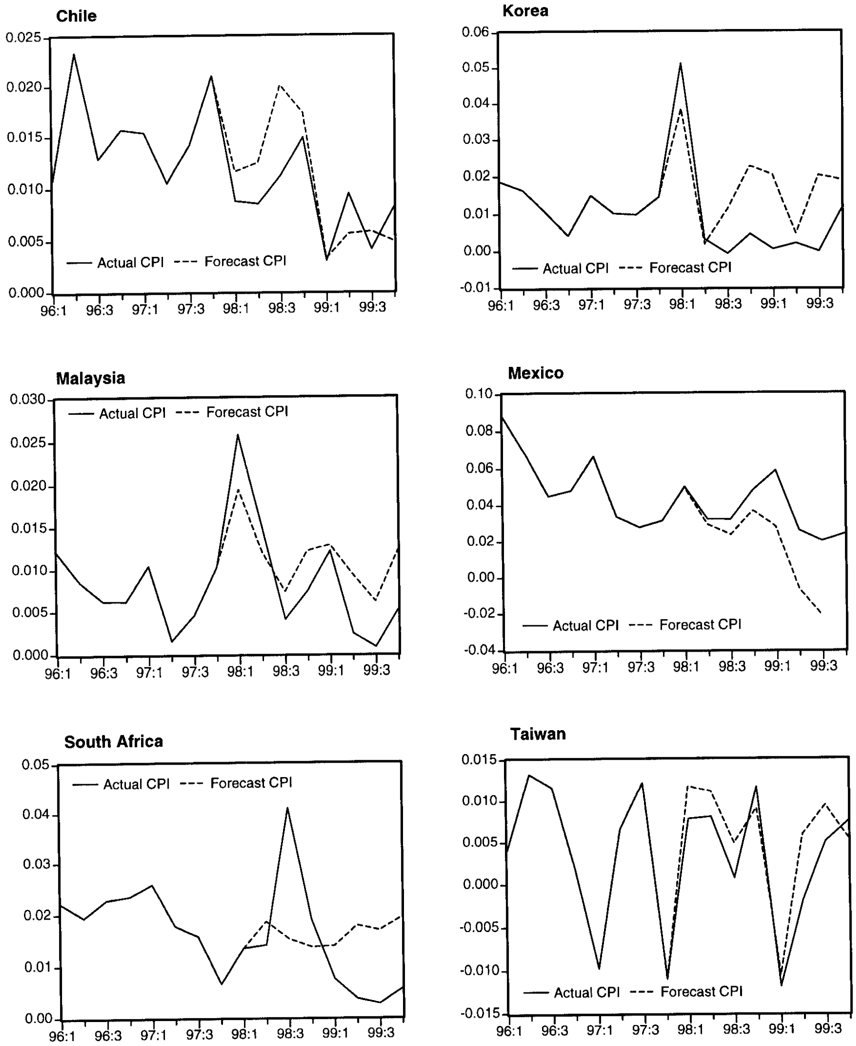
Graph 2c

Recursive estimation: one-step forecast test



Graph 3

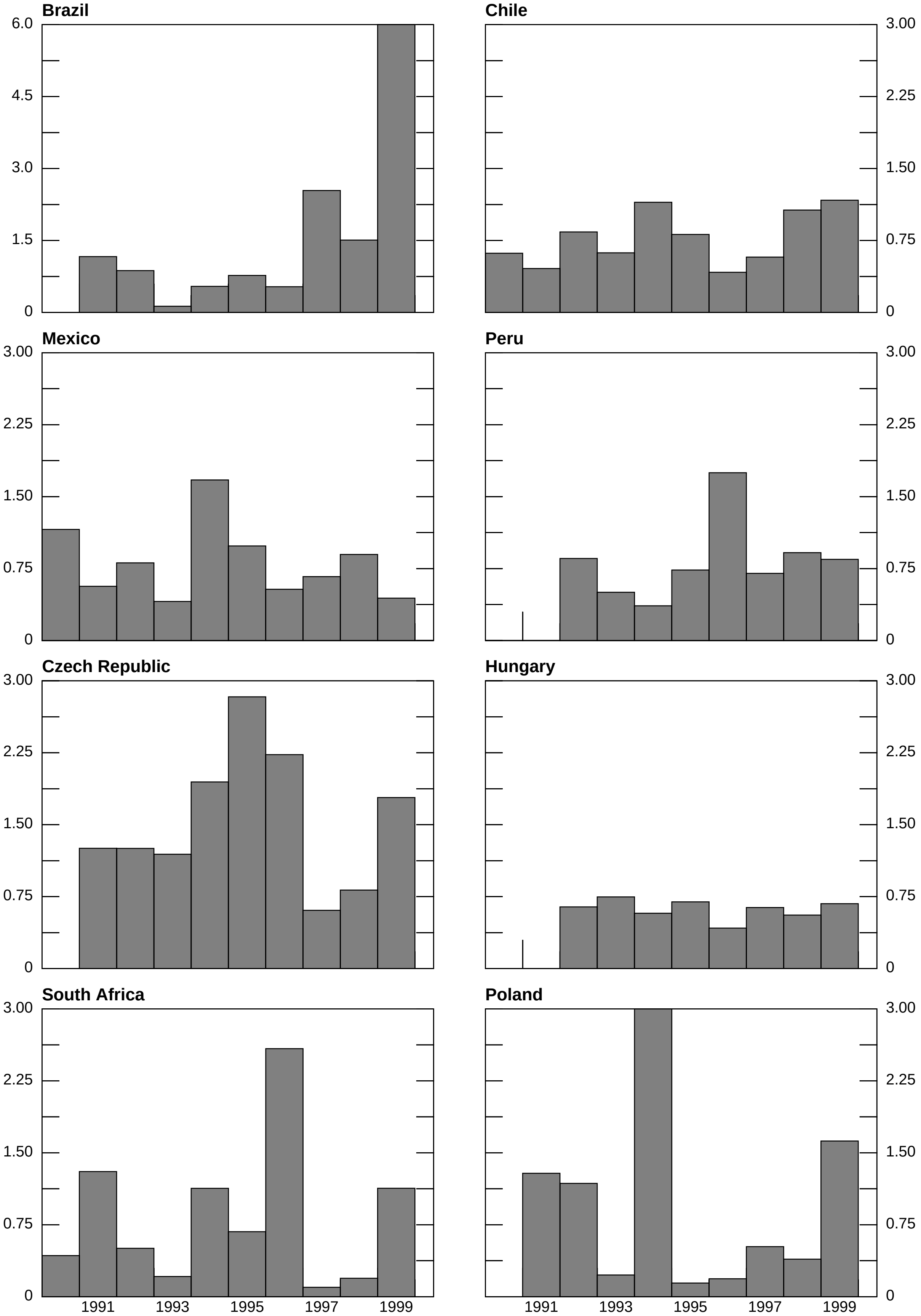
Out-of-sample forecast



Note: Dynamic out-of-sample forecast over the period 1998-99.

Graph 4

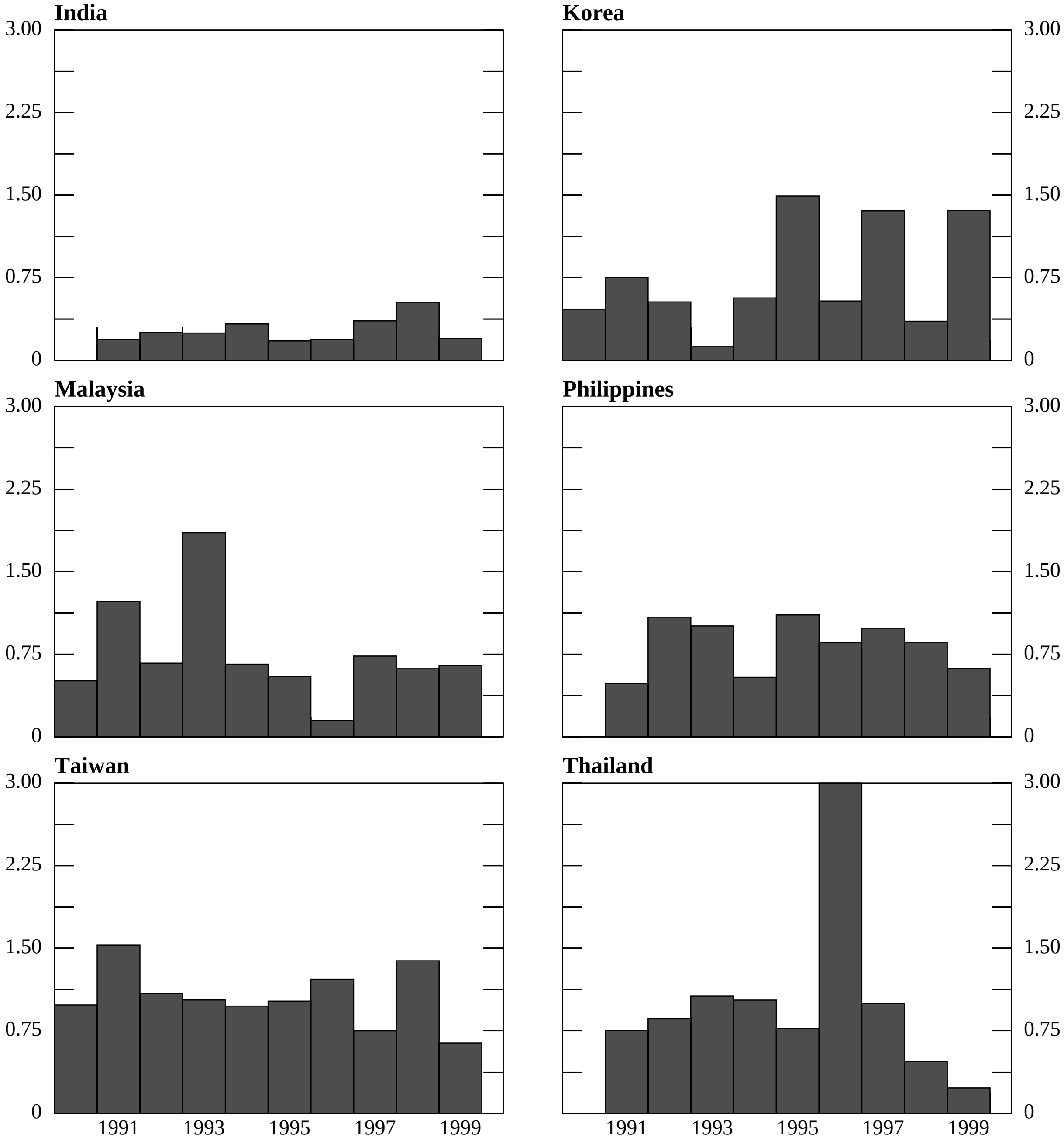
Contribution of food price shock to inflation [1]



[1] The contribution to the volatility of inflation is defined as the ratio of the standard deviation of food price shocks times its estimated coefficient and the standard deviation of inflation.

Graph 4a

Contribution of food price shock to inflation [1]



[1] The contribution to the volatility of inflation is defined as the ratio of the standard deviation of food price shocks times its estimated coefficient and the standard deviation of inflation.

Monetary policy rules in some mature emerging economies

Renato Filosa[1]

Introduction

The last decade has witnessed widespread changes in the monetary and exchange rate regimes of many emerging economies. The central banks of these economies have become more independent, inflation targeting regimes have gained momentum and exchange rate regimes are more flexible.

However, there is limited empirical work assessing the economic consequences of these regime changes, particularly in comparison with the extensive literature that focuses on the same topics for the industrial countries.

In an attempt to partially fill this gap, this paper uses small structural VAR models to explore three connected issues that are relevant to the pursuance of a stability-oriented monetary policy in the emerging markets.

First, is it possible to have model-based measures of core inflation capable of reflecting price level movements that are due to the activity of monetary authorities and for which these authorities are accountable? The first section of the paper explores this topic using a small SVAR not yet considered for this purpose by the existing literature.

Second, is it possible to estimate the reaction function of the central banks of mature emerging economies and compare the results with those obtained for industrial economies? Section 2 of the paper provides these estimates and illustrates the main difficulties in applying to emerging economies analytical tools that have been successfully used for the main industrial economies.

In the third section of the paper simulations of the effects of alternative monetary policy rules or the main macroeconomic variables of a selected number of economies are presented. These simulations are compared with those obtained for the euro area under similar assumptions.

The last section provides a summary of the results and some conclusions.

1. The quest for a robust monetary regime for mature emerging economies

In the past few years momentous changes have occurred in the monetary and exchange rate regimes of most emerging countries. In Latin America, after decades of extreme swings in inflation and in the exchange rate (due to overly accommodating monetary policy and unsustainable fiscal laxity), massive outflows of capital (despite widespread capital controls) and repeated systemic disruptions in the domestic financial systems, successful reforms radically changed the landscape in the second half of the 1990s. Inflation is now under the control of more independent central banks, fiscal deficits have been reduced to manageable proportions, capital mobility is generally very high, and exchange rates far more flexible but nonetheless far more stable than previously. In Asia, countries are recovering from devastating currency and banking crises that have interrupted years of price and exchange rate stability. As in Latin America, exchange rate regimes in the majority of Asian countries no longer exhibit the characteristics of the hard pegs of the 1980s and early 1990s.

[1] I am very grateful to Stephan Gerlach for valuable comments and also to Stephan Arthur, Anna Cobau and Marc Klau for their effective statistical assistance.

Following their exit from monetary arrangements based on exchange rate "fixity", the majority of these emerging economies have been confronted with the need to adopt a new monetary framework and are still facing issues similar to those encountered in the recent past by the industrial countries, namely: the inflationary outcomes of discretionary monetary policies, the difficulties of implementing direct monetary control strategies due to the instability of the intermediate targets stemming from the liberalisation of their financial systems, and the unsustainability of the hard pegs in a world of much increased capital mobility and not fully credible policies.

Economic events, however, do not fully explain the trend towards monetary policy frameworks centred on the basic tenet that the primary, if not exclusive, task of central banks is to achieve and maintain price stability. Important theoretical advances have also played a role in catalysing this global regime shift.

1.1 Monetary policy rules for closed economies

The theoretical work has concentrated on identifying a commitment mechanism capable of ensuring macroeconomic stability while leaving monetary authorities with some room for exercising discretion. Three main theoretical considerations explain these developments.

"First, after a long period of near exclusive focus on the role of nonmonetary factors in the business cycle, a stream of empirical work beginning in the late 1980s has made the case that monetary policy significantly influences the short-term course of the real economy."

"Second, there has been considerable improvement in the underlying theoretical frameworks used for policy analysis." [2]

And, third, *"there may be gains from enhancing credibility either by formal commitment to a policy rule or by introducing some kind of institutional arrangement that achieves roughly the same end"* [3].

Inflation targeting has emerged as a monetary framework that subsumes a complex institutional arrangement. In fact, as Mishkin and Savastano (2000, p 32) put it, inflation targeting involves several elements: *"(1) the public announcement of medium-term numerical targets for inflation; (2) an institutional commitment to price stability as the primary goal of monetary policy, to which other goals are subordinated; (3) an information-inclusive strategy in which many variables, and not just monetary aggregates or the exchange rate, are used for deciding the setting of policy instruments; (4) a transparent monetary policy strategy that ascribes a central role to communicating to the public and the markets the plans, objectives, and rationale for the decisions of the central bank; and (5) mechanisms that make the central bank accountable for attaining its inflation objectives. The list should clarify one crucial point about inflation targeting: it entails much more than a public announcement of numerical targets for inflation for the year ahead."* These elements describe a general *"framework for policy within which 'constrained discretion' can be exercised"*[4] in a world where rigid rules have ceased to have any effectiveness.

Several monetary "rules" have been proposed by the literature that are consistent with this approach. Following Taylor,[5] a very parsimonious representation of the framework for closed economies is provided by the following two expressions:

$$Y_t = A(L,g)Y_t + B(L,g)r_t + u_t \tag{1}$$

$$r_t = g_\pi \pi_t + g_x x_t + g_r r_{t-1} + g_0 + \varepsilon_t \,. \tag{2}$$

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[2] Clarida et al (1999), p 1661.

[3] Clarida et al (1999), p 1663.

[4] Bernanke et al (1999), p 22.

[5] Taylor (1999).

In equation (1), which represents the macroeconomic model of the economy, Y_t is the vector of endogenous variables, r_t is the short-term interest rate, $A(L,g)$ and $B(L,g)$ are vector polynomials in the lag operator L, and u_t and ε_t are serially uncorrelated vectors of random disturbances.

Equation (2) represents the reaction function of monetary authorities or the monetary policy rule. The above reaction function, a seemingly simple one, assumes that the policy variable responds to inflation (π_t) and the output gap (x_t) and its own past value, and it is consistent with several monetary rules proposed by the literature.

In fact, the above reaction function can be interpreted as a Taylor rule[6] according to which the monetary authorities react to *actual* inflation and the actual output gap. However, it can also be consistent with the *inflation forecast targeting* as shown by Svensson: *"The instrument depends on current inflation not because current inflation is targeted (current inflation is predetermined) but because current inflation together with output and the exogenous variable predict future inflation."* [7]

In an inflation targeting context, the "simple" rule subsumes, in reality, a complex set of economic behaviour and preferences. The rule is derived, in fact, from the minimisation of the loss function of the central bank expressing society's preferences about the short-term trade-off between inflation and the level of activity. More specifically, the arguments of the loss function are the discrepancy between actual inflation and the targeted inflation forecast (which monetary authorities are committed to achieve within a prespecified time horizon) and the deviation of the output gap from its targeted level (assumed to be zero).

The inflation forecast in turn depends on a number of relevant variables (wage settlements, changes in the exchange rate, import prices, etc) as summarised in a potentially complex model. In this sense, inflation forecast targeting is consistent with a more realistic representation of the central bank's behaviour than that of the Taylor rule as it reflects the fact of life that interest rate decisions are not based on the observation of two variables only. More fundamentally, in an inflation targeting framework the reaction function describes a definitive commitment on the part of the central bank to achieving the target that is not implicit in the Taylor rule.

In this framework, the most important issue facing policymakers concerns the effects on macroeconomic stability of different monetary policy rules. In fact, the dynamics of the main macroeconomic variables following a shock critically depend (for any given structural model of the economy) both on the variables that are included in the reaction function of the central bank and on the value of the parameters of the monetary policy rule.

Concerning the latter, Taylor[8] and Clarida et al[9] show that $g_\pi \leq 1$ leads to instability in the economy as the response of the central bank to inflation fails to increase the *real* interest rate and therefore to cool down the economy. A "low" response to inflation thus coincides with monetary accommodation. If the output gap is not an argument of the reaction function, the approach coincides with the *strict inflation targeting* regime where the inflation target is achieved – within the time horizon chosen by the central bank – irrespective of the consequence that this action may have on the variability of output and the instrument itself. Several contributions have shown that for the industrial countries a strict inflation targeting regime (ie when $g_x = 0$) leads to high variability of the main economic variable and potentially to instrument instability.[10] If instead $g_x > 0$, the achievement of the inflation target is more gradual, as stated by Svensson (who assumes that the central bank is committed to achieving the inflation forecast target in two years): *"The intuition for this is that always adjusting the two-year inflation forecast all the way to the long-run inflation target, regardless of the one-year inflation forecast, requires more output fluctuations. If there is a positive weight on output stabilisation, a gradual adjustment of the two-year inflation forecast towards the long-run inflation target reduces output*

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6 Taylor (1993).

7 Svensson (1997), p 1119.

8 Taylor (1999).

9 Clarida et al (1998).

10 See, for example, Rudebusch and Svensson (1999).

fluctuations. The higher the weight on output stabilisation, the slower the adjustment of the inflation forecast towards the long-run inflation target (the larger the coefficient)." [11]

Finally, if the lagged interest rate is also present in the reaction function, there is another source of gradualism. In this case, the central bank achieves the "required" change in the interest rate through a succession of "small" steps (the central bank follows the so-called *interest smoothing* approach). From an empirical point of view, all estimated reaction functions of the main industrial countries find that the interest smoothing hypothesis is always validated by data and that g_r is very high (0.8 or 0.9).[12]

One final critical issue is whether central banks should respond differently to different disturbances. More precisely, should central banks use the same rule to respond to supply and demand shocks? From a theoretical point of view, the answer to this question is clear:

"The simple idea is that countering demand shocks pushes both output and inflation in the right direction. Demand shocks do not force a short run trade-off between output and inflation."

"Shocks to potential output also do not force a short run trade-off. But they require a quite different policy response. Thus, eg, a permanent rise in productivity raises potential output, but it also raises output demand in a perfectly offsetting manner, due to the impact on permanent income. As a consequence, the output gap does not change. In turn, there is no change in inflation. Thus, there is no reason to raise interest rates, despite the rise in output." [13]

1.2 A general representation of the Taylor rule

This paper estimates monetary policy rules of the Taylor type following the model proposed by Clarida, Galí and Gertler (CGG).[14]

The model postulates that the central bank aims at maintaining the inflation rate equal to a prespecified target level (for example zero) and keeping the economy as close as possible to a neutral cyclical position. To achieve these objectives, the central bank uses some operating instrument. It is assumed, consistently with the practice of most central banks, that the main operating instrument is a short-term interest rate.

It is therefore assumed that the central bank sets the target short-term interest rate r_t^* conditional on the state of the economy and that the short-term interest rate depends on the deviation of expected inflation and output from their respective targets, that is:

$$r_t^* = \bar{r} + \beta\left(E\left[\pi_{t+n}|I_t\right] - \pi^*\right) + \gamma E\left[x_t|I_t\right] \tag{3}$$

where $\bar{r}$ is the long-run equilibrium nominal rate, π_{t+n} is the inflation rate between time t and time t+n, x_t is the real output gap and π^* is the target level of inflation and output. The symbol E is the expectation operator and I_t is the set of information available at time t.

From Equation (3) one can derive the implied target for the ex ante real interest rate,

$rr_t \equiv r_t - E\left[\pi_{t+n}|I_t\right]$ as:

$$rr_t^* = \overline{rr} + (\beta - 1)\left(E\left[\pi_{t+n}|I_t\right] - \pi^*\right) + \gamma E\left[x_t|I_t\right] \tag{4}$$

where $\overline{rr}_t$ is the long-run equilibrium real rate of interest.

This equation explicitly shows the importance of the value of the coefficient β. If $\beta > 1$, changes in the *nominal* rate induce changes in the *real* interest rate that reduce inflation; if $\gamma > 0$, the *real* interest

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11 Svensson (1997), p 1132.

12 See, for example, Clarida et al (1999).

13 Clarida et al (1999), pp 1674-75.

14 Clarida et al (1998).

rate is also changed to stabilise output. Conversely, if $\beta < 1$, changes in the nominal interest rate *accommodate* changes in inflation instead of *resisting* them. The reduction in the real interest rate derives from the fact that the monetary authorities increase the nominal interest rate by an amount that is *insufficient* to avoid the decline in the real interest rate.

An additional desirable feature of the model is that it allows the control of inflation and the stabilisation of output to be identified as *independent* objectives. In the traditional Taylor rule model, in fact, the central bank reacts to *actual inflation* and actual output gap. In the Taylor rule type of equation, it is not clear that the central bank can respond *independently* to inflation and the output gap. For example, if *actual inflation* and the actual output gap are linked by a linear Phillips curve, responding to inflation implies an automatic response to the output gap as well. If, instead, *expected inflation*, and not *actual inflation*, enters the reaction function of the central bank, this automatic link no longer exists and the equation can test whether there is an independent response to the two variables in the central bank reaction function. The model, then, encompasses the Taylor model.

In order to obtain an estimatable equation, the authors define $\alpha \equiv \bar{r} - \beta\pi^*$.

Equation (3) could then be rewritten as:

$$r_t^* = \alpha + \beta E[\pi_{t+n}|I_t] + \gamma E[x_t|I_t]. \tag{5}$$

The authors, in addition, assume that the actual rate adjusts only gradually to the target as follows:

$$r_t = (1-\rho)r_t^* + \rho r_{t-1} + v_t \tag{6}$$

where $\rho \in [0,1]$.

The parameter ρ captures the degree of interest rate smoothing. Several explanations of the interest smoothing hypothesis have been proposed in the literature: central banks move policy interest gradually for fear of disrupting capital markets, to avoid policy reversals, etc. The error term v_t is a random shock assumed to be i.i.d.

Combining Equation (5) with the partial adjustment equation (6) gives:

$$r_t = (1-\rho)\{\alpha + \beta E[\pi_{t+n}|I_t] + \gamma E[x_t|I_t]\} + \rho r_{t-1} + v_t. \tag{7}$$

The authors eliminate the unobserved forecast variables from the expression by rewriting the policy rule in terms of the actual output gap and the inflation forecast as follows:

$$r_t = (1-\rho)\alpha + (1-\rho)\beta\pi_{t+n} + (1-\rho)\gamma x_t + \rho r_{t-1} + \varepsilon_t \tag{8}$$

where: $\varepsilon_t \equiv -(1-\rho)\{\beta(\pi_{t+n} - E[\pi_{t+n}|I_t]) + \gamma(x_t - E[x_t|I_t])\} + v_t$.

The error term is a linear combination of the forecasting errors of inflation and output and the shock v_t.

Finally, while it is assumed that the central bank can pursue an independent monetary policy, this does not imply, as mentioned before, that the central bank cannot have objectives other than inflation control and stabilisation of the business cycle. For example, it could aim at maintaining the real exchange rate within a predetermined range or it could flexibly pursue a monetary target. This implies that, in the equation describing how monetary authorities set the interest rate, it is possible to include other variables in addition to inflation and output. If z_t denotes one such variable, equation (5) can be replaced by the following equation:

$$r_t^* = \alpha + \beta E[\pi_{t+n}|I_t] + \gamma E[x_t|I_t] + \xi E[z_t|I_t]. \tag{9}$$

As noted in Section 1.1, theory suggests that central banks should respond to demand shocks but not to supply shocks. In addition, it was also noted that different monetary rules, for example the Taylor as compared with the strict Inflation Targeting rule, have different effects on the economy and on the instrument itself.

These considerations therefore suggest that it is important to empirically assess:

– the nature and the intensity of the shocks affecting emerging markets;

– whether there is empirical evidence that central banks in these economies react to variables other than just inflation and output;

– whether different monetary policy rules (and/or the parameters of the reaction functions themselves) produce different effects on the economy when demand or supply shocks hit a country.

2. Supply and demand shocks affecting emerging economies

Small open emerging economies have traditionally been exposed to significant shocks, both real and nominal. These disturbances may, in turn, be of domestic or foreign origin. They have conferred on the economies a much higher volatility than observed in industrial countries. The following paragraph tries to empirically identify the nature and the effects of these shocks on emerging economies.

2.1 A SVAR model for open economies

The importance of shocks and their nature (real and nominal) has often been invoked in the literature[15] to explain the greater volatility in emerging economies compared with the industrial countries.

One convenient way to assess the relative importance of real (supply and demand) and nominal disturbances for these economies and to estimate the effects they produce on the exchange rate and inflation is to estimate the structural VAR (SVAR) originally proposed by Clarida and Galí (1994). One particularly appealing feature of this model is that it has well established theoretical foundations as it represents a stochastic version of the two-country model developed by Obstfeld (1985).[16]

The model aims at identifying three structural disturbances that hit the economy. The first is called *supply shock* and is meant to capture all real disturbances that have a long-run effect on output. Supply shocks include, for example, terms-of-trade shocks or technological changes. The second type of shock considered in the model is the *real demand shock.* It can be originated by a fiscal disturbance or by a change in the propensity to spend or it can arise from an exogenous change in foreign demand for domestic production. The third shock is called *nominal (or monetary) shock*. It can be interpreted as an exogenous change in monetary policy – either domestic or foreign – or in wage claims or in price formation.

Assuming rational expectations and full price flexibility, Clarida and Galí show that the model is lower triangular in the long run and has the following form:

$$y_t^e = y_t^s$$

$$q_t^e = \left(y_t^s - d_t\right)/\,\eta + \left[\eta(\eta + \sigma)\right]^{-1}\sigma\gamma\delta_t$$

$$p_t^e = m_t - y_t^s + \lambda(1+\lambda)^{-1}(\eta+\sigma)^{-1}\gamma\delta_t$$

where y_t^e is the equilibrium level of the domestic product, d_t is the real demand shock, p_t^e is the equilibrium price level, m_t is the money supply, η and σ are the elasticity of output with respect to the real exchange rate (q_t) and to the real interest rate respectively, and λ is the elasticity of money demand to the nominal interest rate. As in the Clarida-Galí model, all variables, except the interest rate, represent domestic relative to foreign levels.

15 See IMF, *International Capital Markets* (November 1997); IMF, *World Economic Outlook* (May 1998), pp 80-82; Hausmann and Gavin (1996), p 36; Bruno (1994), pp 71-74.

16 *"The model not only exhibits the standard Mundell-Fleming-Dornbusch results in the 'short run' when prices adjust sluggishly to demand, money, and supply shocks, but it also embodies the 'longer-run' properties that characterize macroeconomic equilibrium in the open economy once prices adjust fully to all shocks."* (Clarida and Galí (1994), p 24).

The stochastic behaviour of the model assumes that the supply and nominal shocks are permanent while a fraction γ of the demand shock δ_t is assumed to reverse itself within one period after the shock.

The model has the following *long-run properties:*

(a) the level of output is influenced only by supply shocks;

(b) the real exchange rate depreciates following a supply shock but appreciates as a consequence of a real demand shock (nominal shocks have no long-run effects on its level;

(c) the equilibrium level of prices is increased by real demand shocks and nominal shocks but is reduced by a supply shock.

If it is assumed that after a shock the price level adjusts only gradually to the new equilibrium level, the *short-run properties* of the economy are as follows:

(a) the level of output depends on all three shocks;

(b) the real exchange rate is also affected by nominal shocks. To the extent that the effect of such a shock on the real exchange rate is significant, the model is consistent with the Mussa conjecture. It should, in addition, be noted that the model is also consistent with the overshooting hypothesis.

The econometric strategy used to identify the structural shocks consists in the estimation of a structural VAR according to the methodology proposed by Blanchard and Quah (1989) that imposes the long-run restriction in the equations of the unrestricted VAR.

2.1.1 Estimation results

The model has been estimated using the 1980-99 quarterly data for six middle-income countries in Latin America and Asia (Argentina, Brazil, Mexico, Indonesia, Korea and Thailand). The data on the real GDP and the consumer price index have been scaled by the same variables for the United States. The real exchange rate is the bilateral real exchange rate vis-à-vis the US dollar.

The identification strategy used to estimate the structural shocks predicts the following general pattern for the impulse response.

A *positive supply shock* gradually increases output towards a new higher steady state level. The same shock reduces the price level, reflecting the greater efficiency of the productive process or lower production costs. This in turn, by increasing competitiveness, would induce a depreciation of the real exchange rate (given the definition of the exchange rate – quantity of foreign currency per unit of domestic currency – in the graphs an increase (decrease) of the exchange rate signals appreciation (depreciation)). Supply shocks, however, may lead to an appreciation of the real exchange rate if they reflect disturbances in the terms of trade. If the international trade of commodities represents an important component of the GDP, an improvement in the terms of trade would stimulate exports (and so output) and increase the international price of the output of the country (ie the real exchange rate).

A positive *real demand shock* is expected to temporarily increase output, increase prices, due to the creation of excess demand, and appreciate the real exchange rate, both because of the increase in prices and because the demand shock would tend to increase domestic interest rates relative to the foreign one and this would tend to induce a nominal appreciation of the exchange rate.

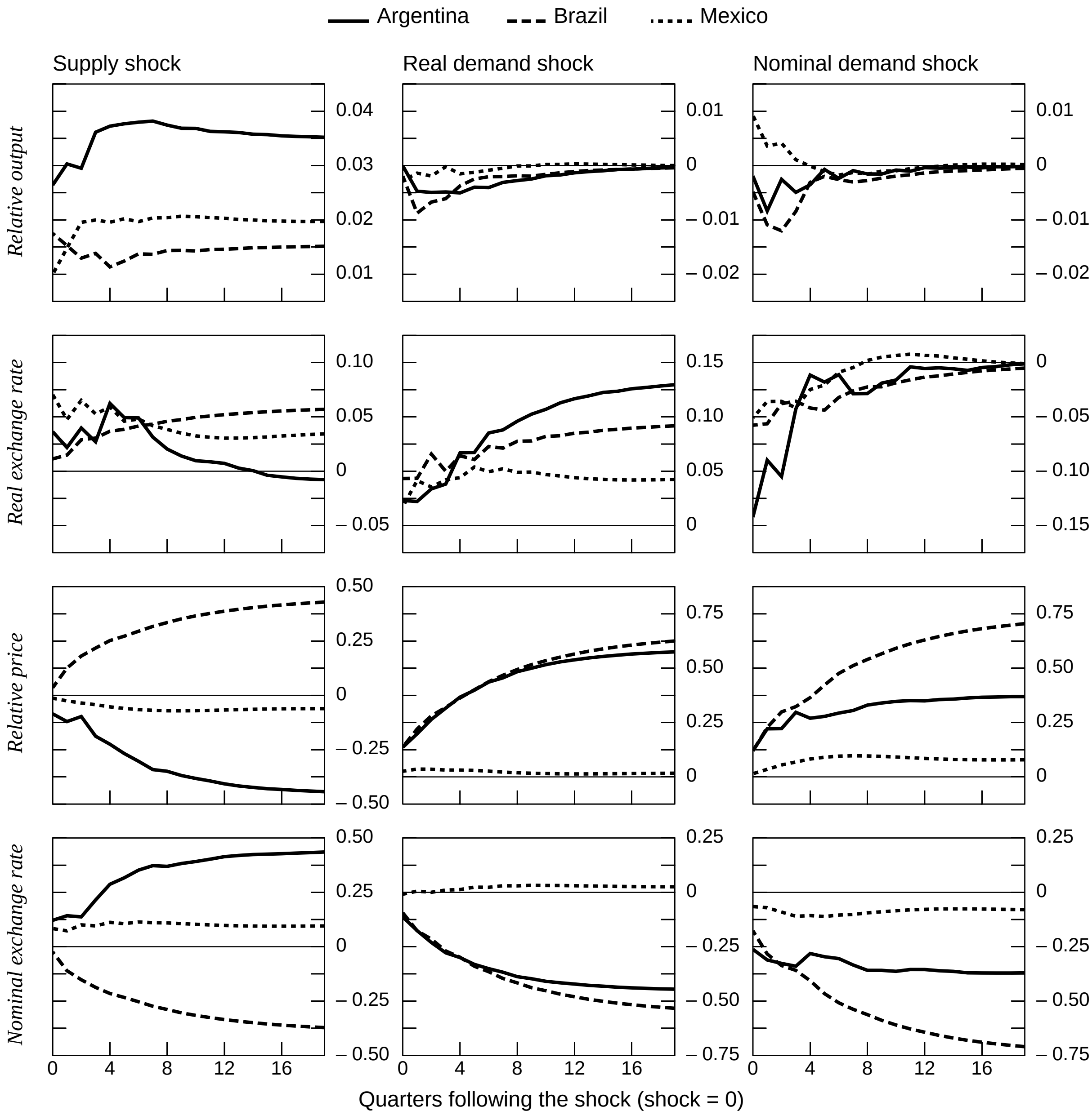
Finally, a *nominal or monetary shock* (such as an easing of monetary policy, a reduction in foreign interest rates or an increase in wage claims) is expected to temporarily increase output and prices and depreciate the real (and nominal) exchange rate. The impulse response can also show overshooting or undershooting of the exchange rate, as explained in the previous section.

The empirical results represented in Graphs 1-2 show that the impulse responses are consistent with the dynamics of the theoretical model with the exception that the real exchange rate appreciates for all countries following a supply shock.

For all countries, a positive *supply shock* increases output to a new higher steady state level, as expected. The shock, however, produces for all Latin American countries an appreciation of the exchange rate instead of the expected depreciation. This appreciation is permanent for all countries except Argentina. One interpretation of this finding is that a positive supply (terms-of-trade) shock has contributed to an improvement in the sustainability of the external position of these countries.

Graph 1

Impulse responses to supply and demand shocks

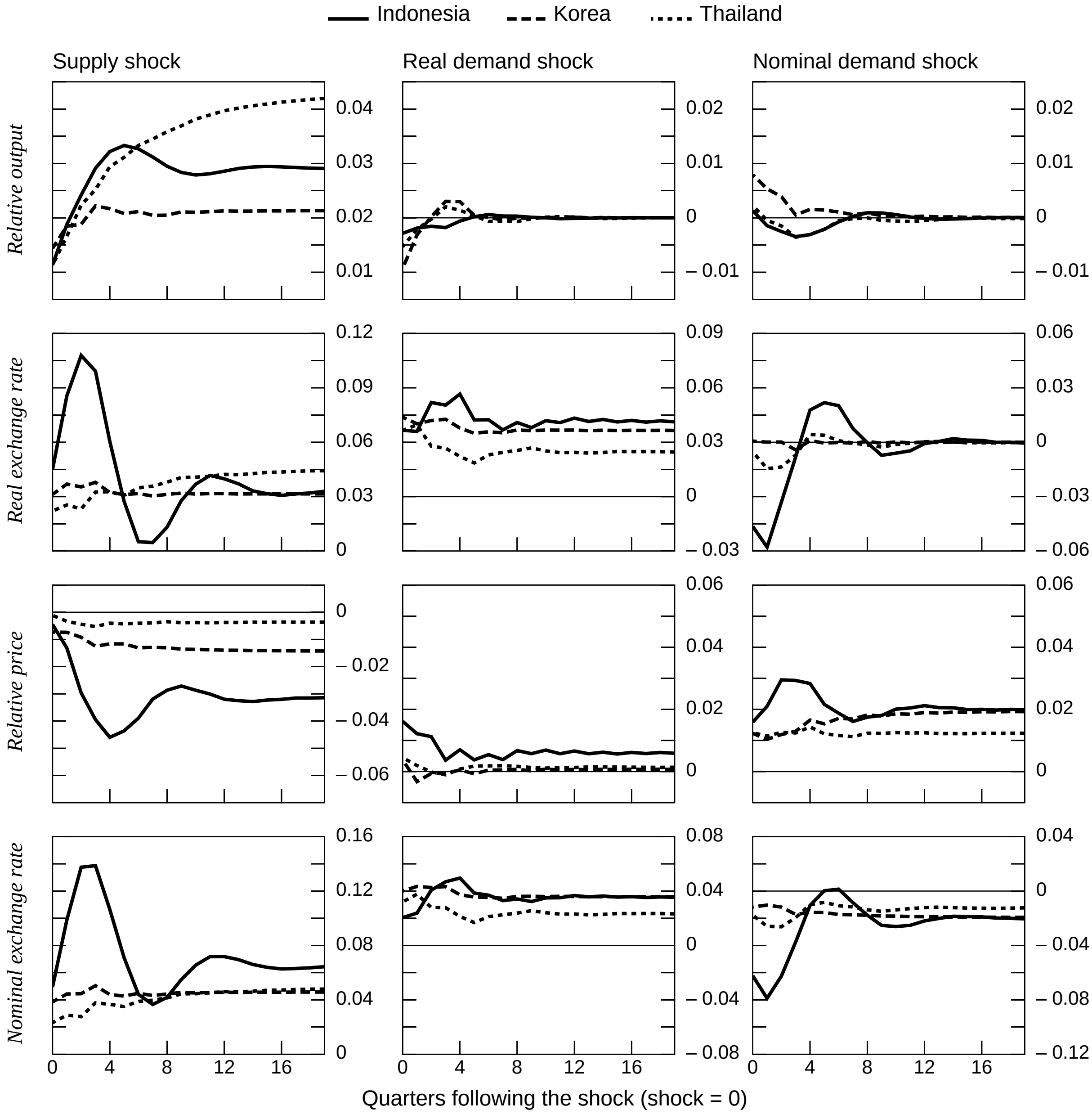


A *real demand shock* increases the relative price (significantly in Argentina and Brazil consistently with their record of being high-inflation countries) and induces an appreciation in the real exchange rate. One important observation is that in Argentina and Brazil the real appreciation due to a real demand shock is entirely attributable to the increase in the relative price as the *nominal exchange rate* (which has been mechanically derived from the log difference between the real exchange rate and the relative price) depreciates. This evidence is consistent with the conjecture that during the period under review fiscal authorities lacked credibility. A fiscal expansion, therefore, led to an immediate surge of inflation and depreciation of the exchange rate. Concerning the effects of a real demand shock on output, data reveal that such a shock does not have a significant impact on real activity, except in Mexico and Korea.

A *nominal shock* produces the expected effects on the real (and nominal) exchange rate along with inflationary pressures that, again, are particularly pronounced in Argentina and Brazil. Following a monetary shock, the real exchange rate depreciates on impact and remains persistently below the pre-shock level in Latin America and Indonesia. In the other two Asian countries the increase in the relative price is exactly matched by nominal depreciation, so that the real exchange rate is not affected at all.

Graph 2

Impulse responses to supply and demand shocks



Furthermore, in all countries there are distinct manifestations of a variability of the real and nominal exchange rate (in addition to the initial overshooting). Monetary shocks thus have persistent *short-term* effects on the real exchange rate in Latin America and Indonesia in accordance with the Mussa conjecture. Finally, monetary shocks do not have significant effects on output, except in Mexico and Korea. These results give empirical support to the proposition that demand management efforts, as captured by the model as the effects of real demand and nominal shocks, were misguided.

2.2 Estimating core inflation

Having established that the response of these economies to the main disturbances is consistent with the theoretical underpinnings of the model, it is possible to turn to the question of whether this methodology allows us to obtain a meaningful estimate of core inflation.

There are several reasons why it is useful, for monetary policy purposes, to have a measure of inflation that represents underlying monetary inflation better than the change of an official price index.

First, central banks need to distinguish between temporary or reversible price changes and trend inflation.[17] Second, it is important that core inflation functions as a leading indicator of future actual price changes. This has an implication for the choice of method to calculate core inflation as certain approaches provide a distorted measure of long-term inflation. Third, and perhaps most importantly, central banks need to have a measure of inflation that reflects monetary policy actions for which they are responsible and accountable. This too is of critical importance for the choice of methodology as certain methods produce a measure of core inflation that does not distinguish between the sources of inflationary shocks, in particular monetary shocks.

As a measure of core inflation, many central banks use a definition of CPI inflation that excludes certain categories of goods and services that are supposedly volatile. The most popular example of this type of definition is the "ex food and energy" price index. The risk of such an approach, however, is to exclude from the index components that, in fact, can contribute to trend inflation and not just to its short-term volatility. Therefore, this approach could lack credibility as it involves arbitrary decisions as to what constitutes the transitory component of inflation.

Because of these shortcomings, a second method of measuring core inflation has been developed. It consists in computing a price index that uses trimmed means of the distribution of price changes.[18] The basic motive for adopting such an approach is that the measure of core inflation obtained by excluding certain items is a distorted measure of the long-term price developments that matter for the decision-making process, as in most cases price changes have a leptokurtic distribution. Trimmed means measures are, instead, robust estimates of long-term inflation when price changes are skewed. While this approach may lead to a conceptually correct way of excluding transitory movements in prices that are not representative of general inflation, it nonetheless suffers from transparency and credibility problems as the general public may fail to understand the complex methodology with which such a measure is calculated.

More importantly, these methods, and their variants, suffer from the basic shortcoming of having no theoretical economic justification. More precisely, they fail to provide an analytical decomposition of the historical profile of inflation into the components that directly reflect the effect of the different sources of inflation, particularly the effects of monetary policy actions, ie monetary shocks.

Different approaches, all based on the estimation of small SVARs, have been developed for this purpose. A thorough review of these models is provided by Folkertsma and Hubrich (2000). It suffices here to recall their main features to clarify their basic differences and similarities in relation to the model used in this paper.

Quah and Vahey (1995) estimate a bivariate SVAR (the endogenous variables are the changes in both output and the inflation rate) to quantify core inflation, which they define as the component of inflation that is originated by shocks not having long-term effects on real output. A basic shortcoming of this approach is that the model assumes super-neutrality of money with the consequence that the level of core inflation is undetermined. *"If we accept that core inflation as measured by Quah and Vahey does in fact correspond to the component of inflation that is under the control of the monetary authority, and also that this component of inflation is in fact neutral with respect to output in the long run, it invites the question of why a central bank would ever want to be concerned about price stability. After all, if all the central bank controls is the price level in the long run, and if the rate at which the price level increases has no implications for the level of real economic activity, then one inflation rate*

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17 *"During periods of poor weather, for example, food prices may rise to reflect decreased supply, thereby producing transitory increases in the aggregate index. Because these price changes do not constitute underlying monetary inflation, the monetary authorities should avoid basing their decisions on them."* (Bryan and Cecchetti (1994), p 195.)

18 Bryan et al (1997).

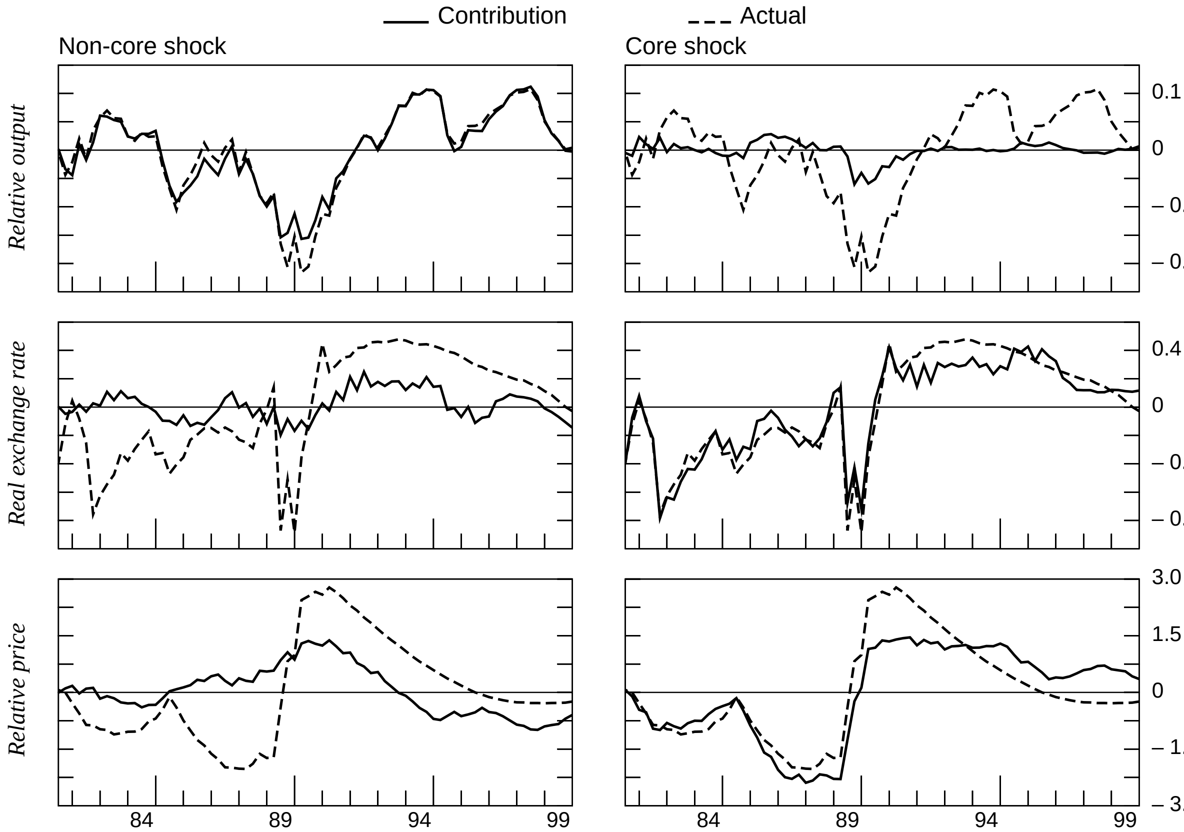
is just as good in welfare terms as another. There is no reason to prefer a steady state inflation rate of 2% over one of, say, 20%. Price stability or zero inflation ought not to play any particular role in the setting of objectives for monetary policy. Of course nobody seriously believes this."[19] A similar problem affects the three-variable SVAR (the endogenous variables of the model are the changes in real output and in the nominal interest rate and the level of the real interest rate) proposed by Dewachter and Lustig (1997) and by Blix (1995) (the three endogenous variables considered by this last author are the changes in real output, inflation and the level of velocity of money). The two-variable SVAR (changes in both output and inflation) proposed by Álvarez and Matea (1999), who identify what they call "permanent inflation", does not make any assumptions as regards the neutrality of money. Finally, money is neutral but not super-neutral in Gartner and Wehinger (1998). In their three-variable model (changes in output and in the nominal interest rate and the rate of inflation) they in fact identify the level of core inflation.

The model used in this paper to identify real (supply and demand) and nominal shocks seems to be better placed than bivariate models to measure core inflation, ie the component of inflation that is originated by shocks "not having long-term effects on real output". The bivariate models in fact cannot distinguish between the inflationary effects of real demand shocks (for example fiscal shocks) from nominal disturbances (typically monetary policy shocks). Both disturbances have no long-term effects on output. Money is therefore neutral in this model.

The model used here could provide two measures of core inflation. According to a narrow concept, core inflation can be computed as the change in the price due to nominal shocks only; a broader concept could estimate core inflation as the sum of the inflationary effects of real demand and nominal shocks.

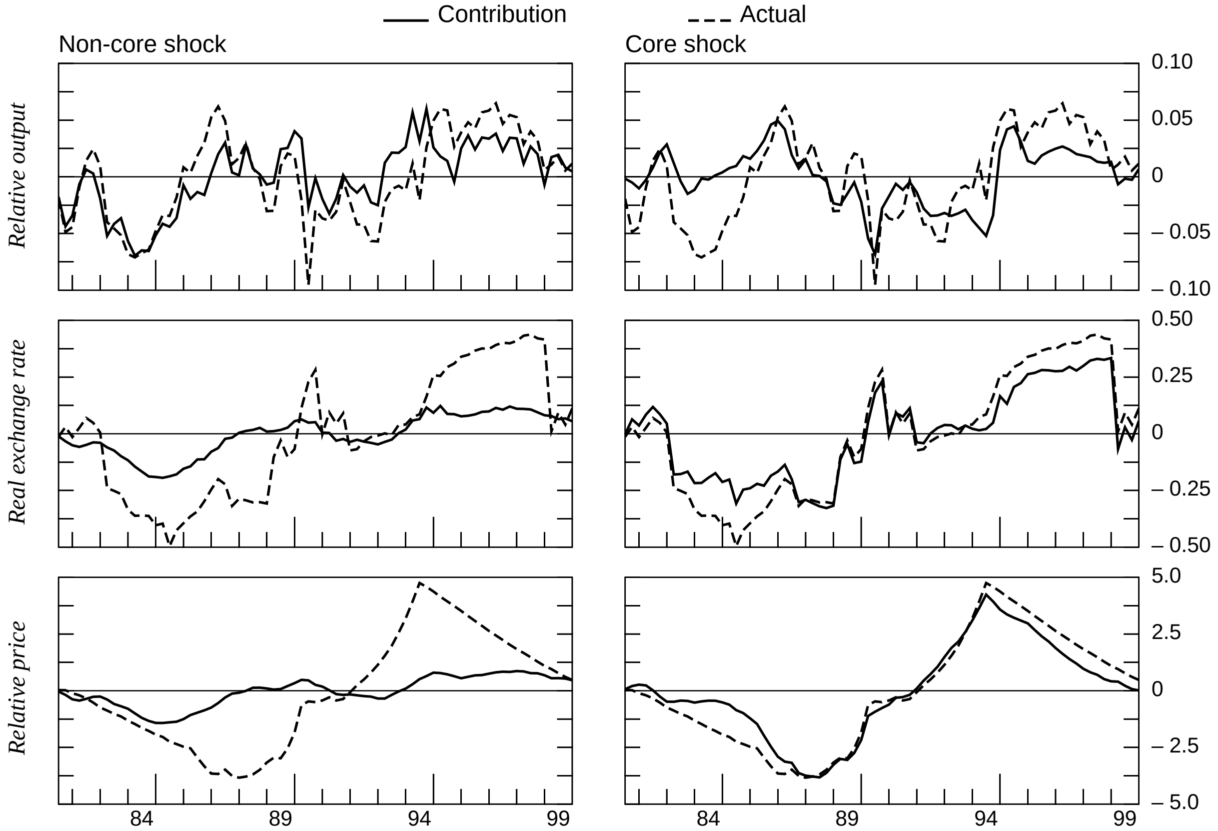
Graphs 3-8 provide the historical decomposition of the *relative price changes* when core inflation is calculated on the basis of the broad concept to which we have just made reference.

Graph 3: **Historical decomposition of supply and demand shocks: Argentina**

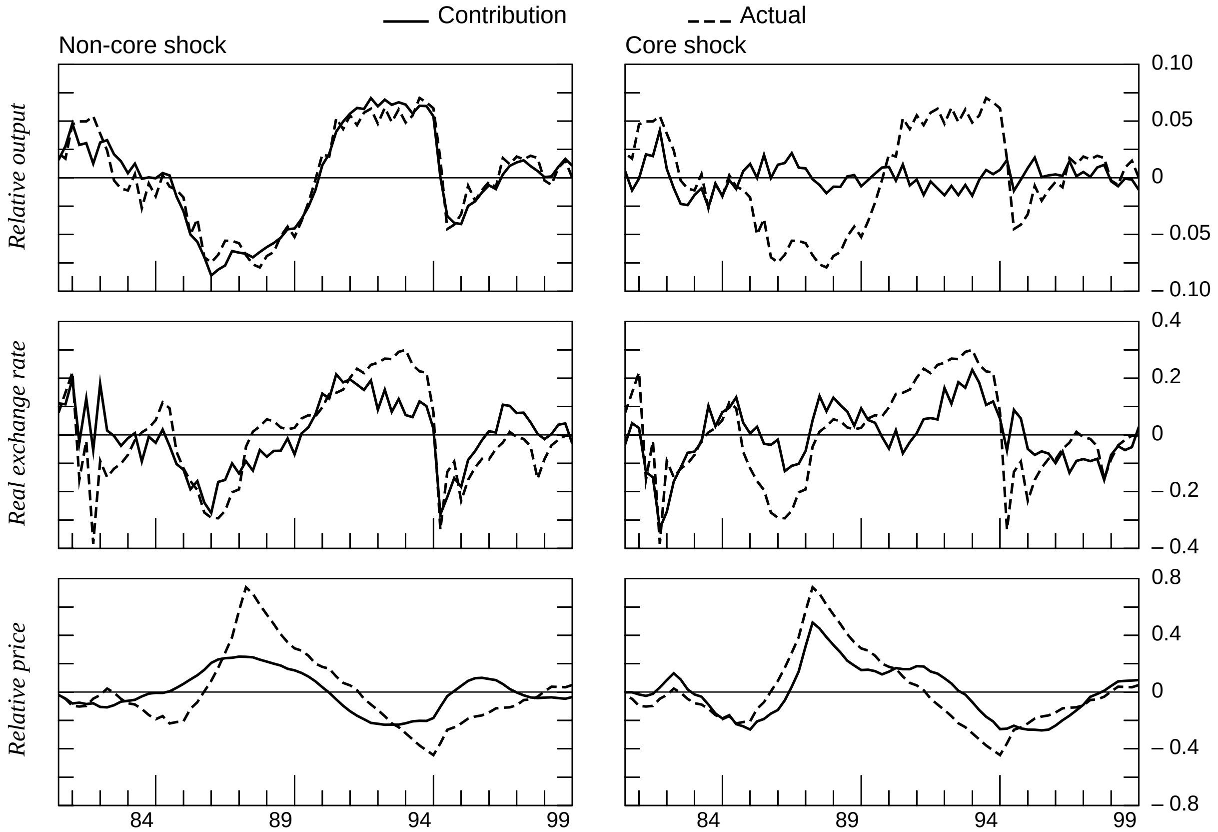


[19] Wynne (1999), pp 12-13.

Graph 4: **Historical decomposition of supply and demand shocks: Brazil**



Graph 5: **Historical decomposition of supply and demand shocks: Mexico**



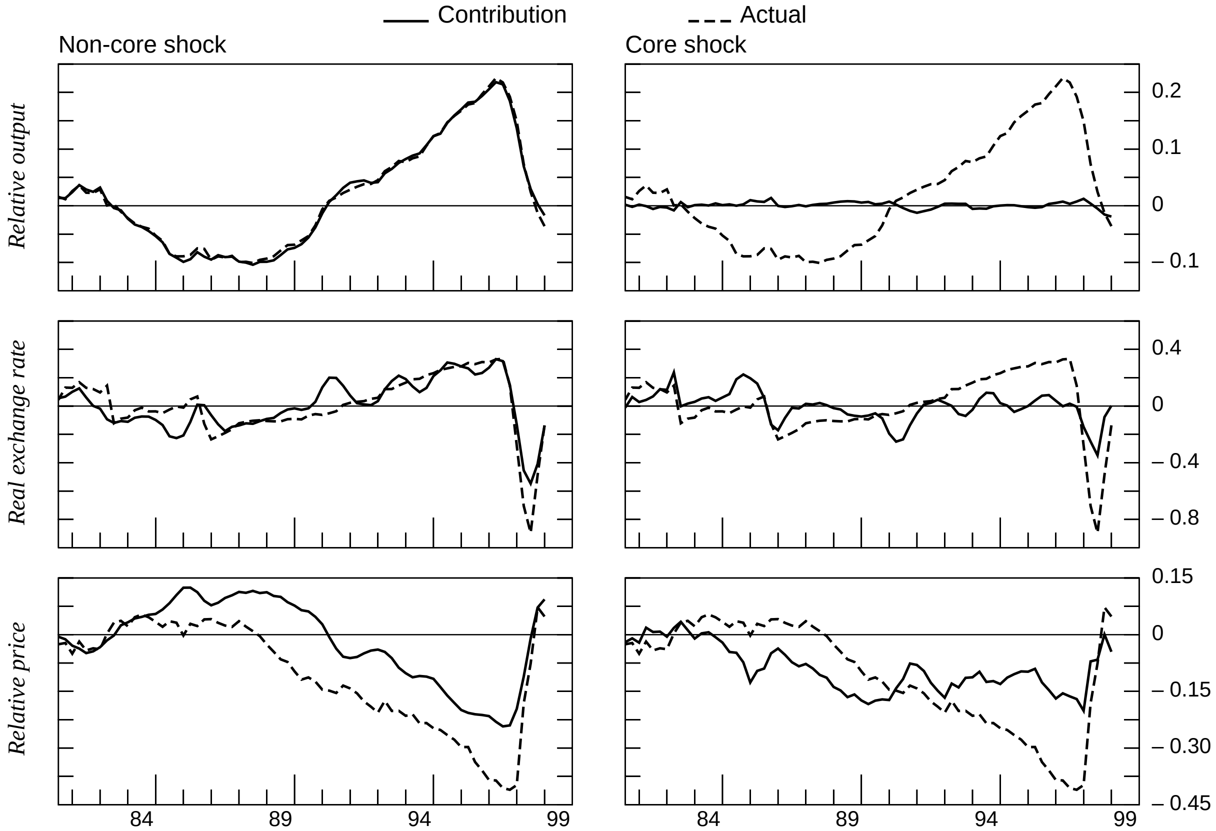
Two characteristics emerge from the graphs. First, the importance of “non-core” (supply) and “core” (demand plus nominal) shocks has changed over time. Second, policies, as captured by the core shocks, are more important than exogenous supply shocks in shaping the time profile of the relative price. This is true in Latin America, both in the first half of the 1980s (during which the relative price showed a falling trend) and subsequently (when the relative price increased). In Asia, this phenomenon is also apparent: from 1981 to 1996, the impulse coming from “core” shocks was more intense than that from non-core shocks, although this is not generally true for all the countries.

Concerning Latin America, these features are particularly evident in the case of Argentina and Brazil. In Argentina, the contribution of core shocks follows very closely the actual price dynamics. In addition, the graph shows that between 1990 and 1994 policies firmed the relative price at the level that prevailed after the 1989-90 crisis (the corollary of this is that the decline in the actual relative price after 1991 is almost entirely due to supply shocks). In Brazil, this evidence is even more pronounced as the cycle of the relative price follows very closely the contribution of core shocks. Furthermore, the coincidence of the contribution of non-core shocks with the actual behaviour of the price index is particularly striking for Venezuela (not shown here). Mexico is an intermediate case. In fact, while non-core shocks track actual data very closely, there is also evidence of a clear correlation of supply shocks contributing to the actual profile of the relative price.

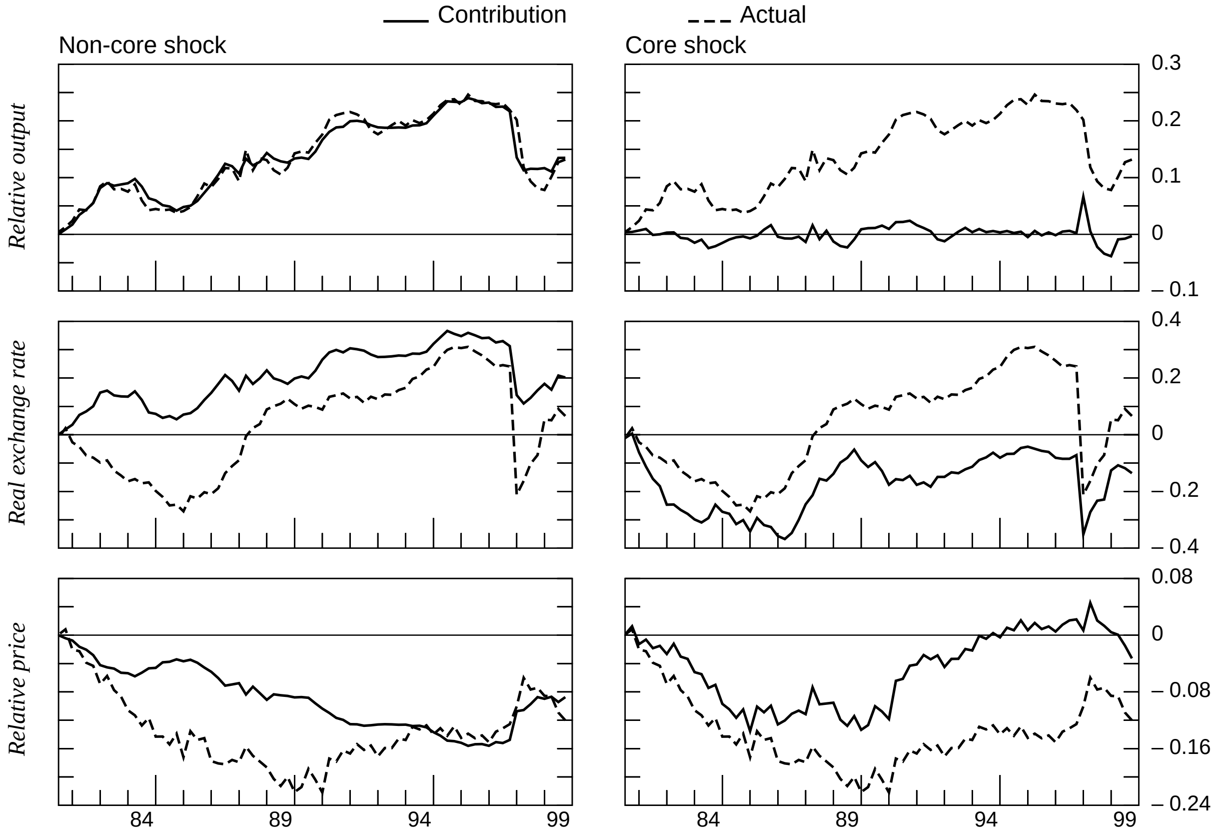
In the case of Asia, the pattern is more diversified. Core shocks almost fully explain the behaviour of the relative price in Thailand. The same can be said for Hong Kong and Singapore, although the results are not reported here. By contrast, in Korea, although the short-term changes and the cycle of the relative price reflect the impulses coming from core shocks, the role played by non-core shocks in determining the trend is very important. This is even more true in the case of Indonesia, where, on balance, non-core shocks appear to be dominant.

To a very large extent these differences are not unexpected. In Latin America the empirical results confirm that erratic policies – both monetary and fiscal – have been the predominant source of inflation. In Asia, where by contrast more stability-oriented policies have been persistently pursued, changes in the low rate of inflation can be attributed to some extent to supply shocks as well.

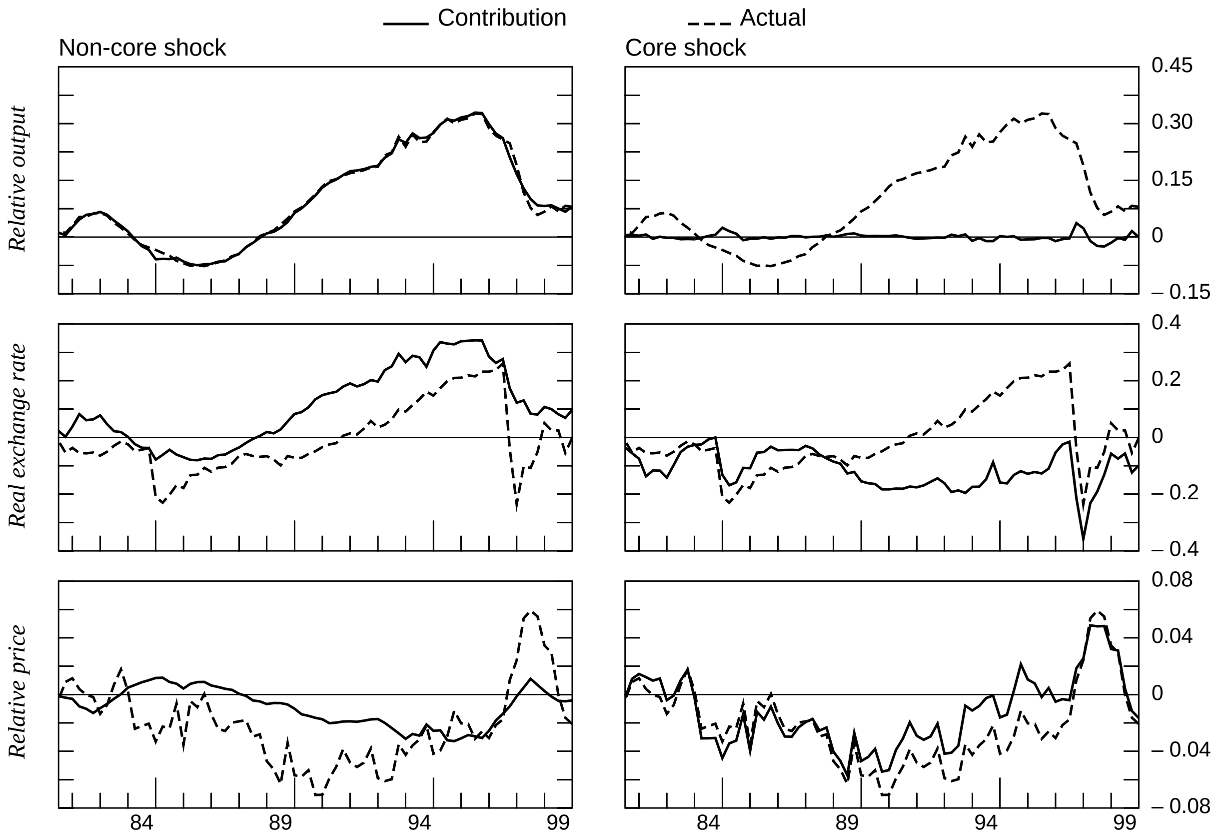
Graph 6: **Historical decomposition of supply and demand shocks: Indonesia**



Graph 7: **Historical decomposition of supply and demand shocks: Korea**



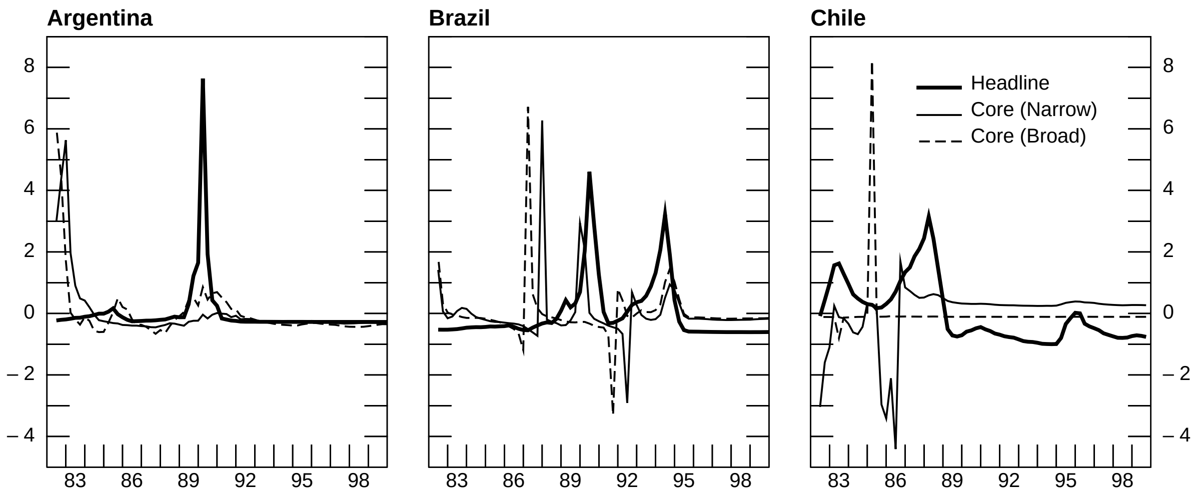
Graph 8: **Historical decomposition of supply and demand shocks: Thailand**



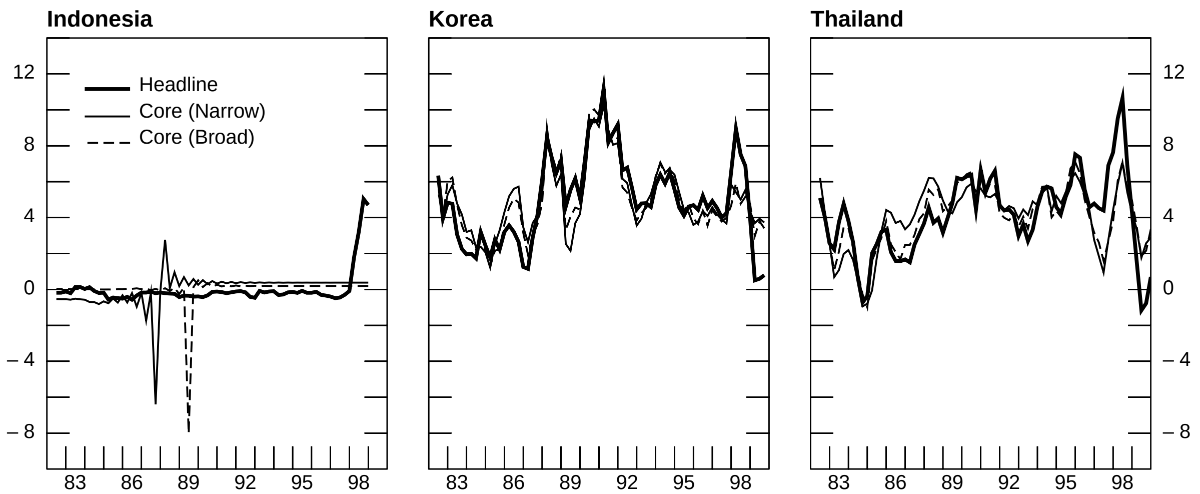
Despite these encouraging results, the graphs of core inflation refer to *relative inflation*, ie inflation in the country under review relative to US inflation. In order to calculate core inflation (narrow and broad), the model has been re-estimated without scaling the endogenous variables. In addition, by way of comparison, the model has been estimated for the three major industrial economies.

The estimated measures of headline and core inflation for the six emerging economies are reported in Graphs 9-10.

Graph 9



Graph 10



As observed above, one important motive for using the trimmed means is that the measures of core inflation obtained by such a statistical approach produce an unbiased estimate of the mean of the original series. In order to test whether model-based measures of core inflation have predictive power, statistical tests have been conducted (t-statistics of a VEC) to assess whether the measures of core inflation, obtained from the estimation of the SVAR model, are cointegrated with headline inflation. Table 1 reports the results of the tests.

From the table it is clear that:

– in the case of Argentina, Brazil, Mexico and Indonesia the mean of both measures of core inflation is way off the mark from the mean of the actual series;

– the test of cointegration indicates that among the emerging markets the measures of core inflation have a predictive power only in the case of Korea and Thailand, where inflation has been rather stable and low for most of the period;

Table 1

Headline inflation and core inflation: descriptive statistics and test for cointegration

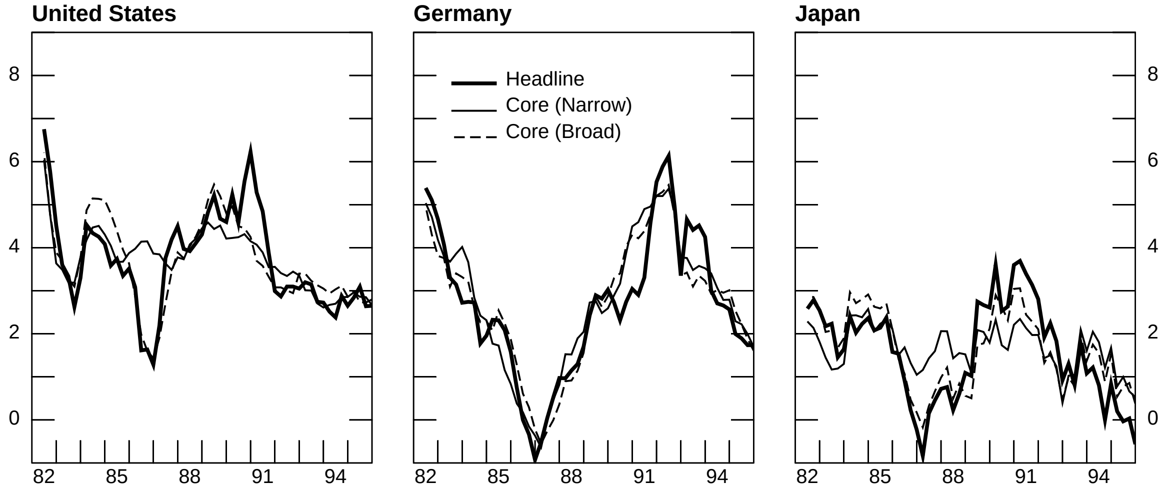
	Mean	Standard deviation	t-statistic on coefficient of VEC
United States (1980-95)			
Headline inflation	3.69	1.15	
Core (narrow)	3.73	0.67	–1.65
Core (broad)	3.69	1.02	–5.13
Japan (1980-95)			
Headline inflation	1.58	1.13	
Core (narrow)	1.67	0.53	–3.35
Core (broad)	1.64	0.91	–2.25
Germany (1980-95)			
Headline inflation	2.66	1.64	
Core (narrow)	2.76	1.58	–15.91
Core (broad)	2.69	1.49	–11.25
Argentina (1980-99)			
Headline inflation	705.87	2,560.41	
Core (narrow)	38.17	105.91	–6.06
Core (broad)	44.38	114.18	–8.31
Brazil (1980-99)			
Headline inflation	722.91	1,184.11	
Core (narrow)	111.39	516.46	–1.15
Core (broad)	72.64	417.88	1.36
Mexico (1980-99)			
Headline inflation	47.86	41.16	
Core (narrow)	–42.82	217.36	1.76
Core (broad)	1,410.99	12,683.57	–1.46
Korea (1980-99)			
Headline inflation	4.98	2.39	
Core (narrow)	5.01	1.93	–8.04
Core (broad)	5.01	2.10	–7.52
Indonesia (1980-98)			
Headline inflation	11.58	14.06	
Core (narrow)	101.15	173.81	–1.69
Core (broad)	–15.39	937.02	–0.35
Thailand (1980-99)			
Headline inflation	4.11	2.25	
Core (narrow)	4.05	1.79	–2.91
Core (broad)	4.00	1.74	–4.90

Note: Core (narrow) is measured as the baseline plus the nominal shock and Core (broad) as the baseline plus nominal and real demand shock.

– for the three Latin American countries, as well as for Indonesia, the presence of episodes of hyperinflation biases the estimation of the model and the measures of core inflation show a dynamics that is significantly different from that of headline inflation (Graphs 9 and 10). The model, in fact, generates arbitrary peaks for some countries because for some countries it fails to correctly identify the nature of the shock that generates extreme inflation values;

– in the case of the G3 (Graph 11), estimated measures of core inflation show statistical properties (particularly in the case of the broad measure of core inflation) that may warrant their use as an operational target for monetary policy purposes. In fact, both core inflation measures have almost the same mean of, and appear to be cointegrated with, headline inflation.

Graph 11



In conclusion, the use of small-scale SVAR to compute measures of core inflation for emerging markets is not appropriate in all cases where episodes of hyperinflation have punctuated the history of the country. In these cases in fact the measures of core inflation produce a biased estimate of the mean of actual inflation and core inflation measures do not have predictive power for future inflation.

3. The Taylor rule for open economies

A large number of emerging economies in both Latin America and Asia have recently moved away from rigid exchange rate regimes. According to the official classification, they are defined as "floaters"; this tends to establish the presumption that the behaviour of the exchange rate has little or no influence on the setting of interest rates.

Recent research has, however, shown that the main features of the exchange rate dynamic of these countries differ from those of true floaters. Calvo and Reinhart (2000) document that the dynamics of some critical variables of emerging economies reveal that they try to voluntarily minimise exchange rate volatility. In their words these countries exhibit *fear of floating*.

There are at least three basic reasons why emerging economies may wish to avoid "excessive" exchange rate fluctuations.

One consists in the fact that emerging economies are characterised by a large pass-through of devaluation into inflation.[20] High indexation de jure or de facto implies that even temporary devaluations are translated into persistent higher inflation: in the extreme case of full indexation, an inflationary shock may determine a shift to a significantly higher and permanent inflation rate.[21]

A second reason, clear evidence of which has been provided by the recent wave of crises in both Latin America and Asia, is that devaluation may significantly weaken the balance sheets of both banks and firms. Thus, significant swings in the exchange rate may lead to systemic financial crises and deep recessions, in addition to inflation.

Third, for countries with a large external debt denominated in foreign currency, devaluation may seriously undermine the fiscal position besides negatively impacting on the fragile balance sheet of the private sector. Again, this may induce a recession and/or a higher rate of inflation.

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20 For an indication of this in the case of Mexico, see Ortiz (2000).

21 On this point, see Bruno (1994).

From an empirical standpoint, in their review of the functioning of the exchange rate regime of a large number of emerging countries, Calvo and Reinhart (2000) find that:

- the variability of the exchange rate of these economies is lower than that of the true floaters;
- the variability of foreign reserves is high, which the authors take as evidence of attempts to lean against the wind through interventions in the foreign exchange markets;
- the volatility of short-term interest rates is high, indicating that monetary policy systematically responds to exchange rate changes;
- the correlation between the exchange and interest rates is positive, while that between foreign currency reserves and the exchange rate is negative. The authors interpret this empirical regularity as additional evidence that monetary authorities both intervene and use monetary policy to limit exchange rate fluctuations.

In sum, the primary conclusion reached by the authors is that countries that have exited from a rigid exchange rate regime have nonetheless tried to avoid clean floating. Their behaviour, rather, seems to be closer to that of countries managing non-credible pegs.

A parallel study that compares the post-crisis dynamics of the exchange rate of Asian countries[22] comes to broadly similar conclusions. The authors find sufficient empirical evidence to support the hypothesis that, despite the greater post-crisis flexibility of the exchange rate regime, Asian countries have not gone as far as allowing the exchange rate to float freely. Countries, in fact, have tried to stabilise high-frequency exchange rate variability, to slow the pace of appreciation after the sharp devaluation due to the crisis, and finally they have accumulated ample precautionary foreign currency reserves. As in the case of the Calvo-Reinhart findings, the evidence is that these countries have deliberately tried to remain in the middle of the continuum of exchange rate regimes and away from either corner solutions.

In the case of the countries studied in this paper, the evidence of fear of floating is however mixed. Table 2 reports the variability (measured by the standard deviation of monthly data) of various measures of the exchange rate, inflation and the short-term interest rate together with simple correlation coefficients between the short-term interest rate and the other variables. These statistics have been computed for different subperiods (except for Chile) to reflect the behaviour prevailing at different points in time before and after the crises that hit these countries.

Concerning the pre- and post-crisis variability of exchange rates, there is distinct evidence that volatility has increased since countries decided to abandon peg arrangements. The only exception to this pattern seems to be Mexico and Brazil. But here it is evident that the enormous volatility of any measure of the exchange rate in these two countries during the 1980s likely reflects the lack of discipline of macroeconomic policies rather than serving as evidence of the inherent variability of floating exchange rate regimes. In the case of Asian countries, the shift from the hard pegs of the 1990s to the more flexible post-crisis exchange rate framework is, instead, clear-cut (with the exception, of course, of Malaysia, which in 1999 adopted a hard peg to the dollar).

By contrast, there is not much evidence of any positive link between devaluation and changes in the interest rates. In the majority of cases the correlations are low, not significant and/or have the wrong sign. Evidence of fear of floating is only significant for Brazil and Mexico, particularly for the latter country.

Simple statistics are, however, a weak tool to establish whether central banks systematically react to exchange rate movements through change in interest rates. The assumption that this may indeed be the case seems to be validated by the findings presented in Section 2.1.1, namely that nominal and real shocks have a significant impact on inflation, output and exchange rates (both nominal and real).

Thus, it seems reasonable to assume that the Taylor rule that is appropriate for large countries with limited exposure to foreign shocks has to be modified to properly fit small open economy circumstances.

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22 Hernandez and Montiel (2001).

Table 2

Short-term interest and exchange rates

Country			Variability[1]					Correlation of changes in interest rate			
			ΔUS$	ΔNER	ΔRER	ΔR	INF	ΔUS$	ΔNER	ΔRER	INF
Brazil	80:01	94:07	10.5	10.8	4.4	11,894.6	44.3	0.012	0.023	0.182	–0.051
	96:01	98:09	0.1	1.0	1.1	5.0	1.8	0.257	0.386	0.418	–0.341
	99:01	00:12	7.6	7.7	7.5	3.3	2.2	0.498	0.465	0.444	0.392
Chile	82:10	00:12	2.1	2.5	2.6	9.0	6.3	–0.035	0.043	–0.040	0.221
Mexico	80:01	94:07	5.9	6.0	5.0	7.4	10.5	0.165	0.163	0.097	0.178
	96:01	00:12	2.2	2.4	2.5	3.0	3.0	0.762	0.748	0.772	–0.231
Indonesia	80:01	97:06	2.9	3.2	3.1	1.3	3.2	–0.011	0.037	0.053	–0.055
	99:01	00:12	6.8	7.1	6.9	2.1	4.0	–0.001	–0.023	–0.033	0.120
Korea	80:01	97:06	0.9	1.5	1.6	1.1	2.9	0.004	–0.147	–0.176	0.074
	99:01	00:12	1.7	1.8	1.8	0.2	2.0	–0.101	–0.054	–0.014	–0.078
Malaysia	80:01	97:06	1.2	1.2	1.3	0.4	1.7	0.139	0.067	0.046	0.156
	99:01	00:12	0.0	0.9	1.0	0.3	1.2	na	–0.091	–0.138	–0.046
Thailand	80:01	97:06	1.2	1.6	1.7	1.7	2.4	–0.028	–0.069	–0.040	–0.054
	99:01	00:12	1.8	2.1	2.1	0.4	1.2	0.137	0.217	0.184	0.328

[1] Standard deviation of change of the US dollar exchange rate, nominal and real effective rate (NER and RER), short-term interest rate (R) and inflation (INF).

Ball (2000) argues in favour of the inclusion of a measure of the real exchange rate in the reaction function of monetary authorities of countries exposed to foreign shocks on the basis of the following simple model:

$$x_t = \mathbf{a}x_{t-1} + \mathbf{b}r_{t-1} + \mathbf{d}e_{t-1} + \varepsilon_t$$

$$\pi_t = \pi_{t-1} + \mathbf{f}x_{t-1} + \mathbf{g}(\Delta e_{t-1}) + \eta_t$$

$$e_t = -\mathbf{h}r_t + v_t \,.$$

The first equation is a standard IS curve for open economies according to which output (x_t) is boosted (reduced) by the devaluation (appreciation) of the lagged real exchange rate (e_{t-1}).

The second equation is a standard Phillips curve where changes in the exchange rate affect inflation (π_t) according to a pass-through coefficient **g**.

The third equation reflects the hypothesis that increases in the real interest rate (r_t) attract capital flows and lead to an appreciation of the exchange rate (in the notation used here the exchange rate is defined as national currency per unit of foreign currency).

From this model the author derives the following modified Taylor rule that minimises a weighted sum of inflation and output:

$$r_t = \beta\pi_t^* + \gamma x_t + \delta\Delta e_t \,.$$

The modified Taylor rule has a number of interesting features.

The first is that $\pi^* = \pi_t - \mathbf{g}\Delta e_{t-1}$, ie the target rate of inflation now represents *"a measure of inflation that excludes the transitory effects of exchange rate fluctuations"*.[23] One can think of this definition in terms of the central bank targeting a measure of *domestic inflation*. In so doing, the central bank is reacting to exchange rate changes not because of movements in the currency per se but because changes in the external value of the currency generate long-term inflation. Implicitly, the modified rule says that the central bank should not react to transitory movements in the exchange rate. This behaviour, in addition, would prevent the central bank from tightening aggressively in response to changes in the exchange rate. In fact, *"by construction, π^* is unaffected by temporary exchange rate movements, so π^* targeters have no incentive to move exchange rates aggressively"*.[24]

Accordingly, an equation similar to that obtained by Ball has been estimated to empirically verify whether, and to what extent, the countries under review have reacted to exchange rate changes.

3.1 Estimation results

Equation (8) is analytically derived by making three important assumptions, namely that the central bank can independently change its operating instruments (normally short-term interest rates), that price stability is the primary objective of monetary policy, and that no significant change in the monetary and/or exchange rate regime has taken place within the estimation period. It is fair to say that in most of the countries under review these implicit assumptions are not verified. In addition, in some countries, the data set includes serious outliers because countries experienced either repeated periods of hyperinflation or serious crises. For all these reasons the estimation results that are presented in Table 3 have to be viewed with caution as the violation of any of the assumptions on which the theoretical model is based or the presence of extreme data may distort the estimates.

To deal with the outliers, the specification of the equations for Brazil and Peru has been changed. The dependent variable of the equation is the *logarithm* of the short-term interest rate as this variable exhibits a strong correlation with both inflation and changes in the exchange rate (the US dollar). The logarithm of the short-term rate, in other words, seems to capture much better than the short-term rate itself the intensity with which both countries have responded to hyperinflation and the sharp devaluation of the currency. On these occasions, in fact, both countries show a disproportionate increase in the real interest rate that has no equivalent in any other country and the timing of changes in the interest rate coincides with the timing of major devaluation episodes.

According to this specification it then appears that the reaction of the central bank to rapidly changing circumstances is highly non-linear as the interest rate, in response to the same increase in inflation or the same devaluation, is increased by an amount that is higher, the higher the prevailing interest rate.

In the case of Brazil, the long-term semi-elasticity of inflation is equal to 1.45 in the first equation. This result seems consistent with the experience where between 1989 and 1990 and prior to 1994 the real short-term interest rate increased enormously. The second equation for Brazil (estimated using instrumental variables) shows two interesting features. First, the interest rate is increased with no lag when inflation rises or when the currency is devalued (the lagged dependent variable is not significant). Second, short-term rates seem to respond with a much greater intensity to currency devaluation than to surges in inflation. It is possible, however, that this result, rather than being reflective of a precise policy strategy, critically depends on the fact that, for example in 1994 and in 1990, when the currency devaluation stops, the short-term interest rate has declined sharply.

The two equations for Peru exhibit features similar to those of Brazil as far as the response of interest rates to inflation is concerned. In the case of Peru, in addition, there is evidence that interest rates respond to the development of monetary aggregates, a feature that has been observed for industrial countries as well. An (excessive) increase in money demand is countered by an increase in interest rates.

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23 Ball (2000), p 3.

24 Ball (2000), p 5.

Table 3

Estimated elasticities of Taylor rule type equations for selected emerging economies

Countries	Equation number	Long-run elasticities		ξ^2	ρ	R^2
		π	x^1			
Brazil[3]						
TSLS	1	0.83	1.84	–0.03	0.00	0.916
OLS	2	1.45	1.96	0.00	0.33	0.880
Chile						
TSLS	3	1.02	0.80	0.00	0.20	0.869
OLS	4	1.19	1.96	–0.53	0.37	0.796
Mexico						
TSLS	5	0.95	1.86	0.00	0.62	0.838
OLS	6	0.72	0.00	–0.43	0.53	0.894
Peru[3]						
TSLS	7	1.72	11.50	0.01[4]	0.77	0.886
OLS	8	1.20	2.02	0.00	0.60	0.925
Korea						
TSLS	9	0.76	1.42	–0.17	0.75	0.780
OLS	10	0.35	0.52	–0.19	0.72	0.850
Malaysia						
TSLS	11	1.11	0.37	–0.07[5]	0.87	0.846
OLS	12	0.63	0.37	–0.06[5]	0.87	0.860

[1] Output gap in the case of Chile and Korea. For all other countries, change in real output. [2] Short-term elasticity of the change in the dollar exchange rate. [3] The dependent variable is the log of the short-term interest rate. [4] $\Delta US\$_{-1}$. [5] $\Delta US\$_{-2}$.

The equation that includes among the explanatory variables the change in money demand, however, exhibits a puzzling result regarding the response to changes in the dollar value of the currency. The equation indicates that, after controlling for inflation and changes in money demand, the central bank leans with the wind rather than against. This result requires further investigation.

For the other countries (Mexico, Chile, Korea and Malaysia) the Taylor rule type of equation has been estimated.

From the estimated equations, it emerges that the change in the nominal interest rate in response to inflation is greater (in the longer run) than the change in inflation itself (ie the central bank induces an increase in the real interest rate) only in Chile and Malaysia. In both these countries, in addition, there is clear evidence that interest rates had been increased in response to currency devaluation and to a weakening of the cyclical position. The response to an increase in the output gap is particularly pronounced in the case of Chile.

Concerning the sensitivity of interest rates to changes in inflation in Mexico and Korea, the estimates indicate that interest rates were increased on average by less than the increase in inflation. By contrast, both countries exhibit a strong response of monetary policy to exchange rate changes in accordance with the importance they have traditionally assigned to exchange rate stability. However, the changes in the exchange rate regime that have occurred in Mexico and Korea (as in all economies considered in this study) make it difficult to precisely quantify the extent to which the central bank responds to domestically induced price changes and to deviation of the exchange rate from "target". In other words, the changes in the monetary regime may bias the empirical assessment of the relative importance assigned by the central bank to domestic equilibrium (price stability) and to external equilibrium (exchange rate stability).

One general characteristic emerges from the estimates. In all countries short-term rates respond with the correct sign to exchange rate changes. Prima facie this can be taken as evidence that central banks react to the inflationary effects of devaluations and not necessarily to the fear that devaluations may generate serious balance sheet problems. This is because the results of the SVAR estimates indicate clearly that nominal and real demand shocks have powerful effects on inflation but not on output.

4. The effects of supply and demand shocks under alternative monetary rules

For the industrial countries – indeed mostly for the United States – there is an extensive empirical literature that provides estimates of monetary policy rules and model simulations that quantify the effects that the adoption of such rules produces on the main macroeconomic variables. There is, on the other hand, very limited empirical evidence on the same topic for the developing countries. This is obviously a consequence of the fact that developing countries have in general not followed such monetary rules and that, as already observed, emerging economies have experienced several changes in their monetary regime. To start filling this gap, the focus of this section is to empirically assess the consequences for inflation, output and the interest rate itself of the use of alternative monetary "rules" in response to shocks. To this end, a small macroeconomic VAR model has been estimated for two of the countries that have adopted either inflation targeting (Korea) or a monetary standard that, while based on money supply control (Mexico), is equivalent to an inflation targeting regime. Implicitly, the estimation of the SVAR would provide an empirical measure of the extent to which the transmission mechanism in these countries would permit an effective implementation of inflation targeting. By way of comparison, the same simulation exercise is also conducted for the euro area.

The model used here is that employed by Gerlach and Smets (1995) in their study of the transmission mechanism in the G7 countries. The model has three endogenous variables: real output, the consumer price and the nominal short-term rate.[25] The three-equation model is a highly stylised representation of the economy. The output equation is to be understood as the IS curve, the price equation is a Phillips curve and the interest rate equation is the reaction function of monetary authorities. The identification strategy uses a combination of long-run and contemporaneous restrictions. Only supply shocks determine in the long run the level of real output, as in the SVAR used in the previous section. The model used for this exercise, however, is also based on the assumption that monetary policy shocks do not have contemporaneous effects on output but can instantaneously affect prices. Concerning the reaction function of the central bank (the interest rate equation of the SVAR), the assumption is that monetary authorities respond to movements in output and prices only. This equation is therefore consistent with most of the Taylor-type equations proposed in the literature. One weakness of applying such an approach to small open economies is that such a reaction function postulates that the central bank does not respond to exchange rate movements that are not due to supply or demand shocks.

After having estimated the model, the analysis of the effects of both supply and demand shocks on the economy under alternative monetary policy rules has been conducted by replacing the interest rate equation of the SVAR with alternative policy rules whose basic parameters have been independently estimated as in the case of the euro area and Mexico or imposed a priori. The arbitrary values of the parameters of the monetary rules have been set as follows:

- the "Taylor" rule, according to which the interest rate is increased by 1.5 percentage points in response to a 1% increase in inflation and by 1% in response to a 1% increase in output. Using the symbols of the parsimonious model briefly described in Section 1.1, it is assumed that $g_\pi = 1.5$ and $g_x = 1$;
- the "Strict I.T." rule, where $g_\pi = 1.5$ and $g_x = 0$;
- the "Very Strict I.T." rule, where $g_\pi = 3$ and $g_x = 0$;

[25] It should be noted that the variable representing the volume of activity is real GDP and not the output gap, as in most empirical work on this topic. This is due to the fact that no reliable measure of the output gap exists for the emerging economies.

– the "Slow Adjustment" Taylor rule, which assumes that the monetary authorities adopt an "interest smoothing" approach. This is accomplished by adding to the Taylor rule the lagged value of the short-term interest rate with a coefficient equal to 0.9 and modifying accordingly the short-term coefficients of inflation and the change in output in order to have their long-run values equal to 1.5 and 1, respectively.

The nature of the exercise conducted here is different from the typical approach of the research on the optimal monetary policy rules. In the latter line of research, the purpose is to identify the optimal rule – as well as those that better proxy it – as the rule that minimises the variability of certain macroeconomic magnitudes (normally output and inflation) given the macroeconomic model and the preferences of the central banks. Here, instead, the purpose is to squarely focus on two issues:

– whether, given the macroeconomic model, the central bank's response should depend on the nature of the shock;

– whether alternative rules yield different economic outcomes mainly, but not exclusively, evaluated in terms of the stabilisation of the price level after a shock that the rules themselves make it possible to attain. As far as price stability is concerned, a rule can be regarded as being better than an alternative only if it permits greater long-term price reduction after a positive supply shock and a lower price level increase after a demand shock.

Before entering into the details of the results, it seems appropriate to note that in general there is a distinct instability in the estimates of the SVAR. This is no surprise as it is well known that the countries in question, perhaps with the partial exception of Korea, have changed their monetary regime several times in the sample period considered here. Furthermore, crises have characterised these economies and it is well known that VAR models are particularly sensitive to the presence of outliers in the value of the endogenous variables.

4.1 Euro area

The first experiment consists in comparing the impulse response function using the "Taylor" and "Strict I.T." rules with the results obtained using the "Model" interest rate equation (see Graph 12).[26]

In the euro area, both a "Taylor" and a "Strict I.T." rule produce higher (but more variable) output levels than the "Model" in the case of positive supply shocks before approaching new, common, equilibrium levels. However, the same rules yield suboptimal results as far as inflation is concerned, as the long-term price reduction due to the supply shock is far less than in the estimated "Model" response. The same rules, however, perform better than the "Model" rule as they contain inflation more successfully than the "Model" in the case of a demand shock. This implies, however, that interest rates have to be increased far more than in the "Model".

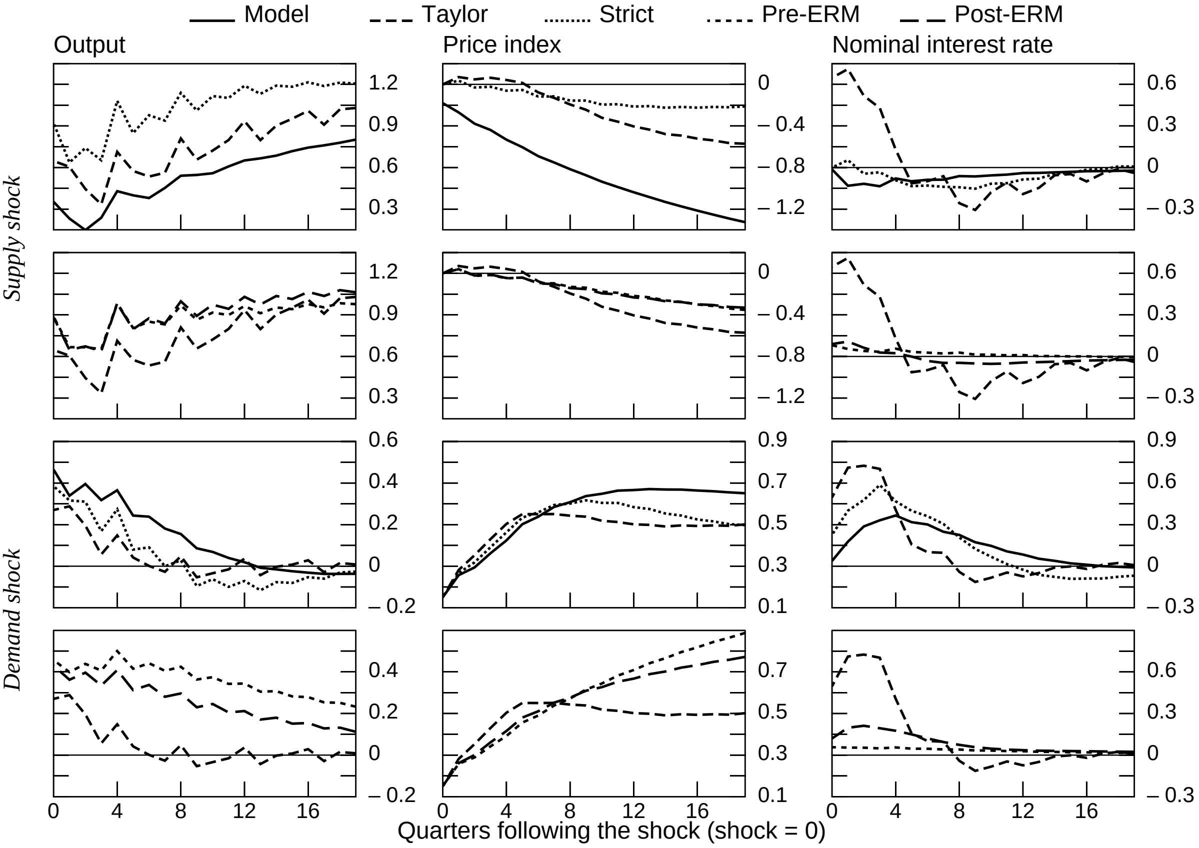
Graph 12 also illustrates a different experiment. The "Model" reaction function is replaced by two other *estimated* equations. The two equations are estimated with the GMM – using the Clarida-Galí-Gertler (1998) approach from two different periods, the "pre-ERM" period (1980-86) and the "post-ERM" period (1997-98).

The estimated results – not reported here – show a significant difference, particularly as far as the magnitude of the response of interest rates to inflation (g_π) is concerned. In the "pre-ERM" equation, the long-run response to inflation in the reaction function is well below unity ($g_\pi = 0.72$), signalling that on average the then non-existent euro area was following an accommodating monetary policy. This result is reversed in the "post-ERM" equation, where $g_\pi = 2.18$.

26 In the case of Mexico and Korea, the attempt at estimating a reaction function à la Taylor has not produced meaningful results.

When these two equations are used in the SVAR, the impulse responses confirm the Taylor/Clarida-Galí-Gertler assertions that $g_\pi < 1$ leads to instability after an inflationary demand shock. The "pre-ERM" path of the price level, in fact, tends to diverge and the increase in output declines more gradually relative to the path of the "post-ERM" simulation. By contrast, the "post-ERM" rule stabilises the price level after the shock (at a level that is lower than "Model") and better contains output because of the more pronounced increase in the interest rate.

Graph 12: **Supply and demand shocks under different policy rules: European Union**



The "post-ERM" rule, however, is outperformed by the "Taylor" rule. By following the "Taylor" rule, there would be a faster reduction in excess demand and the steady state price level increase would be half that obtained with the "post-ERM" rule as the increase in the interest rate in the "post-ERM" case is almost three times that of the "pre-ERM" regime.

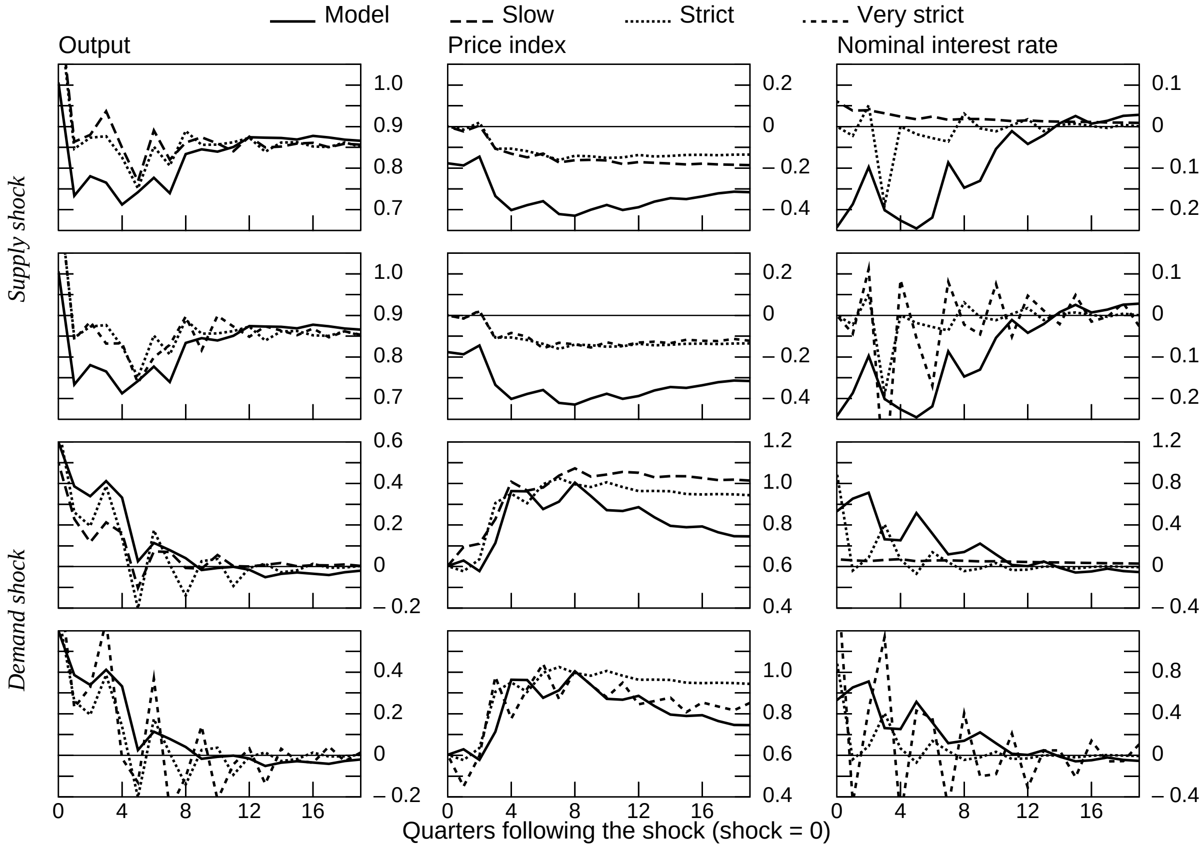
4.2 Korea

In the case of Korea (see Graph 13), the sample period has been shortened to eliminate the 1997-98 outliers.

If the estimated reaction function is replaced by alternative rules, the following results are obtained. "Strict I.T." and "Slow Adjustment" Taylor rules invariably produce worse results than the "Model" as far as inflation is concerned. In the case of supply shock the decline in prices is much more contained than in the "Model" and, following a demand shock, neither rule succeeds in reducing the price level after the initial increase as the estimated reaction function does. Two years after the shock, in fact, the price level stabilised at approximately the peak level, while the "Model" response shows a significant reduction after the initial sharp rise.

A "Very Strict I.T." rule approximates, as far as inflation is concerned, more closely the "Model" response in the case of a demand shock, but this happens at the expense of much increased variability in all three variables of the model. In the case of supply shocks, this rule is even less efficient than the other two, as it increases instrument instability without producing any additional benefit in terms of output or inflation.

Graph 13: **Supply and demand shocks under different policy rules: Korea**



4.3 Mexico

The simulation exercise differs, for Mexico, from that carried out in the case of Korea and the euro area.

In addition to the comparison of the "Model" with the Taylor rule, the effects of supply and real demand shocks have been simulated using the reaction function estimated with TSLS (Equation 5 in Table 3).

To further explore the issue of whether a stronger interest rate response to inflation would be effective in reducing inflation and increase the volatility of the economy, the estimated parameters of the monetary rule have been modified as follows:

(a) in the Variant to TSLS (1) the short-term elasticity of inflation has been kept constant but the *speed of adjustment has been halved*. This amounts to *halving the long-run inflation elasticity*;

(b) in the Variant to TSLS (2) the *short-term* elasticity of inflation has been *doubled*, leaving unchanged the speed of adjustment (this amounts to doubling the *long-term* elasticity of inflation).

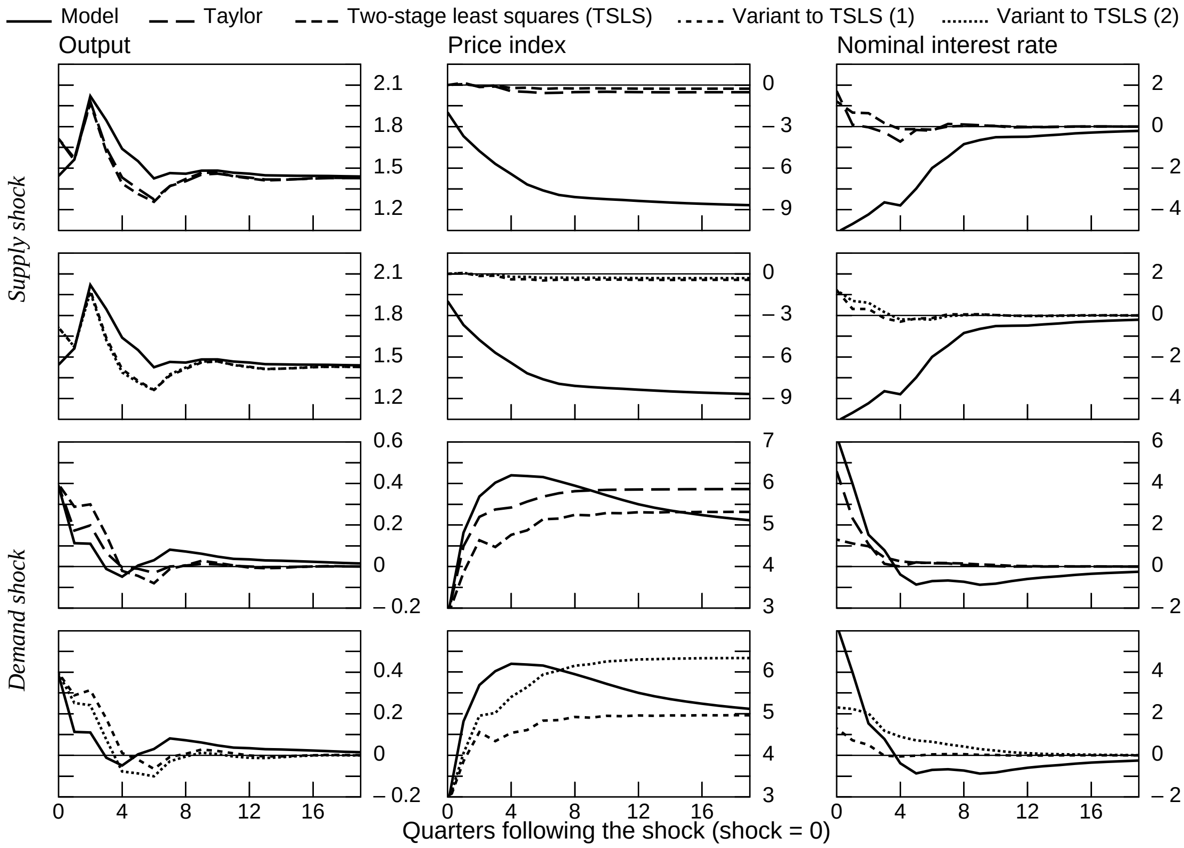
The results of these experiments are illustrated in Graph 14.

After a supply shock, the model yields a significant increase in output and a parallel reduction in the interest rate (nominal and real) and in the price level. If the interest rate equation of the model is replaced either by the Taylor rule or by the independently estimated reaction function, the price level does not fall in any significant way.

In the case of a demand shock, by contrast, the Taylor rule (but not the TSLS estimated reaction function) yields a better (lower) profile for the price level than the "Model" for most of the simulation period.

To test whether a stronger response of the nominal interest rate to inflation would allow a better containment of inflation following a demand shock, the *short-run price elasticity* of the estimated TSLS reaction function was *doubled* (leaving unchanged the parameters of the speed of adjustment). In doing so, the long-run elasticity of the policy instrument is *doubled*. Surprisingly, this change would worsen the inflationary effects of demand shocks (see response TSLS (2) in the graph). The result is counterintuitive, as the interest rate in the short term increases less than in the model.

Graph 14: **Supply and demand shocks under different policy rules: Mexico**



Vice versa, by *halving the speed of adjustment* of interest rates and leaving unchanged the response of the interest rate to inflation (which amounts to *halving the long-run* elasticity of the policy instrument to inflation and output), the inflation performance is better. The price level increase under this policy rule is less than under any other rule (see response TSLS (1) in the graph). The puzzling result is due to the dynamic structure of the model, particularly to the strong autoregressive component of inflation in the Phillips curve and in the positive coefficient of the lagged interest rate in this equation.

One (preliminary) conclusion that can be drawn from this result is that, in an economy characterised by significant inflation inertia, mere monetary tightening would not prove to be sufficient to effectively contain inflationary shocks. A more aggressive monetary policy, in this case, may lead to suboptimal results when the process generating inflation is strongly influenced by the past accommodative stance of policies.

Two main conclusions can be inferred from the simulation results obtained:

- the central bank should not follow the same rule irrespective of the nature of the shocks. In the case of a supply shock, in particular, the central bank should not contrast the increase in output by increasing the interest rate (at most, it should aim to decrease it to facilitate both the growth of output and the decline in prices);
- the conclusion reached in empirical studies on the industrial countries concerning the potentially higher variability that the "Strict I.T." rule may induce is confirmed, but this approach is not necessarily more effective than other "milder" rules in containing inflation as the simulations for Korea and Mexico indicate.

Summary and conclusions

The main motivation of this paper has been to ascertain whether the use of small macroeconomic models helps to answer three critical questions for the conduct of monetary policy in those emerging markets that have assigned to monetary policy the primary objective of attaining and maintaining price stability and that have abandoned a rigid exchange rate regime.

The first question is whether a model-based approach would allow the estimation of a measure of inflation that recovers the core inflation process and provides a reasonable means of extracting price changes that are due to monetary policy actions. There are several methods of measuring core inflation. Among them, univariate time series methodologies (such as moving average or Kalman filters) and techniques that exclude temporary or volatile changes in certain prices (the ex-food and energy price measures or the trimmed mean estimators) are the most popular approaches. At the same time, however, they all fail to distinguish price developments that are due to changes in the monetary policy stance – ie price developments for which monetary authorities are held accountable – from price changes that depend on factors, such as terms-of-trade changes, that are beyond the control of those authorities.

Small SVARs have been used by several authors to identify the effects on prices of monetary policy for several industrial countries. Following such an approach, the paper estimates core inflation for a selected number of mature emerging markets using a model that exhibits the theoretical properties of a two-country macro model of the Mundell-Fleming type. To ascertain the validity of the approach, the paper tests whether on average the measure of core inflation so obtained is an unbiased estimate of headline inflation and whether core inflation is cointegrated with actual inflation.

Both tests are passed only in two cases: Korea and Thailand, where inflation has been relatively low and stable for most of the past two decades. For all the other countries under review, the presence of episodes of hyperinflation biases the estimation of the model. In addition, the model creates a measure of core inflation affected by arbitrary outliers, presumably due to the inability of the model to correctly identify the exact nature of the shocks that in the past have determined the occurrence of hyperinflation. This contrasts with the case of the G3 where tests are passed.

The second question consists in assessing empirically whether the reaction function of monetary authorities can be described by the Taylor rule type of equation and in ascertaining to what extent the inflationary process has been accommodated or resisted by central banks.

Despite the changes in the monetary regimes, the estimates show that monetary policy in Chile, Mexico, Korea and Malaysia can be explained by reaction functions similar to the Taylor rule. In the case of Mexico and Malaysia these reaction functions indicate that central banks have been forward-looking. In the case of Chile and Malaysia, the empirical evidence shows that monetary policy has not accommodated inflation, while this does not seem to be the case for Mexico and Korea. For all the countries under review, however, there is also evidence that monetary authorities strongly reacted to changes in the exchange rate (consistently with the importance attached by these economies to its stability during part of the sample period). Of course, the change in monetary regimes makes it difficult to assess precisely the relative importance that these countries attached to price stability or to external equilibrium.

For Brazil and Peru, by contrast, the Taylor rule is not capable of explaining the behaviour of the short-term interest rate. To capture the high non-linear response of the interest rate to the sharp devaluation and extreme inflation that have characterised these countries during the 1980s and the 1990s, the equation has been estimated using the logarithm of the dependent variable. With this modification, the equation seems to capture relatively well the fact that interest rates in Brazil and Peru have been increased during periods of extreme tension by an amount that was higher, the higher the level of the interest rate preceding monetary policy actions.

Finally, a small SVAR has been estimated to describe the monetary policy transmission in these countries and to deal with the third issue, which concerns the macroeconomic effect of the adoption of alternative monetary policy rules.

Despite data problems and the regime changes, the small SVAR suggests that the transmission mechanism in the small number of economies studied here is very similar to that of industrial economies. Supply shocks increase output and decrease the price level and the real interest rate very much in the same way as in the major industrial economies. Demand shocks increase output temporarily and produce significant inflationary pressures, particularly in Latin American countries.

More importantly, these estimates confirm the theoretical proposition that monetary authorities should not respond to (or even accommodate) supply shocks but instead resist the inflationary pressures of demand shocks.

According to the theoretical results obtained by several authors – and validated empirically for some industrial countries – a stronger response of interest rates to inflation – or an exclusive focus on inflation by the central bank – yields a better inflation performance after a shock, at the price, however, of greater variability in both real output and interest rates.

The simulation of alternative rules for Korea and Mexico do not conform to these theoretical propositions. In the case of Korea an exclusive focus on inflation (and/or a stronger response of interest rates than prescribed by the Taylor rule) yields an inflation performance that is not better than that of other rules while generating a much higher variability in output and, endogenously, in the interest rate itself.

In the case of Mexico a better inflation containment following a demand shock is obtained not by increasing the response to inflation, but rather by accelerating the speed of adjustment of the interest rate to inflation. These results for Mexico are likely to be determined by the estimation of the model over a time span that includes periods of accommodative policy and episodes of sharp devaluation. But they may be taken as illustrative of the fact that changes in the monetary regimes may produce effects only to the extent to which the endurance of a stability-oriented monetary policy would progressively change the inflationary process.

The final conclusion that can be drawn from the simulation results is that the central bank should not follow the same rule irrespective of the nature of the shocks. In the case of a supply shock, in particular, the central bank should not contrast the increase in output by increasing the interest rate (at most, it should aim to decrease it to facilitate both the growth of output and the decline in prices).

An important caveat is, however, in order. The estimations of both the model and the reaction function are very sensitive to the choice of the sample period, to the estimation method and to the variables used as instruments. This is particularly the case where data contain extreme values of the type that have occurred on the occasion of the recent (and less recent) currency and banking crises and when important regime shifts have taken place.

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A note on the pass-through from exchange rate and foreign price changes to inflation in selected emerging market economies

Dubravko Mihaljek and Marc Klau

1. Introduction

This note presents estimates of the pass-through of exchange rate changes and import price changes (measured in foreign currency) into domestic inflation in a group of 13 emerging market economies. The note focuses on the variation in the pass-through elasticities across and within countries, and on their evolution during the 1980s and 1990s. The model and estimation methods used are very simple and are intended to illustrate how the pass-through effects can be analysed with only a few data series in a "bare bones" framework that could be easily replicated by analysts and interpreted by policymakers in the emerging market economies. The main findings are as follows:

- Changes in exchange rates are more strongly and more contemporaneously correlated with inflation than are changes in import prices. There is also some evidence of statistical causality running from exchange rate changes to inflation and, in several countries, from import price changes to inflation.
- Import price and exchange rate elasticities of inflation are approximately the same in four countries in the sample. In two countries the import price elasticity is higher, and in seven countries the exchange rate elasticity is higher. These results indicate that the approach followed in most of the literature, whereby the pass-through effect is estimated from import prices in domestic currency, may not be appropriate. Rather, it seems necessary to analyse the two pass-through effects separately.
- Cross-country differences in the size of pass-through coefficients are large and seem to be related to the volatility - but not the persistence - of inflation.
- The pass-through from exchange rate changes into inflation has generally been stronger than the pass-through from import prices, but has declined since the mid-1990s, probably as a result of more stable macroeconomic conditions and structural reforms implemented in the emerging economies.

The next section describes the data and the estimating framework used. The third section analyses the results of the regressions, and the fourth section provides tentative interpretations of the results.

2. Data and estimation

To estimate the pass-through effect, a very simple specification was adopted. The dependent variable is the average quarterly change in (the log of) a country's consumer price index (dp_t), and the explanatory variables are average quarterly changes in (the logs of) lagged prices (dp_{t-1}), import prices measured in foreign currency (dp^*_t) and the nominal exchange rate (de_t), as well as the output gap ($y_t - y^*_t$):[1]

$$dp_t = c + \beta_1 dp_{t-1} + \beta_2 dp^*_t + \beta_3 de_t + \beta_4 (y_t - y^*_t) + u_t \quad (1)$$

[1] Up to four lags of each explanatory variable were used in estimation, but only one lag is specified in equation (1) to simplify notation.

The expected signs of all parameters in the above equation are positive: higher past inflation, an increase in the foreign currency price of imports, a currency depreciation and a positive output gap are all expected to lead to higher domestic inflation. The lagged CPI is included to allow the possibility of a partial adjustment of domestic inflation to the explanatory variables.[2]

The above specification seeks to estimate separately the pass-through of exchange rate and import price changes into inflation. It is therefore more general than standard pass-through models, which make no distinction between changes in import prices measured in foreign currency and exchange rate changes - these two effects are lumped together in a single variable, import prices in *domestic* currency. For example, in one variant of these models changes in the domestic price of imports are essentially “exhausted” in prices “at the docks”, ie, the first-stage pass-through is approximately unity. The modelling effort then focuses on the extent to which prices “at the docks” are absorbed in producer profit margins or markups, which depends on the cost of domestic inputs (primarily labour) used in the distribution and sale of imported goods, and on the structure of competition in import-competing industries.[3]

The specification of the import price variable is thus crucial for the above model. An ideal indicator would be trading partners’ export prices weighted by the shares of imports from these countries. However, these time series are not available: although the main trading partners of the emerging economies are industrial countries, a significant proportion of their imports come from other emerging markets (eg regional trade in Asia), for which the export price series are not available. In consequence, this note uses an alternative indicator, import prices measured in foreign currency. These data are available for most of the countries in the sample, but the series are relatively short - data going back to the 1980s are available only for Korea, South Africa, Brazil and Mexico.

One rationale for looking at import prices measured in foreign currency as a separate pass-through channel could be that firms and households in the emerging economies have started to follow more closely foreign price developments and take them into account in formulating their business decisions, thus affecting domestic inflation. There are several potential forces behind these developments. The emerging economies have opened up to foreign trade and investment; industrial countries have considerably expanded production in developing countries, resulting in growing importance of intra-industry trade; the economic transformation in central and eastern Europe has taken hold; and means of transportation, communication and information have improved considerably. As a result, foreign prices can be expected to affect domestic inflation not just through the cost of traded goods and services, but also via cross-border price comparisons and inflation expectations. One of the aims of this note is to test whether the influence of foreign prices on inflation has increased in recent years.

The exchange rate is also assumed to affect inflation through several channels: the standard pass-through channel (import price cum markup), and other channels that are not modelled explicitly, eg the impact of exchange rate changes on inflation expectations. Instead of the nominal effective exchange rate, this note uses nominal bilateral exchange rates (domestic currency against the US dollar or the Deutsche mark). The empirical argument for this approach is that the dollar (or Deutsche mark) rate can be easily observed by businesses and households even in less developed countries, whereas the nominal effective rates are poorly understood and available only with considerable lags even in industrial countries. Thus, signals from exchange rate changes to inflation expectations and the CPI are more likely to emanate from changes in a key bilateral exchange rate followed daily by the agents than from the nominal effective rate.

Another difference from the existing literature is that inflation in this note is measured by headline consumer price indices, without adjustment for volatile components such as food, energy or administered prices. The weight of these items in consumer price indices of the emerging economies is often close to or in excess of 50%, so excluding them would significantly limit the relevance of

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[2] Thus, the short-run exchange rate elasticity is given by β_3, the long-run elasticity by $\beta_3/(1 - \beta_1)$; the short-run import price elasticity by the coefficient β_2, and the long-run elasticity by $\beta_2/(1 - \beta_1)$; etc. The discussion in this note focuses on short-term elasticities.

[3] A full pass-through at the second stage is defined by the share of the cost of an imported item in the retail price, which is typically around two thirds in smaller industrial countries (see Dwyer and Leong (2001)). Since distributors in competitive markets often vary their markups, sometimes in inverse proportion to changes in the exchange rate so as to absorb the effects of currency depreciation, the pass-through is usually incomplete in the short term.

estimates.[4] Given the difficulties of obtaining reliable estimates of potential GDP, the output gap serves basically as a controlling variable, to ensure that the pass-through coefficients are not affected by the omission of such a major determinant of inflation as the business cycle.[5]

Equation (1) was estimated separately for South Africa, Brazil, Chile, Mexico, Peru, the Czech Republic, Hungary, Poland, Turkey, Korea, Malaysia, the Philippines and Thailand, using ordinary least squares. This method was chosen for its simplicity and because unit root tests rejected the hypothesis of non-stationarity - all variables (except the output gap) enter in log difference form, which was sufficient to induce stationarity.[6] The equations were estimated separately for the longer-run period (from the 1990s or earlier to 2000-01), and two subperiods split around mid-sample points. For the Czech Republic, Hungary, Malaysia, Poland, Thailand and Turkey, only the longer period was considered because of the shortness of the time series on import prices.

3. Results

Relationships between inflation, import prices and exchange rates in the 1990s are depicted in Graphs 1 and 1a. In Latin America (with the exception of Mexico), central Europe and South Africa, currency depreciation and domestic inflation generally moved in step, especially in the second half of the 1990s. In Mexico and the four Asian countries, however, there is no clear relationship prior to the crises of 1994 (Mexico) and 1997-98 (Asian countries): nominal exchange rates moved little, while inflation was stable (with the exception of the Philippines) (Graph 1a). The devaluations of 1997-98 did not push up inflation in Asia (or in Brazil in 1994 and 1999). And since 1997-98, inflation has moved at a similar pace in all four Asian countries, despite differing exchange rate movements: appreciation in Korea, a fixed rate in Malaysia, and depreciation in the Philippines and Thailand. In most countries, import prices have moved at a considerably slower pace than domestic prices and the foreign CPI, shown in Graphs 1 and 1a for comparison (foreign inflation is measured as the import-weighted average of inflation rates in the main trading partners). However, in the last few years, changes in import prices have been similar to or faster than changes in domestic (as well as foreign) prices in Chile, South Africa, Korea, Malaysia and Thailand.

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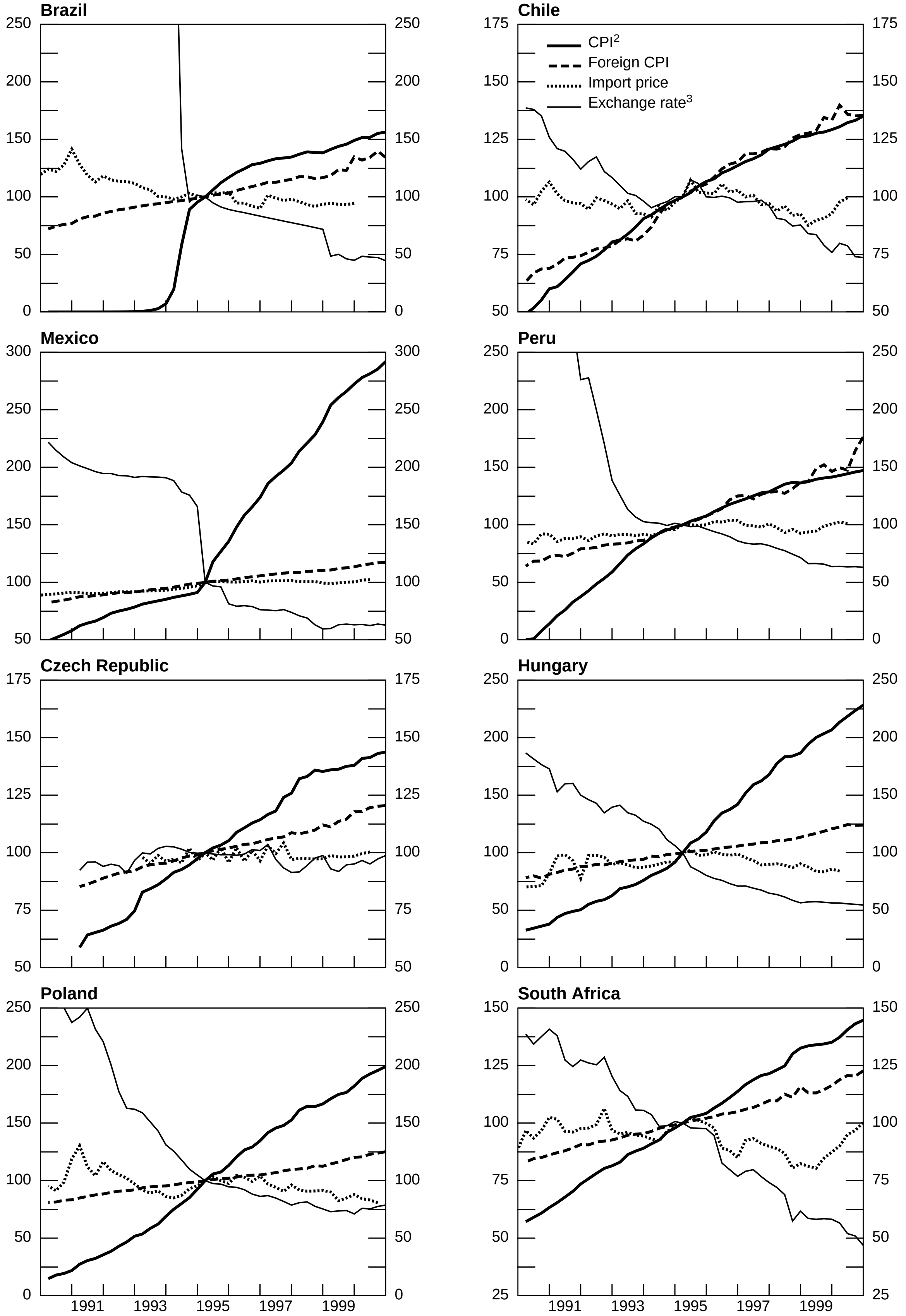
4 For example, Darvas (2001) considers the behaviour of non-food, non-energy and non-administered prices.

5 The output gap is measured as a percentage deviation of quarterly real GDP (in domestic currency at constant prices) from trend real GDP, estimated from annual data using the Hodrick-Prescott filter.

6 This means that the pass-through of exchange rate and import price changes could also have been estimated using an error correction model. However, because of the short data series, this alternative was not explored.

Graph 1

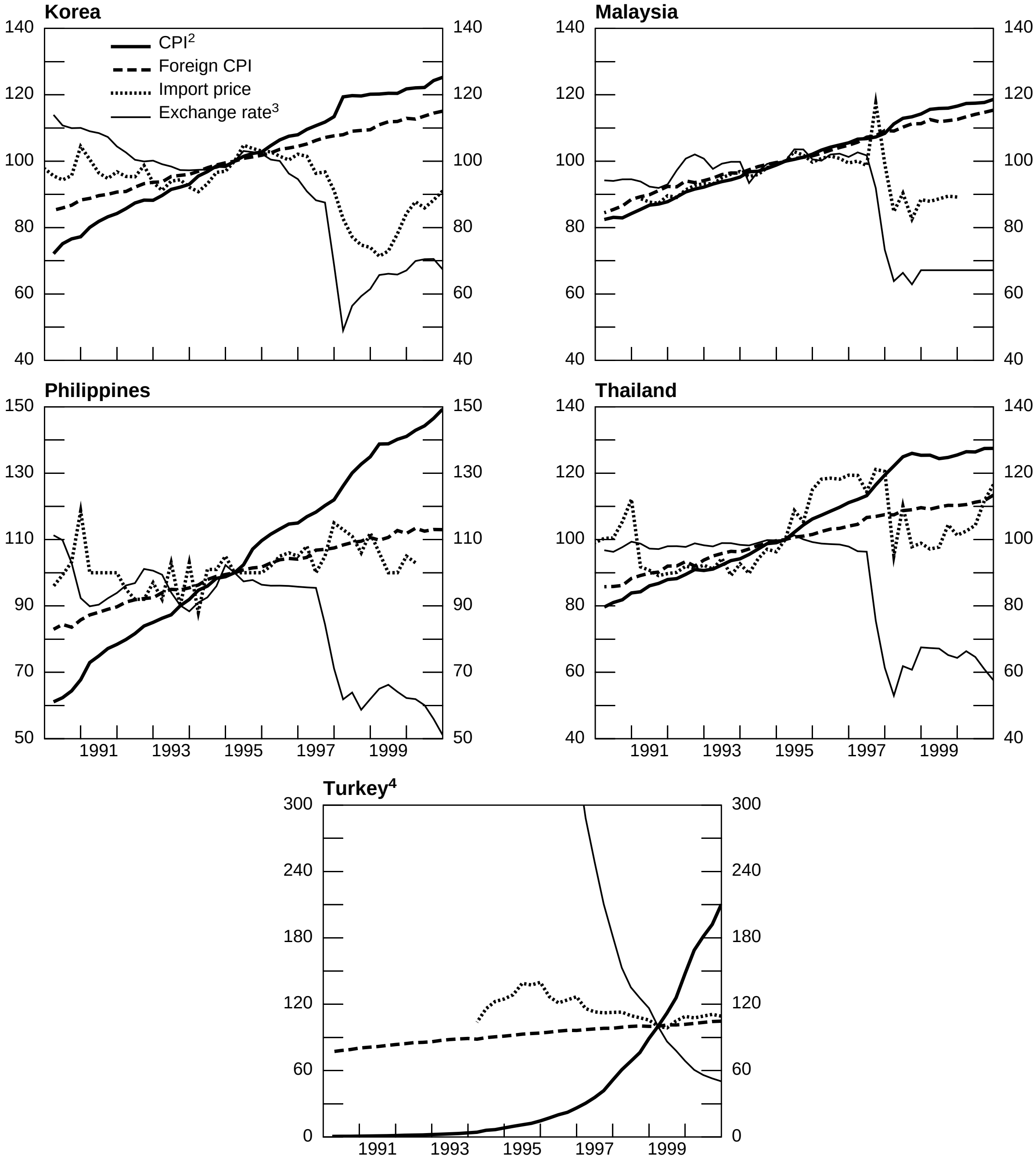
Consumer prices, import and foreign prices and exchange rates[1]



[1] 1995Q1 = 100. [2] Consumer price index. [3] Nominal exchange rate; an increase indicates an appreciation.

Graph 1a

Consumer prices, import and foreign prices and exchange rates[1]



[1] 1995Q1 = 100. [2] Consumer price index. [3] Nominal exchange rate; an increase indicates an appreciation. [4] 1999Q1 = 100.

Cross-correlations between changes in domestic prices, on the one hand, and movements in import prices or exchange rates, on the other, are shown in Tables 1 and 2. The impact on domestic inflation is measured over different time horizons, from the contemporaneous impact (dp_t) to the impact four quarters ahead (dp_{t+4}). Import price changes have been weakly correlated with domestic inflation in Asia and Latin America (with the exception of Mexico) (Table 1), but the correlations became higher in the second half of the 1990s, especially in Latin America. In the transition economies, these correlations are considerably stronger, around 0.45. Import price changes generally take about two to four quarters to filter through to inflation. However, in South Africa, Mexico and Turkey, inflation is highly correlated with import price changes in the same quarter, while in Hungary and Poland inflation is highly correlated with import price changes from the previous quarter.

Table 1

Correlation between import price changes and domestic inflation (dp_{t+i})[1]

	dp_t	dp_{t+1}	dp_{t+2}	dp_{t+3}	dp_{t+4}
Korea	– 0.14	0.06	**0.24**	0.13	0.09
Malaysia	– 0.36	– 0.48	0.21	**0.26**	– 0.15
Philippines	– 0.47	0.19	– 0.35	**0.27**	– 0.07
Thailand	0.06	– 0.04	– 0.02	**0.28**	0.07
South Africa	**0.31**	– 0.02	0.00	0.16	0.05
Brazil	0.02	0.02	– 0.10	– 0.06	**0.08**
Chile	– 0.09	– 0.17	0.01	– 0.33	**0.03**
Mexico	**0.36**	0.34	0.24	**0.36**	0.33
Peru[2]	– 0.28	– 0.15	– 0.21	**– 0.04**	– 0.10
Czech Republic	0.22	– 0.39	**0.43**	– 0.34	0.52
Hungary	0.41	**0.47**	– 0.02	0.13	**0.47**
Poland	0.17	**0.45**	0.17	– 0.09	0.01
Turkey	**0.25**	– 0.01	– 0.25	– 0.39	– 0.03

[1] Based on average quarterly changes in consumer prices. The highest correlation in each row is shown in bold. [2] Most of the correlations are positive for the second half of the 1990s.

Exchange rate changes are more strongly and more contemporaneously correlated with inflation than are import price changes (Table 2). In Brazil and Poland, inflation is almost perfectly correlated with exchange rate changes in the same quarter. In Malaysia, Mexico and Peru, these correlations are also very high, around 0.7-0.8 with a delay of one quarter. In the Philippines, Thailand, Hungary, Poland and Turkey, correlations between inflation and exchange rate changes in the same or the previous two quarters are around one half.

Table 2

Correlation between exchange rate changes and domestic inflation (dp_{t+i})[1]

	dp_t	dp_{t+1}	dp_{t+2}	dp_{t+3}	dp_{t+4}
Korea	**0.38**	0.24	– 0.08	– 0.08	– 0.09
Malaysia	0.31	**0.68**	0.43	– 0.04	0.05
Philippines	0.02	0.36	**0.45**	0.01	– 0.00
Thailand	0.43	0.48	**0.49**	0.14	– 0.10
South Africa	0.06	**0.07**	0.02	– 0.05	– 0.06
Brazil	**0.97**	0.84	0.66	0.54	0.52
Chile	0.08	0.02	– 0.00	**0.14**	0.10
Mexico	0.61	**0.72**	0.48	0.40	0.41
Peru	0.65	**0.81**	0.74	0.73	0.70
Czech Republic	0.10	0.04	**0.19**	0.12	0.04
Hungary	**0.41**	– 0.02	– 0.05	0.09	0.07
Poland	**0.92**	0.44	0.09	0.26	0.67
Turkey	**0.54**	0.25	0.08	0.32	0.04

[1] Based on average quarterly changes in consumer prices. The highest correlation in each row is shown in bold.

To further assess the dynamic behaviour of the variables in equation (1), a series of Granger causality tests was performed. The null hypothesis that import prices do not cause domestic inflation is rejected for Korea, the Philippines, South Africa, the Czech Republic and Poland (Table 3). The hypothesis that exchange rate changes do not cause inflation is rejected for all the countries except Thailand, Chile, Hungary and - surprisingly - Brazil and Turkey. However, Granger causality tests for the *monthly* changes in inflation and exchange rates rejected the hypothesis of no causality running from exchange rates to inflation for Brazil, Hungary and Turkey. Causality between the output gap and inflation cannot be rejected for Korea, Malaysia, Thailand, Peru and the central European countries. These results indicate that the assumption of statistical causality running from the nominal exchange rate to consumer prices and, to a lesser extent, from import prices to consumer prices, is valid for most of the countries in the sample.

Table 3

Granger causality tests

Null hypothesis	Korea	Malaysia	Philippines	Thailand	South Africa	Turkey[1]
Δ log (P^*) ≠> Δ log (P)	√*		√		√	
Δ log (E) ≠> Δ log (P)	√	√	√		√	
($GDPGAP$) ≠> Δ log (P)	√	√		√		

Null hypothesis	Brazil[1]	Chile	Mexico	Peru	Czech Rep	Hungary[1]	Poland
Δ log (P^*) ≠> Δ log (P)					√		√
Δ log (E) ≠> Δ log (P)			√	√			√
($GDPGAP$) ≠> Δ log (P)				√*	√	√	√

Note: Based on quarterly data. P = consumer price index; P^* = import prices in foreign currency; E = nominal exchange rate (an increase means a depreciation); $GDPGAP$ = output gap; Δ = quarterly change.

- The bivariate regressions are of the form: $X_t = \alpha_0 + \alpha_1 X_{t-1} + \ldots + \alpha_n X_{t-n} + \beta_1 Y_{t-1} + \ldots + \beta_n Y_{t-n}$; $Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \ldots + \alpha_n Y_{t-n} + \beta_1 X_{t-1} + \ldots + \beta_n X_{t-n}$ for all possible pairs of (X,Y) series in the group.
- √ means that the hypothesis that X does not cause Y is rejected at a 5% level (* at a 10% level). The results are based on an F-test for the joint hypothesis that $\beta_1 = \beta_2 = \ldots = \beta_n$ are jointly equal to zero for each equation.

[1] Granger causality tests for monthly changes in inflation and exchange rates rejected the hypothesis of no causality running from exchange rates to inflation.

Least-squares estimates of the parameters in equation (1) are shown in Table 4. ***Import price elasticities*** range from 0.5 in Turkey and the Czech Republic to around 0.1 or less in Asia and Chile (Graph 2a). The pass-through of import prices is relatively strong in emerging Europe: a 1% increase in import prices raises domestic inflation by 0.3-0.5%. For the two largest Latin American economies - Brazil and Mexico - the pass-through of import prices is statistically insignificant. One reason for the higher pass-through of import prices in emerging Europe than other areas could be greater proximity of the transition economies to their main trading partners. In addition, these economies went through a simultaneous price and trade liberalisation in the first half of the 1990s. Domestic prices thus had to adjust suddenly from a very low level - consumer goods and services were heavily subsidised under central planning - to a new, higher level. In addition, consumer preferences initially shifted to foreign goods and services.

Estimates of ***exchange rate elasticities*** are very high for Mexico and Brazil, indicating more or less full pass-through of exchange rate changes into inflation (Graph 2b). The pass-through is also fairly high in Turkey, Hungary and Poland. In other countries, the impact of exchange rate changes on inflation is less pronounced. It is interesting that the lags on the exchange rate coefficients in Table 4 are all shorter (mostly *t-2*) than the lags on import price coefficients (mostly *t-3* and *t-4*). This indicates a much quicker pass-through - at most two quarters - of exchange rate changes than of import price changes; the latter affect inflation after two to four quarters.

Table 4

Pass-through of foreign currency import price and exchange rate changes into inflation in selected emerging market economies, 1981-2001[1]

Countries and sample periods	Δcpi_{t-1}	Δcpi_{t-4}	Δimp	Δimp_{t-2}	Δimp_{t-3}	Δimp_{t-4}	Δxr	Δxr_{t-1}	Δxr_{t-2}	Gap[2]	R2	Durbin Watson
Korea **(81:2 - 00:4)**	0.25[3] (2.54)	0.29 (3.27)		0.07 (1.87)			0.09 (3.89)	0.04 (1.69)		–0.11	0.42	1.75
Malaysia **(94:2 - 00:4)**		0.49 (3.83)		0.05 (3.98)					0.07 (4.78)	0.13	0.67	1.58
Philippines **(91:2 - 00:3)**		0.26 (2.65)			0.07 (3.36)	0.04 (2.14)		0.08 (2.96)	0.09 (3.46)	–0.72	0.44	1.25
Thailand **(94:1 - 01:1)**		0.37 (2.22)			0.03 (1.35)			0.10 (3.78)	0.18 (2.47)	0.06	0.59	1.34
South Africa **(88:1 - 00:4)**	0.53 (4.07)		0.16 (3.11)				0.14 (3.32)			0.29	0.42	2.15
Brazil **(87:1 - 00:3)**	0.21 (5.19)				0.17 (1.06)		0.84 (19.52)			2.21	0.97	2.16
Chile **(91:2 - 00:3)**		0.48 (6.62)	–0.09 (–2.20)	0.06 (1.78)		0.07 (1.87)			0.07 (1.78)	–0.43	0.82	1.99
Mexico **(87:1 - 00:4)**		0.19 (2.88)			0.22 (0.44)		0.36 (6.76)	0.40 (7.84)	0.18 (3.73)	0.94	0.83	1.43
Peru **(91:1 - 00:3)**		0.07 (11.94)			0.22 (3.52)				0.11 (22.65)	–1.68	0.98	0.87
Czech R. **(94:2 - 00:4)**	0.34[4] (3.08)	0.33[3] (3.09)	–0.19 (–3.41)	0.20 (3.14)	0.18 (2.37)	0.30 (3.99)			0.06[5] (2.32)	0.89	0.87	2.33
Hungary **(93:2 - 00:1)**		0.45 (4.75)	0.43 (5.71)				0.54 (5.28)			0.16	0.78	1.92
Poland **(90:4 - 00:4)**		0.11 (5.69)	0.19[6] (3.19)	0.13 (2.45)				0.23 (2.61)	0.22 (2.56)	–1.27	0.85	2.65
Turkey **(95:2 - 00:4)**		0.26 (3.30)				0.52 (3.64)	0.56 (6.04)			3.26	0.76	1.51

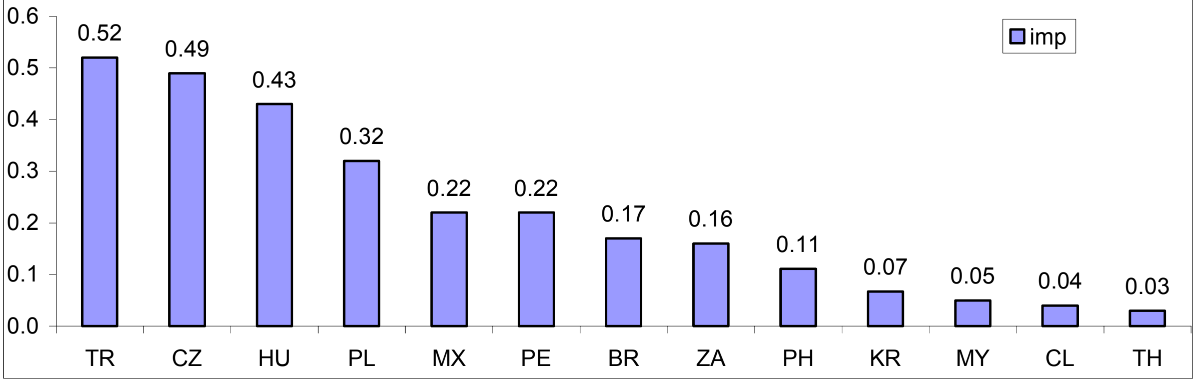
Note: Δcpi = quarterly average change in log of consumer prices; Δimp = quarterly average change in log of import prices in foreign currency; Δxr = quarterly average change in log of nominal exchange rate; gap = output gap (percentage deviation of actual GDP from potential); t-statistics are shown in parentheses.

[1] Estimates of the constant term are not shown in order to simplify the table. [2] This column shows the sum of all statistically significant estimates of the output gap coefficient, from t to t-4. [3] Coefficient for Δcpi_{t-3}. [4] Coefficient for Δcpi_{t-2}. [5] Coefficient for Δxr_{t-4}. [6] Coefficient for Δimp_{t-1}.

Comparing the size of the two sets of pass-through coefficients one can notice that four countries - Malaysia, South Africa, Chile and Turkey - have exchange rate and import price elasticities of approximately the same size. In seven countries the exchange rate elasticity is higher; in two countries (the Czech Republic and Peru) the import price elasticity is higher. These results clearly indicate that it is appropriate to estimate the two pass-through effects separately.

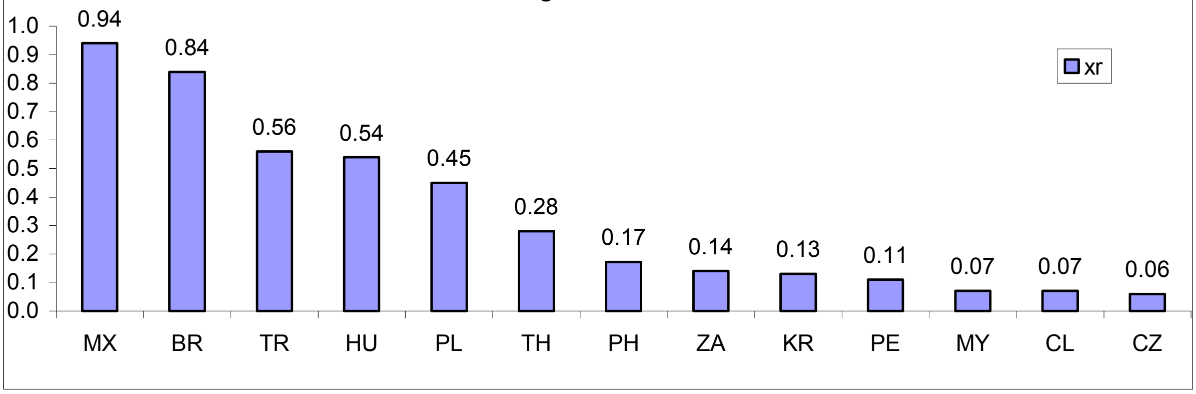
Graph 2a

Import price elasticities



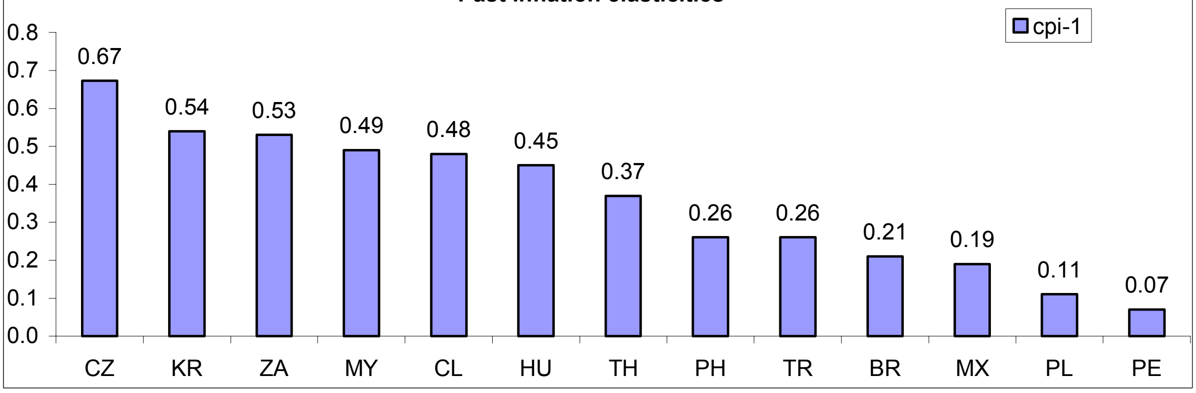
Graph 2b

Exchange rate elasticities



Graph 2c

Past inflation elasticities



There is considerable inflation inertia in many emerging economies. The highest estimated ***past inflation elasticity*** is for the Czech Republic and the lowest for Peru (Graph 2c). Interestingly, the estimated coefficients are fairly low in countries that experienced high inflation at different periods in the past - Brazil, Mexico, Peru, the Philippines, Poland and Turkey (see Table A1).

The estimated relationship between the ***output gap and inflation*** is statistically significant for all the countries with the exception of Hungary and South Africa, and the sign is for the most part positive. Differences in the size of coefficients are large - an increase in the output gap of 1 percentage point is estimated to raise quarterly inflation by 3.3 percentage points in Turkey and 2.2 percentage points in Brazil, and to have almost no impact in the Asian economies. The negative coefficient for Poland probably reflects the events of the early 1990s, when the sharp fall in output resulting from systemic shocks (including the collapse of central planning and trade among former socialist economies) coincided with price liberalisation. Similarly, disruptions in the economy caused by hyperinflation could explain why the output gap coefficient for Peru is negative. But the negative (and statistically significant) coefficients for Chile, Korea and the Philippines are hard to explain.

Have the estimated pass-through parameters changed over time? For Korea, South Africa, Brazil, Mexico and Peru, the null hypothesis of no structural break in parameters is rejected by the Chow test (Table 5). It should be noted that the time series for the countries for which the Chow test is not significant are rather short. Alternative estimates where import prices are replaced by foreign inflation easily reject the null hypothesis of no structural break in parameters for all 13 countries in the sample.

Table 5

In-sample Chow breakpoint stability test

	Korea	Philippines	South Africa	Brazil	Chile	Mexico	Peru
F-statistic	3.07*	1.77	3.47*	9.61*	1.52	4.08*	8.67*

Note: The Chow tests were calculated for sample periods shown in Table A2.

* Indicates that the null hypothesis of no structural break has been rejected.

The estimated exchange rate elasticities declined in all the countries in the second half of the 1990s, though the change was very small in the Philippines, South Africa and Chile (Table 6). While the import price elasticity tended to decline, it rose in Chile, Mexico and South Africa. The decline in the exchange rate pass-through was particularly large in Brazil, Mexico, Peru and Korea. The decline in the import price pass-through was large in Korea, Brazil and Peru. The persistence of inflation has declined only in Brazil and Chile.

Table 6

Change in the pass-through

	Lagged inflation		Import price		Exchange rate	
	1st period	2nd period	1st period	2nd period	1st period	2nd period
Korea	0.23	0.30	0.18	0.06*	0.11	0.05
Philippines	– 0.18	0.16*	0.03	– 0.06	0.18	0.16
South Africa	0.03*	0.49	0.01	0.04*	0.13	0.11
Brazil	0.24	0.03	0.50	0.19	0.96	0.04*
Chile	0.43	0.06*	0.03*	0.07	0.04*	0.02*
Mexico	0.14	0.40	0.14*	0.28**	1.06	0.34
Peru	0.07	0.52	0.31	0.13	0.16	0.01*

Note: Based on sample periods shown in Table A2.

* Indicates estimates that are not statistically significant at the 5% level. ** Indicates estimates that are statistically significant at the 10% level.

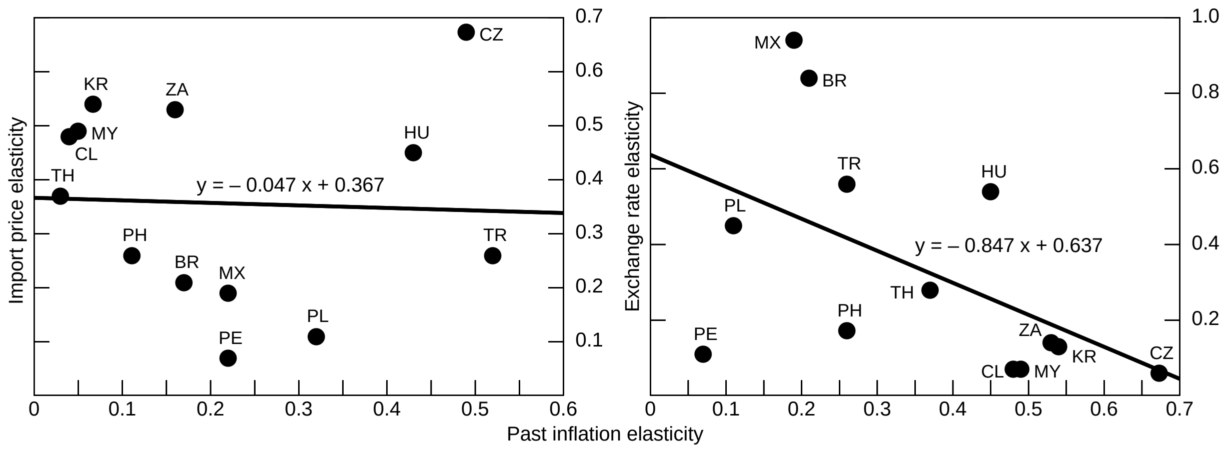
4. Tentative interpretations

The above results provide support for a pass-through model that separates the effects of changes in exchange rates and import prices measured in foreign currency. There are large differences in the size of the pass-through coefficients across countries. Within most countries, the main channel for the transmission of external influences is exchange rate movements. However, the exchange rate pass-through has declined in recent years.

Why do the pass-through coefficients differ so much across countries? One factor could be different histories of inflation performance. Taylor (2000) has argued that lower persistence and volatility of inflation reduce the degree to which firms are able to pass through to their own prices both price increases at competing firms and cost increases due to exchange rate movements or other factors. Thus, low and stable inflation should lead to a virtuous circle of declining markups and weakening pricing power of firms, and less inflationary implications of monetary expansions (including exchange rate depreciation). The link between volatile inflation and the size of the exchange rate pass-through has been documented for the OECD countries (see Campa and Goldberg (2001)).

Graph 3

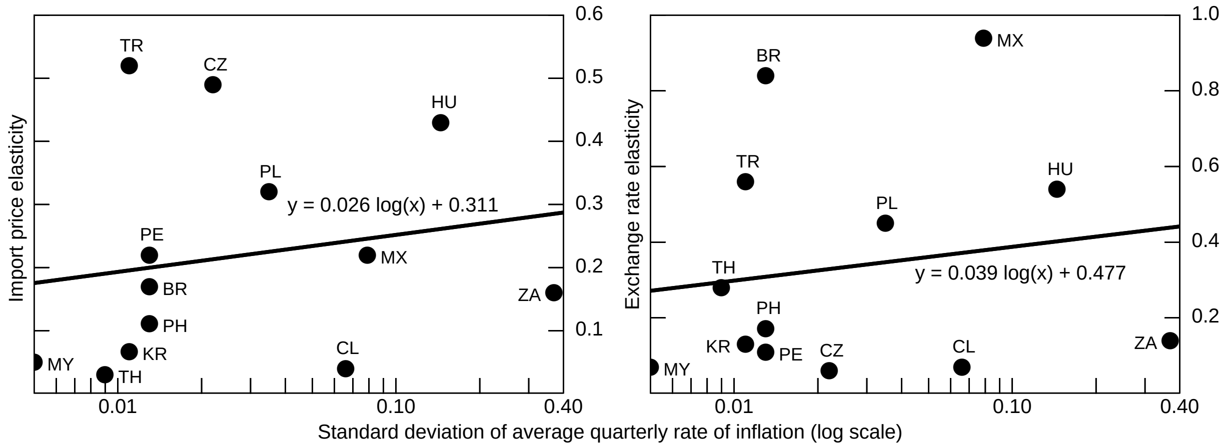
Import price elasticity, exchange rate elasticity and persistence of inflation



The empirical evidence from the emerging economies only partly supports these arguments. The cross-country relationship between inflation persistence (measured by past inflation elasticity), on the one hand, and import price or exchange rate elasticities, on the other, is clearly negative (Graph 3). Lower persistence of inflation in the emerging economies is associated with higher, not lower pass-through elasticities. There seems to be no intuitive explanation why this relationship holds, but statistically it is fairly robust. At the same time, volatility of inflation (measured by the standard deviation of average quarterly inflation rates) does seem to be positively correlated with pass-through elasticities (Graph 4).

Graph 4

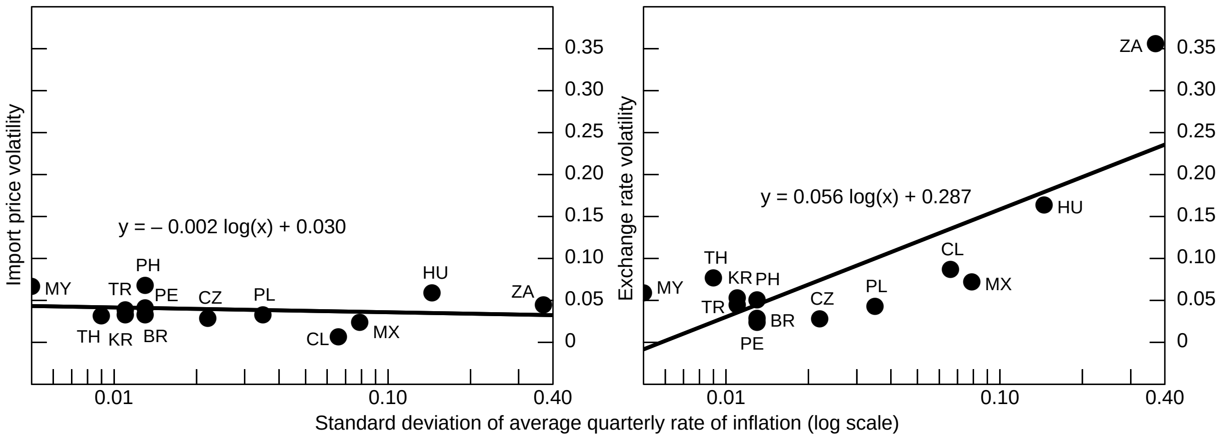
Import price elasticity, exchange rate elasticity and inflation volatility



The next question that arises is: Why is the exchange rate pass-through in most countries higher than the import price pass-through? Statistically, exchange rate changes are on average twice as volatile (as measured by the standard deviation of quarterly average changes) as import price changes and, unlike import price changes, are positively correlated with the volatility of inflation (Graph 5). This positive relationship of exchange rate changes apparently outweighs the impact of their greater volatility, which would normally imply a lower estimated value of exchange rate elasticity.

Graph 5

Import price, exchange rate and inflation volatility



A more intuitive explanation for the higher exchange rate pass-through relative to the import price pass-through could be that high inflation leads to currency substitution, where exchange rates play a role not only in transmitting external influences to domestic prices, but also in affecting the formation of expectations about future inflation. When currency substitution is widespread, changes in exchange rates tend to overshadow other influences on inflation, including changes in import prices. Another common channel for the transmission of exchange rate changes is indexation of wages and debt contracts, which was common in many high-inflation countries in the late 1980s and early 1990s.

The shifts in the rates of exchange rate and import price pass-through probably reflect two main influences: greater macroeconomic stability, and wide-ranging structural reforms implemented in the emerging economies during the 1990s. For example, as inflation and its volatility were sharply reduced in the second half of the 1990s, especially in Brazil, Mexico and Peru (Table A1), the exchange rate volatility dropped correspondingly. This has resulted in a significant reduction in exchange rate elasticities (Table 6). At the same time, in Brazil, Chile and Mexico (as well as South Africa), the import price pass-through has become stronger relative to the exchange rate pass-through.[7]

Structural reforms may have reinforced these trends. Domestic deregulation, foreign trade and investment liberalisation, and globally more integrated production of goods and services have increased competition in import-competing industries in the emerging economies, and made it more difficult for firms to pass on the price increases resulting from currency depreciation, while at the same time making producers and consumers more observant of foreign price movements. Latin American economies and South Africa, where the exchange rate elasticities declined and the import price elasticities rose in the second half of the 1990s, again illustrate these trends.

Additional factors played a role in the transition economies. As prices and foreign trade were liberalised and exchange rates were sharply devalued in the early 1990s - but were subsequently kept relatively stable for a number of years - transition economies experienced bouts of inflation as domestic prices began to adjust to a new, higher level. As a result, the import price pass-through has been stronger on average than in other countries, and it probably also dominated the exchange rate pass-through in Hungary and Poland initially.

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[7] More precisely, the difference between import price and exchange rate elasticities in the first period has switched from negative to positive, or has become less negative, in the second period.

Table A1

Exchange rates, consumer and import prices in emerging market economies[1]

	Exchange rate[2]		Consumer price		Import price	
	Quarterly average	**Standard deviation**	**Quarterly average**	**Standard deviation**	**Quarterly average**	**Standard deviation**
Korea	– 0.6	0.053	1.3	0.011	– 0.1	0.033
Malaysia	– 1.2	0.059	0.8	0.005	– 0.1	0.067
Philippines	– 1.3	0.051	2.0	0.013	– 0.2	0.068
Thailand	– 1.6	0.077	1.1	0.009	0.8	0.032
Brazil	– 25.6	0.356	54.2	0.370	0.2	0.045
Chile	– 1.3	0.029	2.1	0.013	– 0.1	0.033
Mexico	– 3.9	0.087	6.6	0.066	0.5	0.007
Peru	– 4.7	0.072	6.4	0.079	0.3	0.024
Czech Republic	– 0.1	0.024	1.8	0.013	0.2	0.041
Hungary	– 2.9	0.028	4.1	0.022	– 0.2	0.029
Poland	– 4.2	0.164	9.9	0.145	0.1	0.059
Turkey	– 11.4	0.043	14.5	0.035	– 0.5	0.033
South Africa	– 2.4	0.045	2.4	0.011	0.2	0.039

[1] Based on quarterly average changes over the sample period defined in Table A2. [2] An increase indicates an appreciation.

Table A2

Sample periods for estimates of change in the pass-through

	1st period	2nd period
Korea	1981:02-1990:04	1991:02-2001:02
Philippines	1991:02-1995:04	1996:01-2000:04
South Africa	1989:01-1994:04	1995:01-2000:04
Brazil	1987:02-1994:02	1994:04-2000:01
Chile	1991:02-1995:04	1996:01-2000:04
Mexico	1987:01-1994:04	1995:01-2000:04
Peru	1991:01-1995:04	1996:01-2001:01

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Inflation targeting in Brazil: shocks, backward-looking prices, and IMF conditionality[1]

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Abstract

This paper examines the recent evolution of monetary policy since the adoption of formal inflation targeting in Brazil. We argue that the new policy framework has been subject to a severe test in its first years of existence, represented by external shocks associated with oil prices and increased international financial volatility. Moreover, we examine selected issues that deserve due consideration given their importance to the conduct of monetary policy. The first issue is the presence of a substantial portion of prices with backward-looking adjustment, a fact that affects monetary policy reaction since it reduces the efficiency of domestic interest rates in controlling inflation. The second addresses the question of how inflation targets should be monitored in a country that has an ongoing economic programme with the International Monetary Fund. This latter issue is particularly important when considering the effects of shortening monitoring horizons on the variability of inflation and output.

1. Introduction

In mid-January 1999, Brazil abandoned its crawling exchange rate band regime. Surprisingly enough, the country's economic performance in the aftermath of this episode was much better than expected, given the performance of other emerging market economies after a move towards floating. In fact, despite the large devaluation of the domestic currency that followed the regime shift, GDP grew 0.8% in 1999 and 4.5% in 2000, while consumer price inflation behaved much in line with the declining targets, established in mid-1999, of 8% and 6% respectively.

This paper examines the main factors that helped Brazil withstand the negative effects of a change in the exchange rate regime and enabled the economy to recover rapidly; namely the combination of fiscal restraint with a well defined purpose for monetary policy. The following section describes the macroeconomic background that culminated in the currency devaluation, the volatile expectations environment that followed, and the evolution of monetary policy in the transition to inflation targeting.

Section 3 presents a stylised model that we use in our discussion of the transmission mechanism. Section 4 discusses the transmission mechanism, highlighting the main channels, the lag structure and the exchange rate pass-through. These issues are presented with a prospective view of their evolution as the economy converges to its new steady state.

The model outlined in Section 3 serves as the basis for the simulations performed in Sections 5 and 6. Section 5 describes how monetary policy has reacted to shocks since the implementation of the inflation targeting regime based on inflation forecasting. We examine the BCB's track record in responding to all sorts of shocks, including those associated with international oil prices, food price, and volatility in international financial markets. Given the relative weight of institutionally backward-looking prices in the consumer basket, we decompose the model into inertial prices and market prices to show how the institutional framework in Brazil affects the transmission mechanism of monetary policy and therefore the efficiency of its instruments in reacting to shocks.

[1] The opinions in this paper reflect the views of the authors and not necessarily the official position of the Central Bank of Brazil (BCB).

Section 6 focuses on alternative ways to monitor the performance of monetary policy under inflation targeting. This issue is especially relevant when a country has an ongoing programme with the IMF, since the traditional quarterly reviews demand a monitoring horizon much shorter than that of the targeting economy. We show that if the higher-frequency targets are not set in accordance with the lower-frequency ones, and if policymakers try to meet all the targets, there will be suboptimal outcomes in terms of inflation and output variability. Section 7 concludes.

2. Macroeconomic background[2]

The Brazilian economy has undergone significant structural changes in the last decade. In the early 1990s the country's real income remained stagnant, with low investment and saving rates, and very limited access to international capital markets. Inflation was high and rising, helping to conceal the serious structural imbalances of the public sector and making it extremely difficult to carry out even the simplest planning activities. Brazil only started to make real progress in economic and financial stability from 1994, with good results in terms of inflation, growth, trade liberalisation and international insertion. Despite this relative success, critical problems remained to be addressed, mainly the rising deficits in the current account and the deterioration of the fiscal position. It is important to discuss this macroeconomic evolution in order to understand the current economic environment, characterised by a consistent combination of inflation targeting, a floating exchange rate, and fiscal discipline.

2.1 From exchange rate based stabilisation to floating

The stabilisation programme known as the Real Plan was successful in putting an end to Brazil's history of chronic high inflation. It was preceded by a minimal fiscal adjustment and followed by tight monetary control. The key issue was to coordinate a de-indexing process to break the inflationary inertia, since the automatic price adjustments to past inflation were not synchronised. The solution was the introduction in March 1994 of a new unit of account, the unified reference value (URV), whose value the BCB fine-tuned on a daily basis in line with the loss of the currency's purchasing power. All prices and wages, as well as the exchange rate, were denominated in URV. Prices were converted directly, while wages were converted by their average past purchasing power. Then, on 1 July 1994, the indexation mechanism was extinguished and the URV became the new currency, called the *real*. Demand pressures naturally arose with the sharp inflation decline - for example, the reduction of inflation tax alone accounted for an additional disposable income of BRL 15 billion in the subsequent 12 months - and a very tight monetary policy was needed to counter these pressures, mainly with high real interest rates and stringent credit restrictions.

Even though the stabilisation programme was correctly conceived with due attention to fiscal austerity, the implementation of the comprehensive agenda of structural reforms was much slower and more difficult than had been expected, especially when legislative support was needed. On the other hand, the international financial environment seemed favourable, and the Brazilian economy rejoined the route of foreign investment after the rescheduling of its external debt within the Brady Plan. With these perspectives, it was natural for policymakers to concentrate first on the fight against inflation and indexation, since the immediate results on this front would determine the future of stabilisation, and there seemed to be enough time to address the remaining fundamentals later on.

Another key issue in the first phases of stabilisation was the choice of a suitable exchange rate policy. The monetary authorities decided to start with a float, which immediately led to a continuous nominal appreciation, given that the high real interest rates were effectively attracting capital inflows. The Mexican crisis in late 1994 prompted a shift to a crawling band regime, which was formally adopted in March 1995. From July 1995 to mid-January 1999, exchange rate policy was conducted on the basis of an annual devaluation target of around 7.5%. The price stabilisation plan was successful, since the economy eliminated short-run indexation practices, and annual inflation dropped from 929% in 1994 to less than 2% in 1998.

[2] In outlining this section we greatly benefited from internal documents of the Central Bank Research Department, in particular the unpublished manuscript written by Fachada (2000).

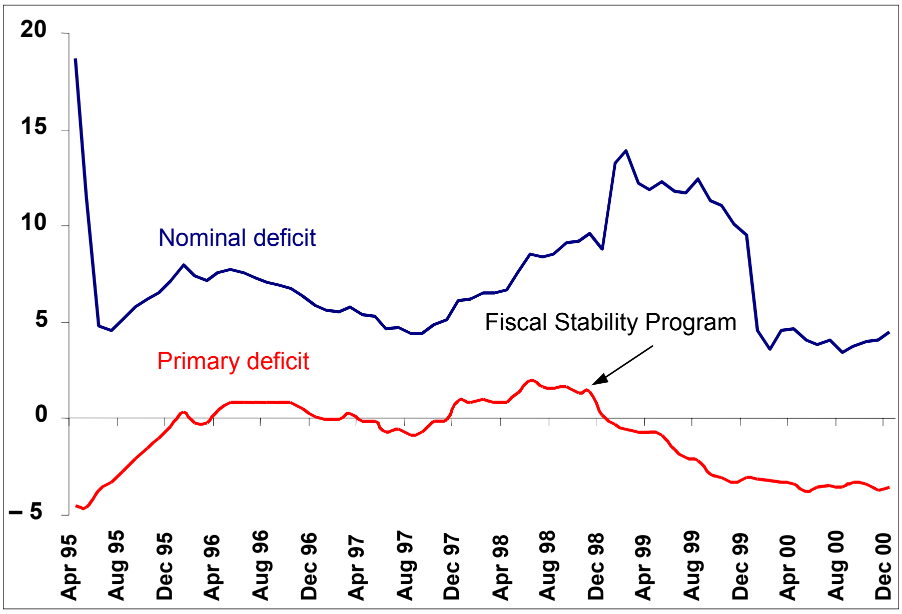
The stabilisation process included a wide programme of economic reforms. The size of the public sector was substantially reduced through privatisation of state companies operating in sectors like telecommunications, chemistry, steel, railroads, banking and mining. Likewise, trade liberalisation was deepened through the reduction of import tariffs and elimination of non-tariff barriers. The financial system was submitted to a full-fledged restructuring: unsound institutions were liquidated, merged or restructured; prudential regulation was updated; and supervision was reorganised to take on a more preventive approach. This strengthening of the financial system was a crucial element in the country's reaction to the external crises that were to come.

The fiscal position gradually worsened, however, as the success in reducing inflation brought to light the masked structural imbalances of public accounts. The initial fiscal adjustment was recognized as insufficient, but efforts to bring about a sounder fiscal environment were frustrated as several constitutional reforms of high priority to the government remained stuck in the congressional agenda. The absence of a further fiscal adjustment, combined with continued high interest rates and sterilized intervention – which were required to support the exchange-rate policy – produced adverse fiscal results, with nominal deficits often tied in with primary deficits (see Figure 1). Currency appreciation, growth of domestic demand, and incentives to short-term capital inflows resulted in a rapid growth of the current account deficit. At the time, the good overall performance of the world economy seemed to guarantee a sufficient amount of private capital flows to finance the Brazilian balance of payments, but confidence shocks were soon to come..

Figure 1

Public sector borrowing requirement

(percentage of GDP in 12 months)



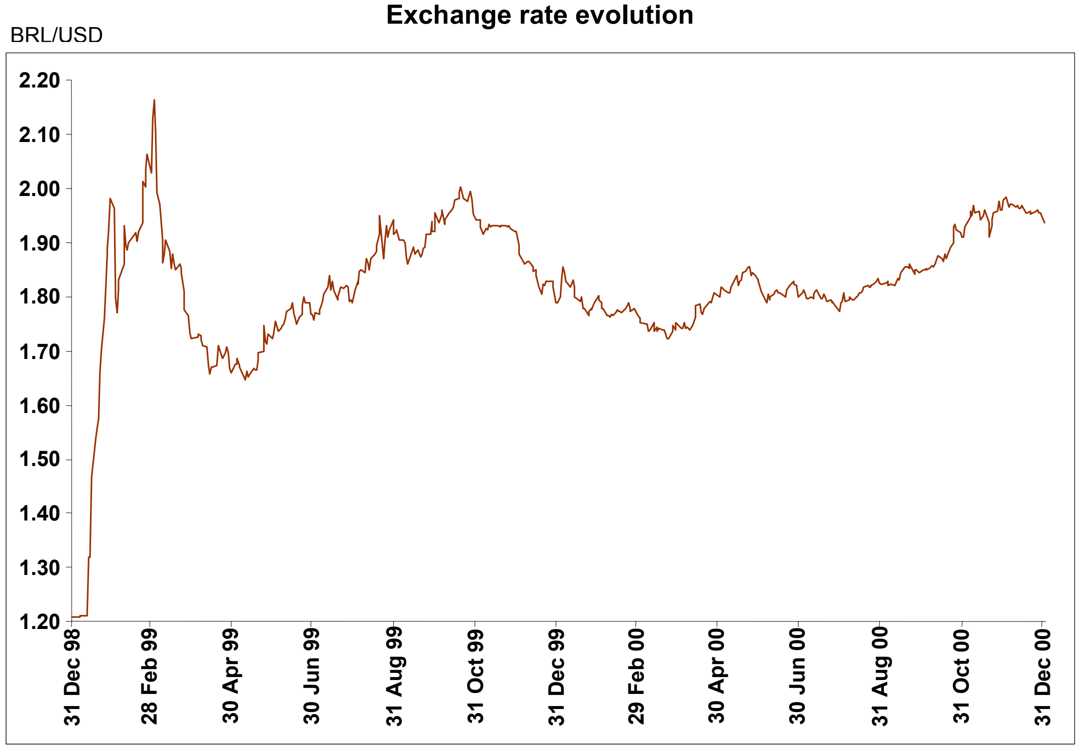
The first shock was prompted by the Asian crisis in the second half of 1997. In the face of falling international reserves, the BCB reacted by doubling the basic interest rate to 43.4% pa in November. The government pressed for a strong fiscal response to complement the monetary tightening. In a matter of weeks, Congress approved a fiscal programme called "Package 51", which featured 51 measures to cut expenditures and increase taxes, totalling BRL 20 billion, or about 2% of GDP. The fast recovery of international reserves that followed allowed the BCB to reduce interest rates, but the fiscal program was only partially executed. In particular, the spending cuts were postponed, as the political will to undertake them diminished in line with the perceived contagion effects.

The second shock followed the Russian moratorium in August 1998. The country was much more affected by international turbulence than in the previous episode as a result of a worldwide reassessment of risk exposure to emerging markets. Capital outflows were substantial in the ensuing months. The authorities responded with the same policy mix used to counter the Asian crisis effects. In September, the basic interest rate doubled to 40%, calling for a new fiscal tightening. This time, however, the government could not count on market support, a price it paid for not delivering the previously promised fiscal results. To address the issue of enforceability of fiscal discipline, the government sought a preventive programme with the IMF. The financial support package amounted to USD 41.5 billion, with about two thirds of the total becoming available in the first year. However, it was not enough to prevent expectations from deteriorating, especially because some of the newly proposed fiscal measures faced strong resistance in the Congress.

This time, the fiscal tightening measures were mostly implemented. Market confidence, however, continued to erode up to January 1999, partly reflecting concerns over the newly elected governors' commitment to adjusting their states' finances. Any new sign of potential deviation from the fiscal target induced extreme market nervousness. Given its limited ability to sustain the exchange rate crawling band regime, the BCB allowed the exchange rate to float by mid-January, and the dollar value quickly jumped from BRL 1.21 prior to the devaluation to nearly BRL 2.00 at the end of January (see Figure 2).

Figure 2

Exchange rate evolution



The currency devaluation set in motion a sharp realignment of relative prices. The wholesale price index increased 7% in February, while consumer price inflation rose slightly more than 1%. Given the change in the exchange rate regime, the agreement with the IMF had to be reformulated. The estimates set in the reviewed Memorandum of Economic Policy were – 3.5% for GDP growth and 17% for inflation as measured by the general price index.[3] The great uncertainties surrounding the country's future and the lack of a nominal anchor prompted a volatile expectations environment, with inflation and recession forecasts much larger than those above.

A new Board of Governors took office at the BCB on March 4th and immediately worked on two main fronts. The first was to calm down the nervous financial markets by raising real interest rates and pinning down inflation expectations in the short-run. The second was to propose inflation targeting as the new monetary policy regime, thereby anchoring expectations also in the medium run.

3 The general price index in Brazil is a weighted average of wholesale prices (60%), consumer prices (30%) and civil construction prices (10%).

2.2 Transition to inflation targeting (March to June 1999)[4]

The shift to a floating exchange rate regime occurred in a moment of crisis. Even so, the regime seemed reasonable for Brazil. The country does not present the classical features required for an optimal currency area with the dollar or any other currency, and it is hard to find arguments to justify the adoption of a fixed exchange rate regime, even in the more recent literature about monetary integration as a credibility instrument. Therefore, the first task of the BCB's new Board was to find a monetary policy strategy compatible with the floating exchange rate regime.

A fully discretionary monetary policy without an explicit anchor would not tackle the inevitable uncertainties, especially during the transition period. It was natural to opt for a more rigid system, one that would represent a definite, strong commitment but that could also offer some indication of the future path of the economy; one that would allow enough flexibility for policymaking but that could also effectively anchor the public's expectations. The authorities therefore decided to set up an inflation targeting framework. However, the immediate announcement of a numerical inflation target was out of the question. The exchange rate was still overshooting, making any realistic assessment of passthrough effects all but impossible. Thus, setting a specific target value would not enhance credibility; on the contrary, it could even bring the new policy regime into disrepute. The BCB took a gradualist approach: it made clear that monetary policy would aim at keeping inflation under control, but a formal inflation-targeting framework would be in place only by the end of June.

At the time, a remarkable turnaround in fiscal policy was materializing. The targets for the cumulative primary surplus of the consolidated public sector were met with margins, in a clear demonstration of the government's commitment to fiscal adjustment. Policymakers seized the opportunity created by the crisis to enforce a major shift in the fiscal regime, thus putting in place a fundamental pillar to support inflation targeting. Although the reforms that were needed to ensure long-run fiscal equilibrium were far from complete, the government had the necessary instruments to achieve a reasonable fiscal performance for at least a decade. Even the most sceptical analysts had to acknowledge the feasibility of the announced fiscal targets. Whereas confidence in the new fiscal stance would require a much longer sequence of positive results to consolidate, the primary surplus served to mitigate concerns about a rising trend in the debt-to-GDP ratio.

The new Board took office at the BCB on 4 March, and the team immediately worked to calm financial markets. The expectation that an inflation hike could cause the real rates of return on public debt instruments to drop into the negative range was the first to be attacked. The Monetary Policy Committee (Copom), whose voting members are the Governor and Deputy Governors, raised the basic short-term interest rate (the Selic) from 39% to 45% pa, taking into account that the future contracts for the next maturity were already trading at 43.5%. The idea was to accommodate the devaluation shock, but to counter its further propagation. It was acceptable that the relative price movements set in motion with the devaluation would shift the price level upward, but the interest rate had to be set high enough to prevent the second-round inflationary process that could follow. The question was how to translate these ideas into practice, given the then chaotic state of expectations.

Expectations had to be anchored one way or another, and for that purpose clear communication was crucial. The Committee therefore released a brief explanation of the policy decision right after the meeting - previously the minutes would be released only after three months - asserting that "maintaining price stability is the primary objective of the Central Bank".[5] Other official declarations indicated that price stability meant a monthly rate of inflation in the range of 0.5-0.7% by the end of the year. Moreover, "in a floating exchange rate regime, sustained fiscal austerity, together with a compatible monetary austerity, supports price stability; as fiscal policy is given in the short run, the control over inflationary pressures should be exerted by the interest rate; observed inflation is due to the currency depreciation, and markets expect a further rise in the price level this month; the basic interest rate should be sufficiently high to offset exchange-based inflationary pressures; and so, we

4 Fraga (2000) provides a comprehensive discussion of the problems faced by the Central Bank at this period and the steps taken to deal with them. This subsection draws a lot on this article.

5 Explanatory Note to Copom's Decision - 4 March 1999.

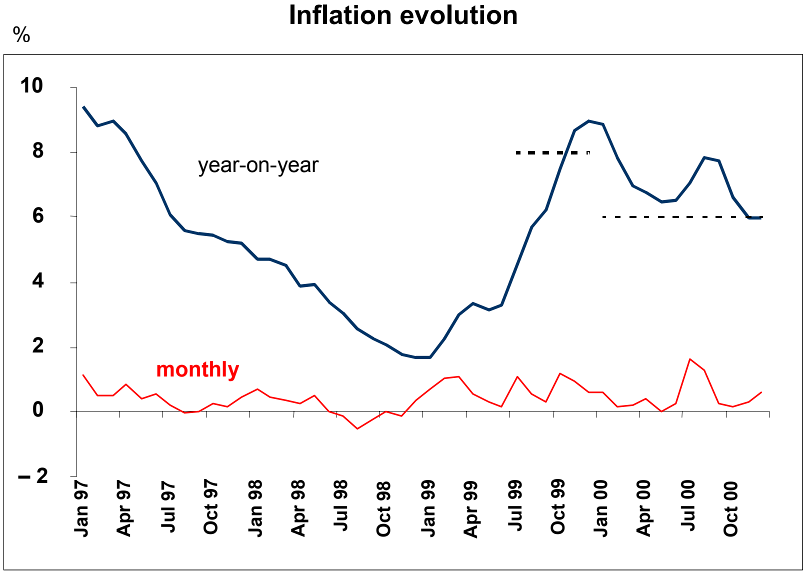
decided to raise the basic interest rate to 45% pa, but with a downward bias,[6] for if the exchange rate returns to more realistic levels, keeping the nominal interest rate that high would be unjustified".[7]

The complementary issue to address was the external financing of the balance of payments, since the doubts about its availability were thought to be one of the main reasons behind the exchange rate overshooting. The financial support package coordinated by the IMF already covered part of the needs; the remainder was sought through the voluntary commitment of foreign banks to roll over trade-related and interbank lines. Here again transparency played an important role: detailed information on overall bank exposure to Brazil was provided, a practice that was to continue through regular updates. In addition, temporary incentives for capital inflows were granted in the form of tax reductions scheduled to last until the end of June. In the foreign exchange market, the rule was free floating, with the BCB only keeping the prerogative to carry out a limited amount of unsterilised intervention to counter disorderly market conditions.[8]

The general outlook started to improve soon after. The reversal of the exchange rate overshooting occurred very fast, in tandem with the change in the slope of the term structure of interest rates. The exchange rate fell from a peak of BRL 2.16 in early March to BRL 1.72 at the month-end, while the one-year forward interest rate plunged from 55% to 31% (Figure 4), prompting a reduction in both observed and expected inflation rates.

Figure 3

Inflation evolution



Confidence was strengthening for a number of reasons. Domestically, consumers put up resistance to price increases, giving rise to a profit margin squeeze along the supply chains and helping dampen latent inflationary pressures. The indicators then released failed to confirm a deep economic slowdown; on the contrary, agricultural output was growing rapidly and the open unemployment rate was stable. The fiscal stance delivered a primary surplus of 4.1% of GDP in the first quarter, in excess of the government's target. The improvement in the trade balance came primarily through a decline in imports, but on the financial side capital inflows were recovering, and in particular foreign direct investment (FDI) was pouring in at a strong pace. Therefore, the downward bias was applied twice before the Copom's next meeting: the interest rate was reduced first to 42% in late March and then to 39.5% in early April. In the mid-April meeting, a further reduction to 34% was decided on..

6 The bias on the interest rate was also an important novelty: it delegated to the BCB's Governor the power to alter interest rates during the period between two ordinary Committee meetings (usually five weeks). A downward bias allows the Governor to reduce the interest rate. However, if an increase in the interest rate is needed, while a downward bias is valid, an extraordinary meeting is required.

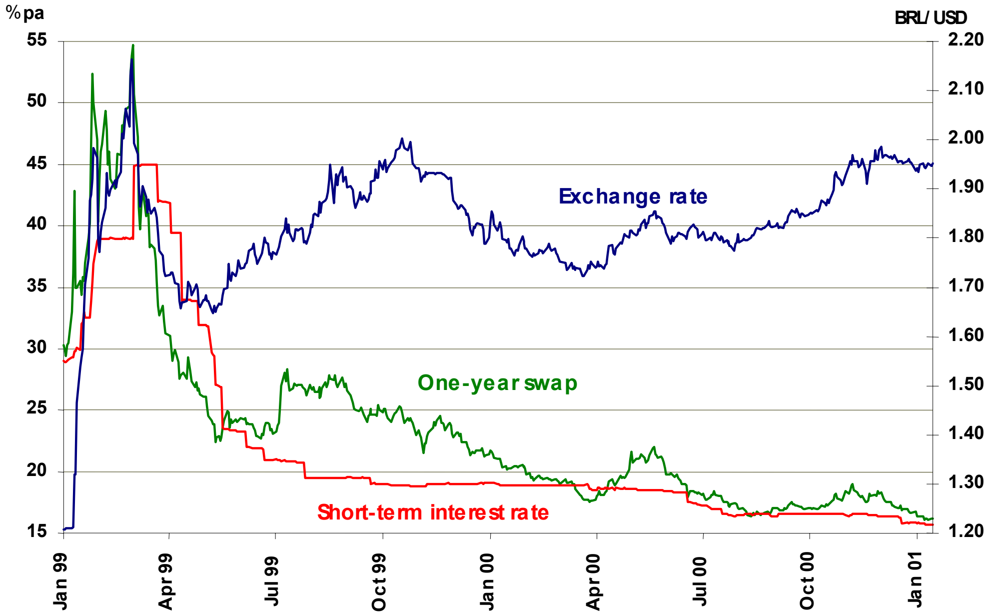
7 Explanatory Note to Copom's Decision - 4 March 1999.

8 Brazil Memorandum of Economic Policies, released on 8 March 1999.

The behavior of observed inflation and the pace of convergence of inflation expectations served as a rough guide to determine the appropriate rhythm of nominal interest rate reductions. This was the case in April and May, when the confirmation that inflation was decelerating allowed the basic interest rate to be lowered by more than ten percentage points, from 34% to 23.5%. The reversal of the exchange rate overshooting and a positive supply shock – the downward pressure the new harvest exerted on food prices – were held responsible for the immediate decline in inflation. The wholesale price index even showed a slight deflation in these two months. Consumer inflation measured by the broad consumer price index (IPCA) fell to 0.3% in May from more than 1% in February and March (Figure 3), and inflation expectations followed suit.

Figure 4

Interest rates and exchange rate



In June, however, the level of uncertainty rose again as a result of external developments. The U.S. Federal Reserve Board set an upward bias for the federal funds rate, suggesting that the combination of rising energy prices, robust aggregate demand and record-low unemployment could require a tighter monetary policy in the second half of the year. The perspective of deterioration in international liquidity conditions, the concentration of amortization payments of private sector external debt due in June, and the near termination of the incentives on capital inflows introduced in March, all led to an increase in Brazil's risk. The immediate repercussions were on market-determined interest rates and the exchange rate. The slope of the term-structure curve turned from negative to positive and the exchange rate weakened (figure 3). Therefore, monetary policy became somewhat more conservative, reducing the interest rate at a slower pace.

In sum, the policy response to the crisis entailed a combination of tighter fiscal policy, tighter monetary policy with a price-stability objective, and external financial support. The exchange rate stabilized quickly and inflation expectations also came down, allowing a 50-percent cut in the basic interest rate between March and June. With the strengthening of confidence and the fact that the private sector was adequately hedged against foreign exchange risk at the outset of the crisis, GDP was already able to recover in the second quarter. The average maturity of the government's securitized debt underwent a gradual extension, while the fiscal stance was consolidating. FDI inflows were more than enough to cover the declining current account deficit, thus averting the need of other than trade-related short-term capital to finance the balance of payments. In this improved after-crisis environment, a full-fledged inflation-targeting framework could be implemented with a fair chance to succeed.

3. The stylised structural model[9]

According to Mishkin and Savastano (2000), inflation targeting comprises five main features: (i) the public announcement of medium-term numerical targets for inflation; (ii) an institutional commitment to price stability as the primary goal of economic policy, to which other objectives are subordinated; (iii) an information-inclusive strategy, encompassing the use of several variables and models, to enable the monetary authority to set policy instruments; (iv) a transparent monetary policy strategy that ascribes a central role to communicating to the public the plans, objectives and rationale of the central bank's decisions; and (v) mechanisms for making monetary authorities accountable for achieving the inflation targets. The first feature, a numerical target value, must be low, feasible and compatible with the macroeconomic outlook.

With this in mind, the Brazilian authorities placed a high priority on understanding the transmission mechanism of monetary policy to prices, with emphasis on developing a set of forecasting tools, including structural models for the transmission mechanism, non-structural time series vector autoregression (VAR) and autoregression moving average (ARMA) models for short-term forecasting, measures of core inflation, leading inflation indicators and surveys of market expectations. The most important of these tools is the family of structural models, which is estimated and/or calibrated with the dual objective of identifying the mechanism of monetary policy and assessing the transmission lags involved. A representative structural model of this family contains four basic equations. The first is a standard IS equation that captures the aggregate demand response to the real interest rate and the real exchange rate. The second is a typical open economy Phillips curve, representing the supply side trade-offs. The third is an equation for the exchange rate and the fourth is an interest rate rule that is essential for simulations.

The standard specification of an IS curve with quarterly frequency could be as follows:

(I) $$h_t = \beta_0 + \beta_1 h_{t-1} + \beta_2 r_{t-1} + \beta_3 \theta_t + \varepsilon_t^h$$

where h is the log of the output gap; r is the log of the real interest rate (log(1+R)); θ is the log of the real exchange rate; and ε^h represents a demand shock. Other specifications might include different lag structures or additional explanatory variables. Bogdanski et al (2000), for example, present a "fiscal" IS specification, which explicitly considers the effects of the shift in fiscal regime on aggregate demand.

The first problem for the BCB was how to measure the variables that are not directly observable, like the output gap. The usual starting point is the calculation of potential output, either by extracting a linear time trend from historical GDP data, by filtering out the GDP series, or by estimating production functions. In the Brazilian case, the linear trend and HP filter were preferred since both produced similar results. The output gap was then obtained by the difference between actual and potential GDP, allowing direct estimates of the different IS curves. However, research efforts on this crucial topic are far from over.

The estimation results posed a second problem, since they were heavily influenced by post-Real-Plan data (third quarter 1994 to fourth quarter 1998). As mentioned in the previous section, the managed exchange rate regime in the Real Plan was very instrumental in reducing inflation and keeping it low, at the cost of setting the domestic interest rates high enough to attain a balance of payments position compatible with the desired parity. The equilibrium real interest rate under the current floating exchange rate regime should therefore be substantially lower than under the previous regime. The transition effects stemming from the new equilibrium level of real interest rates called for a long-term calibration of the demand side reduced-form model. In the long-run steady state, the output gap should remain constant at zero. As a first approximation, it is assumed that the long-term equilibrium real interest rate must equal the potential GDP growth rate. A thorough analysis of this question should also include fiscal policy considerations, like the long-run fiscal balance and debt administration issues, which may add or subtract a few percentage points to the first approximation for the neutral rate. In the IS curve specification above, this is equivalent to setting $\bar{r} = -\beta_0/\beta_2$, since β_3, the real exchange rate coefficient, is very close to zero. So, a straightforward calibration would consist of estimating the IS curve with the additional restriction on the pair (β_0,β_2), whose ratio must equal the long-term equilibrium real interest rate.

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9 This section is based on Bogdanski et al (2000).

The supply side of the economy is modelled with a Phillips-curve specification, directly relating price inflation to some measure of real disequilibrium (typically the output gap), inflation expectations and exchange rate changes. For example,

(II) $$\pi_t = \alpha_1 \pi_{t-1} + \alpha_2 E_t(\pi_{t+1}) + \alpha_3 h_{t-1} + \alpha_4 \Delta\left(p_t^F + e_t\right) + \varepsilon_t^n$$

where π is the log of consumer price inflation, h is the log of the output gap, p^F is the log of the foreign producer price index, e is the log of the nominal exchange rate, Δ represents the first-difference operator, $E_t(\cdot)$ is the expectation operator, conditional on information available at time t, and ε^n stands for a supply shock. The coefficients on the right-hand side of the equation, except for that of the output gap, are constrained to sum to unity; this ensures the long-run verticality of the Phillips curve, that is, that inflation is neutral with respect to real output in the long run.

This specification combines backward- and forward-looking elements. A purely backward-looking specification would be simpler to estimate and would fit past data. However, it would also be vulnerable to the Lucas critique. Its predictive power would be weak because of the recent changes in monetary policy and exchange rate regimes, which have almost certainly altered the formation of inflation expectations and the short-run trade-off between inflation and output. Using a purely forward-looking specification would be an attempt to overcome the parameter instability commonly found after structural breaks. It might also stem from the natural assumption that as the inflation targeting regime gains credibility, expectations tend to converge to the targeted value. However, such a specification raises difficult estimation issues about the appropriate measures of expectations, especially when reliable survey data are not available.

The Bank tested different assumptions about the expectations mechanism, but the estimations generally led to a weighted average of past and future inflation, with at least 60% on the forward-looking component. The preferred Phillips-curve specification, together with the other equations in the complete model, exhibited the desired dynamic properties of the economy, with inflation persistence arising from sluggish adjustment forced by the backward-looking terms, while the rational expectations environment was preserved by the forward-looking component, thought to be increasingly important in the transition period after the changes in monetary policy and exchange rate regimes.

For the purpose of running simulations to investigate the implications for inflation and output of different monetary policy rules, it is easy to experiment with alternative assumptions about the expectations formation mechanism. For example, expectations can be taken exogenously from a market survey and augmented by a hypothesis about how they react to new information, or they can be calculated recursively to ensure consistency with the model.

The pass-through of exchange rate changes to domestic inflation is another key issue in the Phillips curve setup. Several linear and non-linear specifications for the pass-through coefficients were tested, and the alternatives implemented in the preferred simulation tool were narrowed down to four. The first is a standard constant coefficient $\alpha_4 =$ constant, simply estimated from a suitable sample of past data. The second is a quadratic transfer from exchange rate variations to inflation, $\alpha_4 = \alpha_{41} + \alpha_{42}\,\Delta\left(p_{t-1}^F + e_{t-1}\right)$. The third is a level-dependent coefficient, $\alpha_4 = \alpha_{41} + \alpha_{42}\, e_{t-1}$, which is estimated under the assumption that the pass-through depends on the level of the log of the nominal exchange rate. Finally, the fourth is a quadratic function of the nominal exchange rate level $\alpha_4 = \alpha_{41} \frac{E_{t-1}^2 - \alpha_{42}}{E_{t-1}^2 + \alpha_{42}}$, motivated by a simple partial equilibrium model in which exchange rate devaluations shift the supply curve of competitive producers of tradable goods.[10] All non-linear variants aim to capture more precisely the effects of a temporary exchange rate overshoot. Given the small number of observations available in a quarterly frequency, however, their results were very close to the linear variant and consistent with international evidence that the pass-through coefficient is inversely proportional to the degree of real exchange rate appreciation at the moment prior to the devaluation.

The determination of the nominal exchange rate is as important as it is difficult. The BCB's first approach was to use an uncovered interest parity (UIP) condition to model the link between the exchange rate and the interest rate through capital markets. The UIP condition relates expected

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[10] See the appendix in Goldfajn and Werlang (2000).

changes in the exchange rate between two countries to their interest rate differential and a risk premium:

(III) $$E_t e_{t+1} - e_t = i_t - i_t^F - x_t$$

where e is the log of the exchange rate, i is the log of the domestic interest rate, i^F is the log of the foreign interest rate, and x is the log of the risk premium. Taking the first difference $E_t e_{t+1} - E_{t-1} e_t - \Delta e_t = \Delta i_t - \Delta i_t^F - \Delta x_t$ and assuming for simplicity that the expectation change follows a white noise process[11] $E_t e_{t+1} - E_{t-1} e_t = \eta_t$, it is possible to specify the exchange rate dynamics as:

(IV) $$\Delta e_t = \Delta i_t^F + \Delta x_t - \Delta i_t + \eta_t .$$

This equation contains two exogenous variables: the foreign interest rate and the risk premium. Given the relative stability of foreign interest rates, reasonably accurate projections can be obtained from contracts traded in international futures markets. However, the risk premium, which can be measured by the spread between US Treasury bonds and Brazilian sovereign debt, has presented high volatility in recent years. The risk premium is usually associated with macroeconomic fundamentals and a number of other subjective factors that are not easily anticipated. Two alternative approaches were therefore considered. The first was to gather the opinions of Copom members about the future evolution of the country's risk premium, conditional on the overall scenario and based on anecdotal evidence; these opinions were then translated into an exogenous expected path to be used in simulations. The second approach was to make assumptions linking risk premium behaviour to the main objective factors thought to influence it, thereby allowing the model to endogenously determine the premium. A list of these factors would typically include the fiscal stance, perspectives on the current account balance, international liquidity conditions and interest rates, the performance of foreign capital markets, commodity prices and country rating.

Finally, the fourth equation is left unspecified in the general model. Since the primary instrument of monetary policy is the short-term interest rate set by the BCB, it is necessary to choose a policy rule in order to run simulations in any of the different reduced-form model specifications. The rules can be divided into three basic families: fully exogenous interest rate paths, linear combination of system variables and optimal response functions.

An exogenous interest rate path is useful for analysing the consequences of a particular interest rate trajectory, such as that implied by financial market instruments or the implicit path considered in the government budget. A particular rule of this family is helpful for institutional communication. The inflation forecasts published in the quarterly inflation report are traditionally constructed under the assumption that the short-term interest rate will remain constant at the current level along the projection period. This projection is illustrated by means of an inflation fan chart, which shows the probability distribution around the central forecast for each quarter. On visual inspection, one can infer whether monetary policy should be altered and in which direction.[12]

The interest rate rule can be written as a linear function of some system variables. For example, monetary policy can react contemporaneously to the output gap and deviations of inflation from target: $i_t = (1-\lambda) i_{t-1} + \lambda \left(\omega_1 \left(\pi_t - \pi^* \right) + \omega_2 h_t + \omega_3 \right)$. When λ=1, this is equivalent to a standard Taylor rule, whereas it is a Taylor rule with interest rate smoothing when $\lambda \in (0,1)$. The values of ω_i can be set arbitrarily or using specific optimisation procedures available in the simulation tool. Finally, an optimal interest rate rule can be found by minimising an appropriate loss function, subject to the model in use.

[11] This is equivalent to a random walk with monetary surprise, where a surprise is characterised by changes in interest rate differentials or in risk perception.

[12] Britton et al (1998) explain how to interpret inflation forecasts presented as fan charts. Haldane (1997) discusses how the introduction of a partially subjective probability distribution may help clarify policymakers' assessment of the current economic stance. The Brazilian *Inflation Reports* make use of both resources to convey information about monetary policy decisions.

4. The transmission mechanism

The initial modelling efforts succeeded in reaching an early mature stage - that is, a reasonable degree of reliability and sensible dynamics. Two qualifications must be stressed, however. First, the general limitations stemming from model and parameter uncertainty apply. Second, the statistical time series for the Brazilian economy after the float is too short to yield sufficiently robust results. Moreover, a sequence of failed stabilisation plans from 1986 to 1994 produced important structural breaks in many economic series, thus making it extremely difficult to treat them with the usual econometric techniques. The various non-structural tools are therefore fundamental for complementing and checking the consistency of structural modelling results. Policymakers are well aware of the limitations of the available tools and have no illusions about their effectiveness. Nonetheless, the models have been very useful and have helped discipline the discussion on monetary policy within the BCB.

This modelling approach embodies the understanding that, as in most other economies, the most important transmission channels are through aggregate demand, exchange rate and expectations. Preliminary estimation results with quarterly data indicate that permanent changes in the basic interest rate take one to two quarters to impact aggregate demand. This aggregate demand response, in turn, takes an additional quarter to be fully perceived in consumer inflation. Changes in short-term interest rates are thus transmitted to inflation through the aggregate demand channel with an estimated lag of two to three quarters. The exchange rate channel is estimated to have a shorter transmission lag: the effect of permanent interest rate changes on consumer prices through this channel is contemporaneous (on a quarterly basis), but its magnitude is smaller than through the demand channel. These results are based on the strong assumptions that expectations remain consistent with the model after any policy change and that the policy change itself is a sufficiently small departure from the initial position so that the log-linear approximation remains valid.

Further qualifications come into play at this point. First, the lag structure in the aggregate demand channel is shorter than that found in the majority of either industrialised or developing economies. This may be the result of the large swings in real interest rates that characterise the post-Real-Plan sampling period. These large swings generated prompt output and inflation responses, although the magnitude of the responses was relatively small in comparison with the interest rate variations. The lag is expected to increase gradually as the economy converges towards its long-run steady state equilibrium.

Second, although the lag structure is short, the overall effect is modest, for several reasons. The financial system, for example, is overregulated, with a variety of credit restrictions, mandatory allocation of funds and distorting taxes. The banking spread has therefore remained extraordinarily high, and the system as a whole presents a low leverage compared to international standards. This banking spread makes the transmission channel from the basic interest rate to market-determined final loan rates much weaker than desirable, and it explains part of the high volatility of interest rates observed in the last three to five years. This fact leaves the impression that a slight deviation from the expected path requires a significant change in the basic interest rate to bring the economy back to the central path. In other words, the interest rate elasticity of the macroeconomic equilibrium is low. A series of parallel projects is under way to correct these distortions in the financial system and improve the efficiency of the transmission mechanism.

The third qualification has to do with the pass-through. Goldfajn and Werlang (2000), who analyse panel data, conclude that the pass-through coefficient generally depends on four main factors: the degree of overvaluation of the exchange rate prior to the devaluation, the previous level of inflation, the degree of openness and the economic activity level. On this ground, Brazil shifted to a floating exchange rate regime with good prospects for a low degree of pass through, since inflation was low and the exchange rate showed clear signals of overvaluation after the deterioration of the terms of trade and the Russian crisis in 1998. Open and heated economies tend to present higher pass-through coefficients, other things equal. Although trade liberalisation progressed well and fast in the 1990s, the degree of openness of the Brazilian economy (around 14%) is considerably low in comparison with international standards. Furthermore, the economy evolved below its potential after the Russian crisis. When the real floated, the output gap was undoubtedly negative, which provided a major force for countering pass-through pressures. Preliminary results thus confirm the tendency for a low pass-through.

5. Policy reaction to shocks

In this section we examine how monetary policy reacted to shocks after inflation targeting was implemented in Brazil. We begin by identifying the main shocks that occurred after July 1999 and the corresponding policy behaviour. The identification process addresses the nature as well as the duration of shocks. This task is obviously easier with the benefit of hindsight, although in some cases even the ex post interpretation of shocks is not straightforward.

The problem of inflation persistence is another key factor for understanding the policy reaction. Given the Brazilian institutional setting, which features a high weight of backward-looking prices in the consumer basket, policy responses are different from those in an environment in which all prices are forward-looking. Other peculiarities of the Brazilian inflation targeting framework are also relevant for discussing policy reactions. These include the absence of escape clauses, the use of a headline price index and the adoption of multi-year targets. All these peculiarities leave relatively little room for accommodation by monetary policy.

The term “backward-looking prices” deserves an explanation. These prices are also known as “government-managed prices”, given that they used to be arbitrarily set by the government before the privatisation of state companies. Government-managed prices are now those that, in one way or another, are defined or affected by a public sector agency, independently of current supply and demand conditions, but not arbitrarily. The major administered prices (and respective weights) in the reference consumer price index (IPCA) fall into two categories: those that are defined at the federal government level, including oil by-products (6%), electricity fees (3.3%), telephone and postal services fees (3%) and the minimum wage (3%); and those that are defined at local government level, including water and sewage fees (1.5%), public transportation (6%) and property taxes (1%).[13] Taken together, these components account for around 25% of the IPCA, reflecting their importance in daily expenditures of households in the income bracket from one to forty times the minimum wage. It is important to stress that “managed” does not mean “controlled”. Public utility fees constitute a substantial component of these prices. Their adjustment leaves no room for discretion; they follow the terms of their concession contracts. This links them to the past behaviour of general price indices and thus justifies the designation of “institutionally backward-looking prices”. The minimum wage, in turn, is set by Congress. The central government has effective direct control only over the wholesale prices of oil by-products, and it has been resetting them in accordance with international prices, in anticipation of the full liberalisation of the domestic oil market scheduled for 2002.

5.1 Description of main shocks and corresponding policy behaviour

We identified a total of eight shocks between July 1999 and November 2000, including a wide variety of supply and “financial” shocks. The supply shocks were primarily associated with food market conditions and backward-looking prices, which include the effects of international oil prices. The financial shocks mainly derived from increased international volatility and deterioration of the market perception of Brazil’s risk premium, which immediately alters the exchange rate value. Seven out of eight are classified as adverse shocks, to the extent that their preponderate effect was to press inflation upward. The taxonomy is somewhat dubious, given the fact that the economy is generally hit by more than one shock at the same time. Disentangling the combined effects of simultaneous shocks is somewhat arbitrary, as is associating monetary policy decisions with individual shocks.

The Brazilian economy in this period was far from its long-run balance, particularly with regard to the level of nominal and real interest rates. This means that in the absence of shocks, the interest rate would be expected to follow a declining path. Therefore, when policy reacted by keeping the interest rate constant, this actually represented a policy tightening and not an accommodative stance.

Table 1 summarises the main shocks that hit the Brazilian economy in the first 18 months of inflation targeting.

[13] These figures are approximations, given that the actual weights vary over time.

Table 1
Main shocks and policy reaction

	Type of shock	Timing	Description	Reaction
1	Backward-looking prices (BLP)	Jul 1999	BLP higher than expected by the market; oil price	Interest rate reduced from 22% to 21%
2	BLP	Jul/Aug 2000	BLP accompanied by adverse oil and food prices	Interest rate held constant at 16.5%
3	Food prices	Jun 2000	Inflation much lower than expected in the first half	Interest rate reduced from 18.5% to 17.5%
4	Financial	Aug 1999	Disagreement with monetary policy, increased hedging demand	Interest rate held constant at 19.5%
5	Financial	Oct 1999	Inflation above expectations; trade deficit; concerns about pass-through and Y2K-related capital outflows	Interest rate held constant at 19%; net international reserve floor reviewed
6	Financial	Apr/May 2000	International stock market volatility; oil price upsurge; robustness of fundamentals	Interest rate held constant at 19%
7	Financial	Nov 2000	Oil price; Argentina	Interest rate held constant at 16.5%
8	Oil prices	Dec 1999	Concerns about tightening abroad, oil price evolution and BLP for 2000; unexpected rise in food prices	Interest rate held constant at 19%; foreign exchange auctions

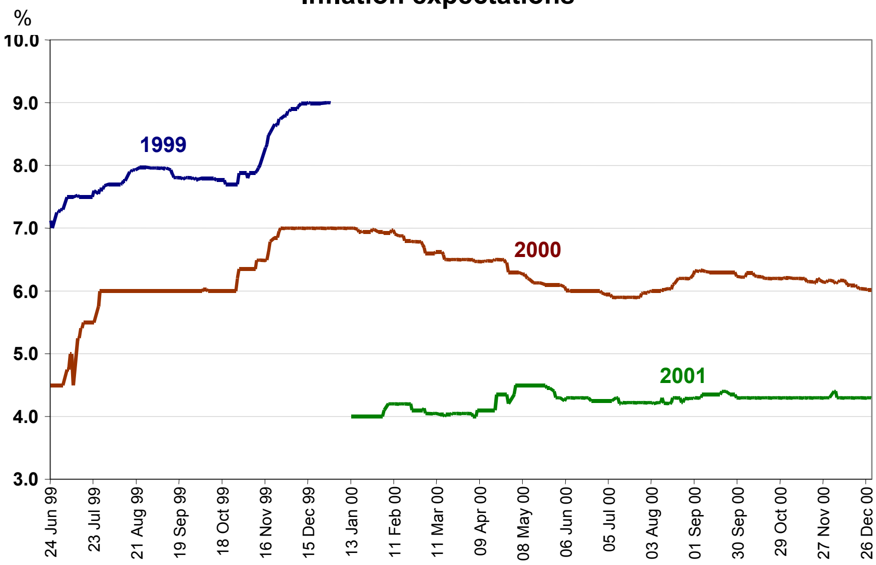
The shocks that we classify as “backward-looking prices” (BLP) stem from the annual resetting of public utility fees (including electrical energy, telecommunications, and water and sewage) that occurs at the beginning of the third quarter in most of the 11 cities covered by the IPCA.[14] A great part of these services were privatised in the late 1990s, and their price adjustment follows contracts linked to the past variation of general price indices. The first shock (number 1 in Table 1) is considered so because market participants did not anticipate it correctly. After the inflation figures for July 1999 were released, inflation expectations rose by one full percentage point (see Figure 5). However, Copom had been taking this temporary inflation rise into consideration since the first issue of the BCB’s *Inflation Report* (June 1999). The Committee decided to reduce the basic interest rate, since forecast year-end inflation was very close to the targeted level.

When the second BLP shock (number 2) occurred one year after the first, it was fully anticipated. Throughout the previous three quarters, monetary policy decisions had been explained to the public as aiming to counter possible second-round effects of this expected rise in backward-looking prices. However, this shock coincided with two other adverse developments. First, the domestic price of oil by-products was raised as a result of a new upsurge in international prices. Second, bad weather conditions throughout the country pushed food prices strongly upward. Consequently, the inflation forecast for the year was revised upward, and the interest rate was held constant. At the time, evidence from previous episodes (for example, in the last quarter of 1999) indicated that the effects of supply shocks vanish quickly once they are recognised as temporary, and they seem to have little impact on inflation expectations. This low price inertia was confirmed with the substantial decline in inflation that was observed in September and October 2000 (see Figure 3).

[14] Other managed prices, like the minimum wage, oil by-products and urban bus fares, are not necessarily readjusted at the beginning of the third quarter.

Figure 5

Inflation expectations[1]



[1] Median of market expectations for year-on-year IPCA inflation.

Source: Investor Relation Group - BCB.

The food price shock (number 3) was the only positive supply shock in the covered period.[15] It consisted of a gradual reduction in food prices that began in February 2000, but became stronger only in May and June. Thus, although this shock was identified early, the presence of other shocks in April and May concealed its effect on inflation expectations. The external uncertainties were attenuated in late June and the inflation forecast was revised downward with the positive influence of food prices, allowing a 1 percentage point reduction in the basic interest rate.

The shocks we denominate as "financial" comprise four episodes featuring considerable shifts in financial market perception of risks, which led to an increased difference between medium- and short-term interest rates, as well as to changes in the value of the exchange rate. These financial shocks reflect both the market reaction to monetary policy stance and changes in risk premium motivated either by domestic fundamentals or by external developments.

The first of these shocks (number 4), which hit the economy in August 1999, stemmed from a combination of factors. First, as shock number 1 caused market inflation expectations to rise sharply in July, the pace at which the BCB was reducing the interest rates was seen as too rapid (see Figure 5). Second, the level of external uncertainties was rising fast, mainly because monetary tightening in the United States had generated concerns that financing for the Brazilian private sector would be inadequate, especially towards the end of the year. Also, for the first time since the Gulf war, oil prices became a serious concern, together with their potential inflationary impact on Brazil. This caused a continuous depreciation of the real, and the demand for hedging instruments against further devaluation rose. Monetary policy response was twofold. First, hedge demand was matched by increased placement of dollar-indexed liabilities, since private market instruments were not available in appropriate amounts.[16] Second, the interest rate was held constant, interrupting the sequence of reductions initiated in mid-March 1999 (see Figure 4). The interest rate level was thought to be sufficient to take care of inflationary pressures through the aggregate demand channel. If expectations had deteriorated further, however, then the pass-through could have endangered the achievement of the year target, making a tougher policy response advisable. The strategy was successful, as

[15] Positive here means that it contributed to bringing inflation down.

[16] These dollar-indexed bonds are not foreign debt, as they are payable in domestic currency, even though their face value is adjusted according to the current exchange rate at maturity. The share of these bonds in total public domestic debt had been declining gradually since January 1999.

expectations improved: fiscal policy delivered better results than targeted, observed inflation fell until September, and sovereign risk perception started a continuous decline that ended only in April 2000.

In October the foreign exchange market experienced a liquidity shrinkage that coincided with a concentration of amortisation payments of private sector debt (shock number 5). Moreover, the trade deficit was not recovering at the expected velocity and there were mounting concerns that Y2K fears would trigger capital outflows by the end of the year. These factors brought about renewed pressure on the exchange rate. The policy reaction this time was of a different nature, aimed at coping with the temporary liquidity shortage expected for the upcoming weeks. The measures included lowering the floor on net international reserves (NIR) - a performance criterion in the IMF agreement - by around USD 2 billion; issuing new sovereign bonds; and arranging a loan from the Inter-American Development Bank (IADB). In early December, the BCB structured two forward foreign exchange auctions, in which it would sell a certain amount of dollars at the end of December and repurchase the same amount at the beginning of January, thereby eliminating doubts about possible currency shortages arising from Y2K problems. The strategy was instrumental in improving confidence and, as a result, capital inflows expected only for the next year were anticipated.

Shock number 6 is a good example of how robust domestic fundamentals can withstand the harmful effects of high external volatility. It started in April 2000 with the strong asset price correction in international markets, combined with a new upsurge in oil prices and an additional rise in the US federal funds rate. As in all other recent cases of increased external uncertainty, the risk premium was the first variable to adjust to the new conditions. Inflation expectations did not deteriorate, however. Expectations even improved somewhat, as the domestic macroeconomic outlook presented no fundamental misalignment and the food price shock kept current inflation low. The foreign exchange market adjusted itself smoothly, without any intervention. There was no perceptible increase in hedging demand, and the maximum exchange rate variation was less than 7% during the period April-May (see Figure 4). Copom held the interest rate constant in this period, but it clearly signalled in the minutes from the April meeting that the real interest rate would decline as soon as the external uncertainties had been mitigated.

This brief description of the Brazilian experience shows that there is no unique prescription for how monetary policy should react to shocks. Similar events may demand different responses because the overall economic conditions should be taken into account. Inflation targeting in Brazil was subject to serious tests right from start. For example, the oil price shock, which pervaded this entire period with an intensity not seen since the 1980s, led to a substantial rise in domestic fuel prices, which more than doubled in less than a year. Nonetheless, inflation was kept within target in 1999 and 2000.

5.2 Monetary policy response: theoretical and empirical evidence

This section presents impulse response functions to different shocks and compares them to the actual reaction of monetary policy to supply and financial shocks. The results are summarised in Figures 6-9.

We suppose that the economy can be described by the four-equation system presented in Section 3: the IS curve specification is given in equation (I), the augmented Phillips curve in equation (II), and the exchange rate dynamics in equation (IV). To complete the model, we assume that the interest rate is set by the BCB with the objective of minimising the following loss function:

$$\min_{\{i\}} L_t = \sum_{j=1}^{T} \rho^j \left[\omega_\pi D_{t+j} \left(E_t \pi_{t+j} - \pi^*_{t+j} \right)^2 + \omega_h \left(E_t h_{t+j} \right)^2 + \omega_i \left(\Delta i_{t+j} \right)^2 \right]$$

This loss function is a weighted average of the squares of the deviation of expected inflation (π) from the target (π^*), of the expected output gap (h) and of the nominal interest rate variation. The weighted average is discounted by a factor ρ (0<ρ<1). *D* is a dummy variable that equals one in the last quarter of each year and zero otherwise; it characterises the fact that the Bank is concerned only with year-end deviations of realised inflation from the established target.

We assume that the economy starts from a steady state equilibrium and is hit by shocks of one standard deviation, whose magnitudes are 0.3 percentage points for supply (equation (II)), 0.45 percentage points for demand (equation (I)), and 5 percentage points for financial shocks (equation (IV)).

As standard models would predict (see Clarida et al (1999)), demand shocks require the largest reaction. Figure 6 shows that demand shocks lead to the highest nominal interest rates during the first six quarters. Supply and financial shocks lead to very similar reactions, despite the fact that the financial shock is almost 10 times as large as the supply shock. This can be explained by the fact that the reaction of monetary policy to financial shocks is mainly through its effect on inflation, with a negligible influence on the output gap. Since the pass-through from exchange rate variations to inflation is about 10%, the final impact of a financial shock on inflation is approximately the same as the supply shock, which suggests that a similar reaction is appropriate for both cases.

The real interest rate presents a different response pattern. It increases in the first period after a demand shock, but it decreases in the first period after supply and financial shocks. In other words, right after the economy is hit by the latter two shocks, the optimal response of the BCB is to increase nominal interest rates by a lower amount than the increase in inflation, thus bringing about an initial reduction in real interest rates. In the following periods, however, real interest rates rise above equilibrium, putting inflation into a sine wave convergence path to its steady state value. Figure 7 shows that the deviations of real interest rates from equilibrium after supply and financial shocks are usually higher than those observed after demand shocks. The counterpart to this finding is a more stable path for the output gap following supply and financial shocks, as shown in Figure 9. The accumulated deviations of the output gap, measured by the area between the impulse response curve and the horizontal axis, can be interpreted as the sacrifice ratio. After one year, the accumulated deviation of the output gap is 0.83 for demand shocks, 0.14 for supply shocks and 0.12 for financial shocks; the long run values are 0.73, 0.04 and 0.03 respectively.

One should not expect the real economy to replicate the behaviour of an impulse response function, since it is awkward to identify and isolate the effects of individual shocks. However, an analysis of Figure 10 reveals some similarities between the actual behaviour of nominal interest rate and inflation and the prediction of the impulse response functions. Only supply and financial shocks occurred after the devaluation of the *real* in early 1999, as described in Section 5.1.

It is interesting to examine the shocks that hit the economy in the second half of 1999. The exchange rate depreciated by 10% from the second to the third quarter of that year; backward-looking prices increased 8% in the third quarter and 3% in the last quarter; and food inflation reached 5.6% in the last quarter. In the face of such supply shocks, the BCB kept the nominal interest rate constant for almost six months. Given the prevailing out-of-equilibrium environment, this procedure was equivalent to an increase in the nominal interest rate when the economy is in steady state. It took from two to three quarters for the nominal interest rate to resume its downward trajectory, as in the impulse response cases.[17] The behaviour of real interest rates was also consistent with the predictions of the impulse responses; despite the "increasing" nominal interest rate in the first period (fourth quarter 1999), there was a contemporaneous reduction in the real interest rate. In the following quarter, however, the real interest rate did rise. Finally, as predicted, inflation increased in tandem with the shocks, but it declined faster than expected; in the first quarter of 2000, IPCA inflation was already below the target value for the year, if expressed in annualised terms.

[17] The overnight rate was lowered from 21% to 19.5% in July 1999, and it remained constant until October, when it was reduced by 0.5 percentage points. The overnight rate was not lowered again until March 2000, this time to 18.5% (see Figure 4).

Figure 6
Impulse response of nominal interest rate

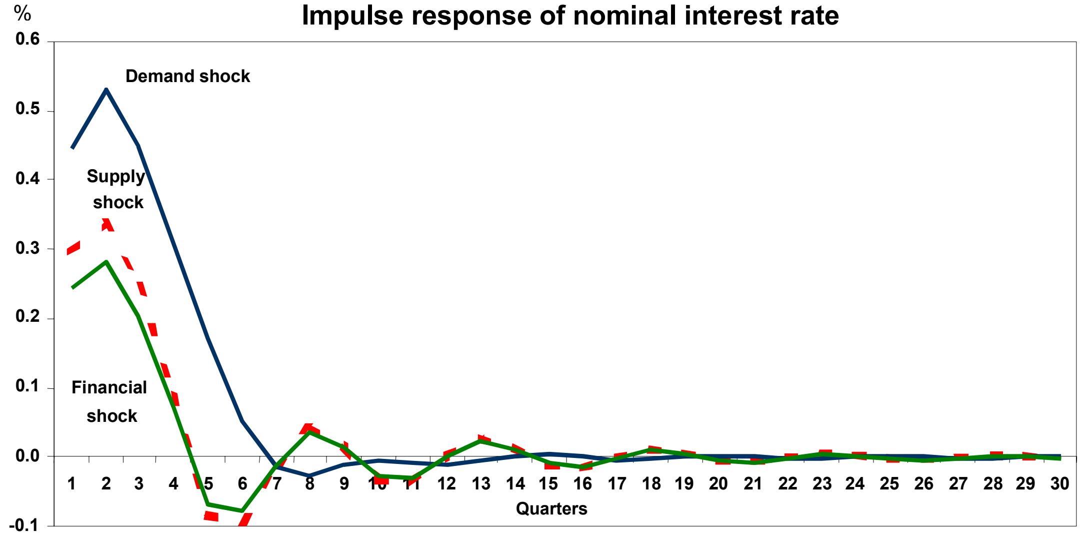


Figure 7
Impulse response of real interest rate

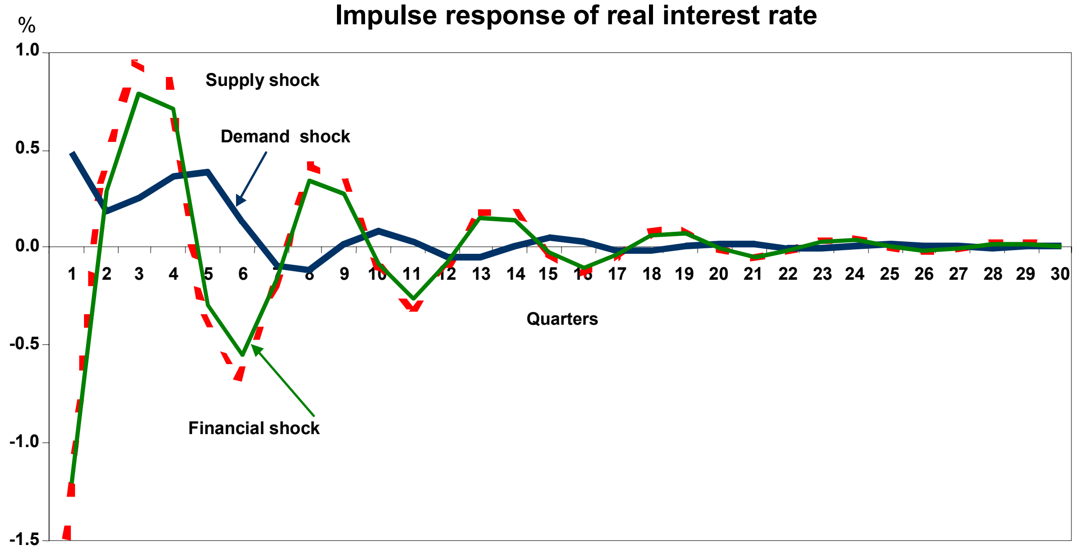


Figure 8
Impulse response of inflation

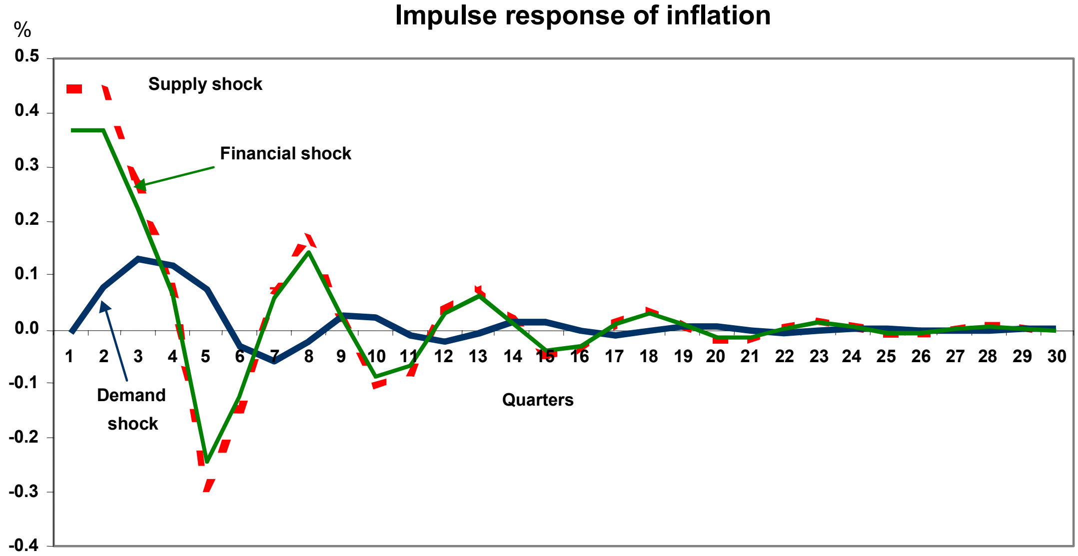


Figure 9
Impulse response of output gap

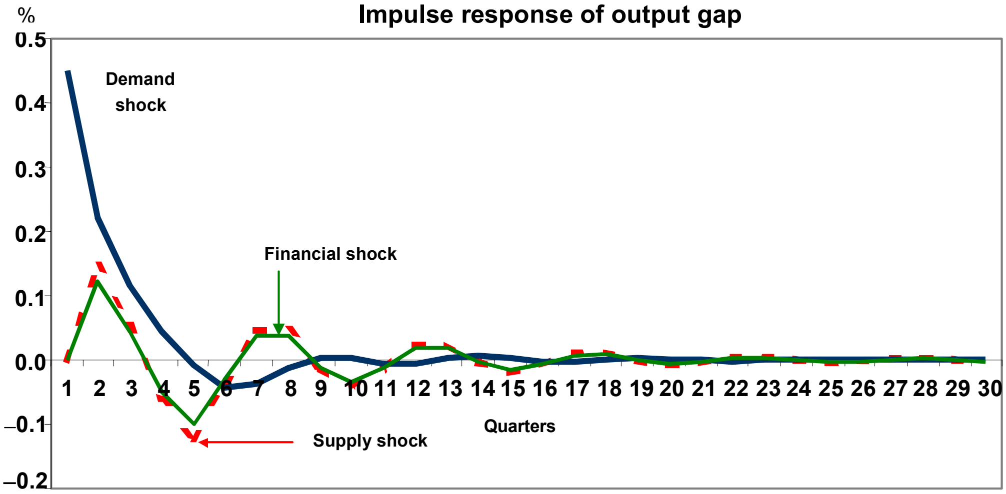
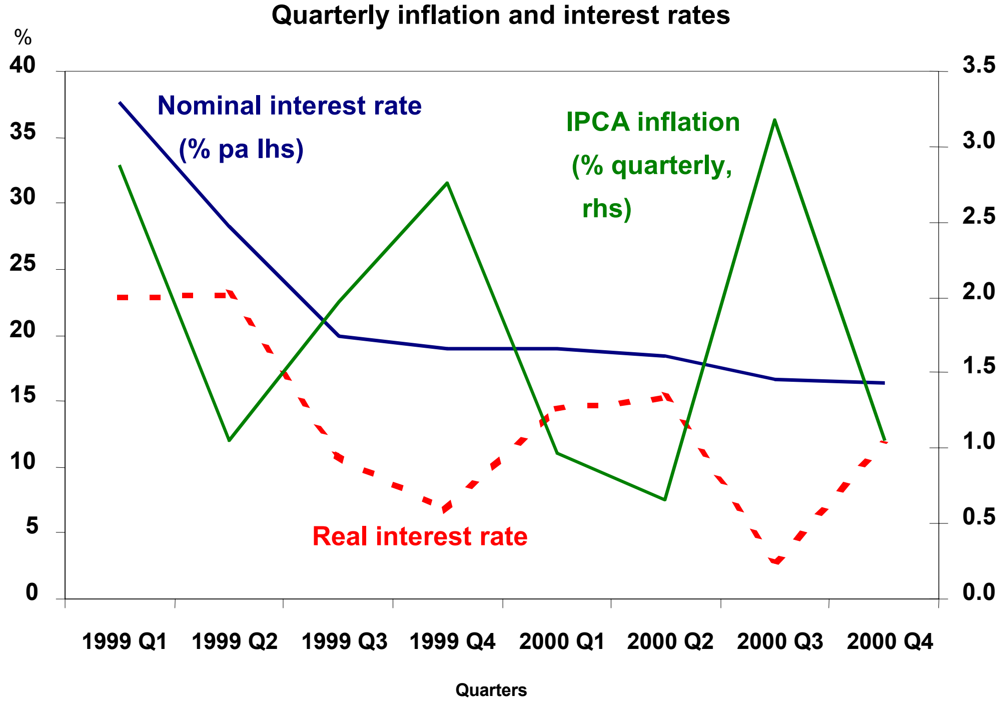


Figure 10
Quarterly inflation and interest rates



5.3. Inflation targeting and backward-looking prices

In the Brazilian framework, the inflation target is set for the annual variation of the IPCA, a consumer price index in which the weight of backward-looking prices is approximately 25%. This particularity poses an additional challenge for monetary policymaking, since backward-looking prices are insensitive to interest rate decisions.

The most important items with regard to backward-looking prices are public utilities, fuel, public transportation and the minimum wage.[18] The adjustment of these prices follows several rules. To respect contractual clauses, increases in utility fees are generally based on past inflation as measured

[18] In the IPCA, the minimum wage variation corresponds to the full variation of the "Domestic Employee" category, whose weight is around 3%.

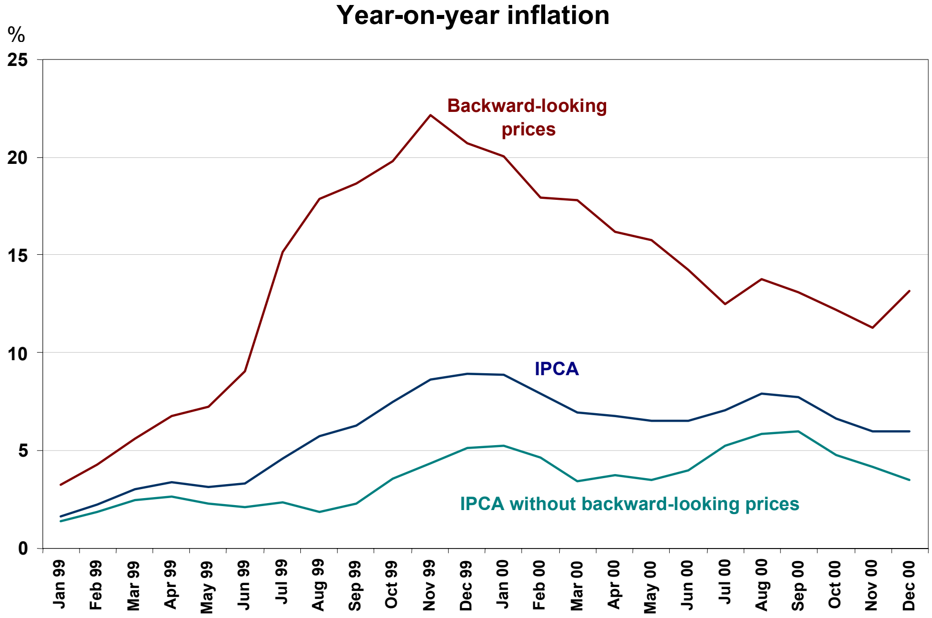
by the general price indices. Prices of gasoline and oil by-products tend to increase in accordance with the exchange rate and international oil prices. Finally, the annual adjustment of the minimum wage is not defined by formal rules, but the political discussion in Congress usually starts from past consumer price inflation.

The group of backward-looking prices accumulated a 36.6% increase in 1999-2000, while other prices in the economy rose only by 8.8%. Figure 11 shows the evolution of headline IPCA inflation, along with a breakdown of the behaviour of backward-looking prices and the remaining prices. Because the targets are set for headline IPCA inflation, the behaviour of backward-looking prices clearly imposes an important restriction on monetary policy; real interest rates need to be high in order to keep the forward-looking prices at levels below the inflation target.

To quantify the influence of backward-looking prices on monetary policy decisions, we simulate the behaviour of monetary policy from 2000 to 2002, assuming that the economy starts from the initial conditions that prevailed at the end of 1999. We then compare this behaviour using different assumptions about the weight of backward-looking prices in the IPCA and about their adjustment rules. The results of the exercises are based on the four-equation model presented in Section 3. The only difference is that the Phillips curve is modified to take explicit account of backward-looking prices in explaining inflation.

Figure 11

Year-on-year inflation



The estimation of the Phillips curve is based on the following system:

$$p_t = \omega \cdot p_t^m + (1-\omega) \cdot p_t^{bl} \tag{5.1}$$

$$z_t \equiv e_t + p_t^* \tag{5.2}$$

$$p_t^m = \delta \cdot w_t + (1-\delta) \cdot z_t \tag{5.3}$$

$$w_t - w_{t-1} = \psi \cdot E_{t-1}\pi_t + (1-\psi)\pi_{t-1} + \kappa \cdot h_{t-1} \tag{5.4}$$

All variables are expressed in logarithms, p stands for the price level, w for wages, h for the output gap, e for the nominal exchange rate, the superscript m for market goods (that is, goods and services whose prices are free to adjust to market conditions), and the superscript bl for backward-looking prices.

Equation (5.1) establishes that consumer prices are a weighted average of market and backward-looking prices. Equation (5.2) defines the variable z as international prices (p^*) expressed in terms of the domestic currency. Note that the exchange rate, e, is the number of units of domestic currency needed to buy one unit of foreign currency, such that an increase in e means a depreciation of the domestic currency. Equation (5.3) is the price equation for market goods. Such prices are a weighted average of international prices and domestic wages. Equation (5.4) defines the wage dynamics, which depend on expected inflation, past inflation and the output gap. The restriction that the coefficients of expected and past inflation sum to one guarantees the verticality of the Phillips curve.

After differentiating equations (5.1) and (5.3) and substituting equations (5.3) and (5.4) into equation (5.1) we get the reduced-form Phillips curve:

$$\pi_t = \omega \cdot \delta \cdot \left[\psi \cdot E_{t-1}\pi_t + (1-\psi)\pi_{t-1} + \kappa \cdot h_{t-1}\right] + \omega(1-\delta)\Delta z_t + (1-\omega)\pi_t^{bl}\ . \tag{5.5}$$

The estimated coefficients presented the expected sign, and all were significant at conventional values. Wald tests also showed that the reduced-form coefficients were statistically different from zero at conventional significance levels.

Varying the value of ω, the weight of market prices in the consumer basket, generates a family of Phillips curves. We now define the "market inflation equation" as the Phillips curve that results when $\omega = 1$. Otherwise, we refer to the "headline inflation Phillips curve". Before comparing the two curves, it is necessary to model backward-looking prices. By assumption, they are a weighted average of past inflation and external price variation:

$$\pi_t^{bl} = \beta \cdot \pi_{t-1} + (1-\beta)\Delta z_{t-1}\ . \tag{5.6}$$

Table 2 shows the difference between the estimated coefficients of the market and headline inflation equations for different values of β. The degree of inertia, measured by the estimated coefficient of past inflation in the reduced form, depends positively on the value of β. When β increases, headline inflation shows stronger persistence, as evidenced by a larger coefficient of π_{t-1}, while for $\beta = 0$, market inflation is more lag dependent. The exchange rate pass-through is smaller for market inflation only if $\beta = 1$. Finally, as expected, the sensitivity of inflation to the output gap is larger in the absence of backward-looking prices ($\omega = 1$). In this case, the transmission mechanism of monetary policy through the aggregate demand channel is relatively efficient.

Table 2

Difference between headline and market inflation coefficients

Variable	**Headline inflation coefficient minus market inflation coefficient**		
	$\beta = 1$	**$\beta = 0.5$**	**$\beta = 0$**
$E(\pi)$	– 0.073	– 0.073	– 0.073
π_{t-1}	0.086	0.017	– 0.052
h	– 0.031	– 0.031	– 0.031
$\Delta z_t + \Delta z_{t-1}$	– 0.012	0.056	0.125

A more reactive monetary policy is expected under strong inertia, as in the case $\beta = 1$, since the level of interest rate needed to reduce inflation by any amount is higher than in the case of weak inertia. On the other hand, since monetary policy is relatively inefficient in this environment and the BCB's loss function is assumed to include output gap and interest rate smoothing, monetary policy should not react strongly to deviations of inflation from the target, as Clarida et al (1999) point out. Henceforth, we refer to these two factors as inertial and efficiency effects. Since they work in opposite directions, it is not possible to tell a priori in which case the BCB would be more aggressive.

Based on the equations for headline and market inflation, we ran simulations with the assumption that the economy starts from the initial conditions that prevailed at the end of 1999 and that the BCB chooses the interest rate path (from 2000 to 2002) to minimise the loss function presented in Section 5.2:

$$\min_{\{i\}} L_t = \sum_{j=1}^{T} \rho^j \left[\omega_\pi D_{t+j}\left(E_t\pi_{t+j} - \pi_{t+j}^*\right)^2 + \omega_h\left(E_t h_{t+j}\right)^2 + \omega_i\left(\Delta i_{t+j}\right)^2\right] \tag{5.7}$$

Tables 3 and 4 display the results of the simulations under two alternative rules for the adjustment of backward-looking prices, that is different values of β. The first column in Table 3 presents the baseline case of year-end market inflation, generated from simulations using the estimated coefficients of the Phillips curve (ω = 1). The remaining columns show how the baseline results change in the presence of backward-looking prices, when their weights in the Phillips curve are restricted to 13% and 20%. These columns exhibit the difference between the cases of headline and market inflation for three variables: year-end inflation, and yearly averages of nominal and real interest rates. Finally, Table 4 shows the differences in results that arise when we simulate a faster disinflation; that is, instead of pursuing inflation targets of 6%, 4% and 3.5% from 2000 to 2002, the BCB would need to meet targets of 5%, 3% and 2.5%.

For 2000 and 2001, when the degree of inertia is the highest (β = 1), the inertial effect dominates the efficiency effect. Nominal and real interest rates would have to be about ½ percentage point higher in the case of the headline inflation Phillips curve than in the case of the market inflation Phillips curve. The difference in interest rates would have to be even greater if the weight of backward-looking prices increased from 13% to 20%. This pattern is reversed for 2002, however: nominal and real interest rates are smaller under headline inflation than under market inflation.

We attribute this result to the offsetting nature of the inertial and efficiency effects. To achieve the target in 2000, inflation should be reduced by 2.9 percentage points, which is the difference between observed inflation in 1999 (8.9%) and the 6% target for 2000. For 2001, inflation would have to be reduced by 1.55 percentage points in the market inflation case. For 2002, however, the disinflation effort is significantly smaller, at 0.55 percentage points for market inflation. The inertial effect thus dominates the efficiency effect when annual disinflation is high. The figures in Table 4 are consistent with this interpretation. When disinflation is faster, the interest rate difference between headline and market inflation rises to 1.10 percentage points in 2000 and 0.61 percentage points in 2001, implying a stronger inertial effect.[19]

Table 3

Effect of backward-looking prices

Period	Market inflation ω = 1	Difference between the cases of headline and market inflation					
		β = 1			β = 0		
		Inflation	Interest rate		Inflation	Interest rate	
			Nominal	Real		Nominal	Real
Weight of backward-looking prices = 13% (ω = 0.87)							
2000	5.55	– 0.03	0.55	0.55	– 0.27	– 1.59	– 1.22
2001	4.05	0.16	0.58	0.39	0.03	– 0.50	– 0.52
2002	3.64	0.03	– 0.15	– 0.18	– 0.10	– 0.68	– 0.55
Weight of backward-looking prices = 20% (ω = 0.80)							
2000	5.55	– 0.01	0.93	0.90	– 0.32	– 2.39	– 1.93
2001	4.05	0.24	0.80	0.52	– 0.02	– 0.95	– 0.89
2002	3.64	0.01	– 0.37	– 0.36	– 0.18	– 1.05	– 0.83

[19] A faster disinflation allows the BCB to set relatively lower nominal interest rates. In the model, this results from the fact that a smaller target for inflation would also reduce inflation expectations and, hence, current inflation. Since the optimal real interest rates are higher, a faster disinflation still implies a tighter monetary policy.

Table 4

Effects of a faster disinflation (ω = 0.87)

Period	Market inflation			Headline inflation β = 1			Headline inflation β = 0		
	Inflation	Interest rate		Inflation	Interest rate		Inflation	Interest rate	
		Nominal	Real		Nominal	Real		Nominal	Real
2000	– 0.97	– 0.56	0.50	– 0.98	0.06	1.10	– 1.15	– 1.75	– 0.45
2001	– 0.95	– 0.85	0.19	– 0.79	– 0.24	0.61	– 0.88	– 1.04	– 0.07
2002	– 0.97	– 0.89	0.12	– 0.95	– 1.10	– 0.10	– 1.04	– 1.32	– 0.22

It is more difficult to compare the case of headline inflation with β = 0 with the baseline market inflation case. The higher pass-through may slow the reduction in interest rates, given the inflationary effects of the consequent exchange rate depreciation. On the other hand, the case of β = 0 presents a relatively small degree of inflation inertia and a reduced efficiency of monetary policy, which encourages the BCB to cut interest rates aggressively. According to Table 3, the balance of all these factors favours a faster reduction in interest rates when the Bank faces a headline inflation Phillips curve with β = 0.

6. Monitoring inflation targets under an IMF programme

This section focuses on alternative ways of assessing the monetary policy stance in inflation targeting countries that have an ongoing programme with the IMF. Brazil was the first country to adopt inflation targeting while a financial support programme was under way. This raised some important issues with regard to assessment. The usual performance criterion on net domestic assets is not adequate for an inflation targeting regime, because it harms transparency and may induce unnecessary monetary movements.

We compare the behaviour of inflation, the output gap and interest rates under alternative criteria to evaluate the monetary policy stance, which may be more suitable for an inflation targeting country. We first describe four accountability alternatives:

I) Year-end inflation target. This is the original inflation targeting framework in Brazil. The Ministry of Finance sets the year-end target and the tolerance bands two years in advance. The current targets are 6%, 4% and 3.5% for 2000, 2001 and 2002 respectively, and the BCB is considered successful in achieving the target if actual year-end inflation falls within a ±2 percentage point band around the target.

II) Quarterly inflation targets set by a linear convergence rule, as established in the fourth review of the current agreement with the IMF. According to this criterion, 12-month inflation for each quarter should equal the value obtained by linear interpolation of the adjacent year-end targets. For example, given the 6% and 4% year-end targets for 2000 and 2001, the target path from the first to the third quarter of 2001 should be 5.5%, 5% and 4.5%. A potential problem with this criterion is the fact that shocks in a given year contaminate the quarterly 12-month inflation figures of the following year, and force the monetary authority to react unnecessarily to such shocks.

III) Quarterly inflation targets that take into account the actual outcomes observed in the previous year. Whereas the previous alternative outlines a quarterly target path based on year-end targets, this criterion is based on the actual inflation figures of the previous year. In logarithm terms, this target is set according to the formula below:

$$\tilde{\pi}^*_{T,i} = \sum_{\substack{j=i+1 \\ i<4}}^{4} \pi_{T-1,j} + \frac{i}{4}\pi^*_T$$

where $\tilde{\pi}^*_{T,i}$ is the 12-month inflation target for quarter *i* in year *T*; $\pi_{T-1,j}$ is the actual inflation observed in quarter *j* in year *T*-1; and π^*_T is the inflation target for year *T*. The target for the first quarter of a year would be the actual inflation observed in the last three quarters of the previous year, plus a quarter of the inflation target for the current year; the target for the second quarter would be actual inflation observed in the second half of the previous year, plus half of the inflation target for the current year; and so on. The target path should be reset at the beginning of each year, once the previous year's inflation is known. This criterion overcomes one of the major drawbacks of alternative II, namely the fact that shocks in a given year contaminate monetary policy decisions in the following year, irrespective of the effects such shocks have on inflation. Both criteria, however, have the potential drawback of increasing the frequency of monetary performance evaluation from yearly to quarterly.

IV) A Taylor-type rule.

The starting point of the analysis is to assume that the BCB sets the nominal interest rate *i* to minimise the loss function:

$$\min_{\{i\}} L_t = \sum_{j=1}^{T} \rho^j [\omega_\pi D_{t+j}(E_t\pi_{t+j} - \pi^*_{t+j})^2 + \omega_h (E_t h_{t+j})^2 + \omega_i (\Delta i_{t+j})^2] \tag{6.1}$$

subject to:

$$\pi_t = \alpha_1 E_t \pi_{t+1} + \alpha_2 \pi_{t-1} + (1-\alpha_1-\alpha_2)\Delta(e_t + \pi^f_t) + \alpha_3 h_{t-1} + \varepsilon_{\pi,t} \tag{6.2}$$

$$h_t = \beta_0 + \beta_1 h_{t-1} + \beta_2 (i_{t-1} - \pi_{t-1}) + \beta_3 \theta_{t-1} + \varepsilon_{h,t} \tag{6.3}$$

$$\Delta e_t = \Delta i^f_t + \Delta x_t - \Delta i_t + \varepsilon_{e,t} \tag{6.4}$$

$$\Sigma = \begin{bmatrix} \sigma^2_\pi & \sigma_{\pi,h} & \sigma_{\pi,i} \\ \sigma_{\pi,h} & \sigma^2_h & \sigma_{h,e} \\ \sigma_{\pi,i} & \sigma_{h,e} & \sigma^2_e \end{bmatrix} = \begin{bmatrix} \sigma^2_\pi & 0 & 0 \\ 0 & \sigma^2_h & 0 \\ 0 & 0 & \sigma^2_e \end{bmatrix}. \tag{6.5}$$

Equation (6.1) is the loss function already discussed in Section 5.2. The value of the dummy variable, *D*, varies according to the alternative chosen. For alternative I, in which the BCB cares only about year-end inflation, *D* equals one in the last quarter of each year and zero in all other quarters. Under alternatives II and III, *D* equals one in all quarters, meaning that monetary policy should be evaluated every quarter.

Equations (6.2) to (6.4) are the constraints of the minimisation problem; they form a small structural macroeconomic model along the lines presented in Section 3. Condition (6.5) assumes a diagonal variance-covariance matrix. Additionally, the error terms are assumed to be independent and identically and normally distributed. The calibrated values for the standard errors were 0.5 percentage points for output gap, 0.3 percentage points for inflation, and 5 percentage points for the exchange rate.

To run stochastic simulations, we assumed that the BCB minimises the loss function taking into consideration eight periods ahead, with a discount rate of 1% (ρ = 0.99). This horizon might be considered relatively short by international standards, but it is a reasonable hypothesis for the Brazilian economy, which is characterised by a higher level of uncertainty, given that it is still in transition to its steady state inflation level. Furthermore, evidence shows that optimising periods beyond eight quarters does not yield gains in terms of efficiency in the output-inflation variability locus (see Freitas and Muinhos (2001)). Finally, this optimisation horizon is also in line with the *Inflation Report*, which releases the forecasts of inflation up to two years ahead.

In the stochastic simulations, we assumed that at the beginning of quarter *t*, when the interest rate is set, the BCB knows the realisation of all variables up to *t*-1, but does not know the shock. The results presented in Table 5 were obtained after 150 simulations. We performed the simulations as if the economy were at the beginning of 2000. All variables took their actual values as initial conditions, except for the output gap, which was set to zero at the end of 1999. This modification in the initial conditions regarding the output gap allows us to concentrate on the contamination effect described in alternative II above, since IPCA inflation in 1999 was 0.9 percentage points above the target.

Finally, the simulations for alternative IV do not need the optimisation procedure, since with the Taylor-type rule the interest rate is simply set according to observed outcomes. The specification of the traditional Taylor rule is:

$$i_t = i_t^* + 1.5(\pi_{t-1} - \pi_{t-1}^*) + 0.5h_{t-1} \qquad (6.6)$$

where i is the annualised quarterly interest rate and i^* is the equilibrium nominal interest rate. To be consistent with the loss function, we introduced interest rate smoothing: the actual interest rate is the weighted average of the previous value of the interest rate and the one given by equation (6.6), with weights 0.60 and 0.40 respectively.

Table 5 shows that all alternatives lead to a level of expected year-end inflation that is well within the ±2 percentage point tolerance bands established in the Brazilian inflation targeting framework, despite the initial conditions (inflation was almost 1 percentage point above the target). Such results can be explained by the short lag of the transmission mechanism. Decisions regarding interest rates affect inflation contemporaneously through the exchange rate channel and take only two quarters to affect inflation through the aggregate demand channel. The output gap performance was also good, in the sense that it stayed within a band of ±1 percentage point during most of the period for all alternatives.

Table 5

Results of the stochastic simulations

Year	Q	12-month inflation				Output gap				Nominal interest rate				Std dev of inflation			
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
2000	**1**	8.28	8.26	8.27	8.14	1.05	0.98	1.05	1.04	20.2	20.5	21.0	24.9	0.51	0.50	0.53	0.56
2000	**2**	8.65	8.63	8.54	8.28	1.16	1.12	1.10	0.77	20.5	20.9	21.7	33.2	1.53	1.50	1.44	1.26
2000	**3**	7.62	7.59	7.49	7.19	0.77	0.65	0.62	–0.62	20.1	20.1	20.9	30.4	1.24	1.22	1.12	0.98
2000	**4**	**6.03**	**5.99**	**5.91**	**5.66**	**0.23**	**0.25**	**0.13**	**–1.50**	**19.0**	**18.4**	**19.0**	**20.3**	**0.60**	**0.55**	**0.53**	**0.72**
2001	**1**	5.22	5.22	5.14	4.89	0.06	0.09	0.01	–1.10	17.6	16.6	17.7	13.3	0.56	0.63	0.61	0.89
2001	**2**	5.11	5.12	5.11	4.72	0.01	0.19	–0.03	–0.25	15.9	14.9	16.1	13.4	0.68	0.67	0.67	0.74
2001	**3**	4.94	5.01	4.98	4.55	–0.02	0.18	–0.09	–0.07	14.2	13.3	14.4	14.7	0.82	0.87	0.83	0.81
2001	**4**	**4.29**	**4.40**	**4.29**	**3.95**	**–0.19**	**0.04**	**–0.31**	**–0.35**	**12.7**	**11.8**	**12.5**	**13.5**	**0.69**	**0.74**	**0.71**	**0.84**
2002	**1**	3.61	3.64	3.57	3.57	–0.37	–0.17	–0.41	–0.50	11.0	10.3	10.6	9.3	0.61	0.68	0.61	0.87
2002	**2**	3.28	3.33	3.31	3.48	–0.35	–0.14	–0.34	–0.14	9.4	8.9	9.1	8.4	0.79	0.73	0.75	0.84
2002	**3**	3.39	3.47	3.44	3.57	–0.21	0.04	–0.10	0.07	7.9	7.7	7.9	8.7	0.65	0.62	0.67	0.80
2002	**4**	**3.58**	**3.69**	**3.66**	**3.57**	**–0.05**	**0.18**	**0.01**	**–0.09**	**6.8**	**6.8**	**6.9**	**9.1**	**0.60**	**0.65**	**0.66**	**0.89**

Year	Q	Std dev of output gap				Prob ($\pi - \pi^* > 1$ pp)				Prob ($\pi - \pi^* > 2$ pp)			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
2000	**1**	0.45	0.41	0.47	0.46	3.0	3.3	7.3	9.3	0.0	0.0	0.0	0.0
2000	**2**	0.52	0.52	0.55	0.61	67.0	72.7	66.0	43.7	13.0	10.7	10.0	8.7
2000	**3**	0.56	0.56	0.54	0.64	50.5	52.0	45.3	30.0	5.5	4.7	2.0	4.3
2000	**4**	**0.57**	**0.57**	**0.57**	**0.76**	**11.0**	**7.3**	**5.3**	**17.0**	**0.0**	**0.0**	**0.0**	**0.3**
2001	**1**	0.59	0.64	0.58	0.95	7.0	10.0	10.7	25.3	0.0	0.7	0.0	1.3
2001	**2**	0.66	0.65	0.53	0.96	14.0	11.3	12.7	20.0	0.0	0.7	0.0	0.0
2001	**3**	0.65	0.57	0.54	1.06	22.5	27.3	23.3	21.3	0.5	1.3	0.7	1.7
2001	**4**	**0.59**	**0.63**	**0.58**	**1.05**	**13.0**	**20.0**	**14.7**	**24.0**	**0.5**	**0.0**	**0.7**	**0.7**
2002	**1**	0.65	0.64	0.62	1.08	10.0	15.3	9.3	22.0	0.0	0.0	0.0	2.3
2002	**2**	0.66	0.57	0.66	1.12	20.5	14.7	17.3	22.3	1.0	0.7	0.7	1.3
2002	**3**	0.58	0.57	0.65	1.19	12.0	10.7	13.3	20.0	0.5	0.0	0.0	1.0
2002	**4**	**0.58**	**0.59**	**0.60**	**1.15**	**9.5**	**14.0**	**12.0**	**22.7**	**0.0**	**0.0**	**0.7**	**2.7**

(i) Alternative I: original Brazilian inflation targeting framework, with targets set only for year-end inflation. (ii) Alternative II: quarterly inflation targets set by a linear convergence rule. (iii) Alternative III: quarterly target path based on the actual inflation figures of the preceding year. (iv) Alternative IV: use of a Taylor-type rule. (v) The standard deviation of inflation refers to deviations from the target, not from the mean. Since there is no quarterly target defined for alternative I, the standard deviation was estimated using the target set for alternative II.

It is difficult to rank the alternatives by looking only at the variability of inflation and output. Only the Taylor rule (alternative IV) yielded generally higher volatility for both inflation and output. The figures for the other three alternatives do not prompt clear-cut conclusions, either because the qualitative pattern is not stable or because the differences in standard deviations are small. The results presented in Table 6 were calculated from the loss function for alternative I (in which only year-end inflation rates matter). The performance of the Taylor rule[20] was clearly the worst, while alternatives II (linear target path) and III (target path based on the previous year's outcomes) yielded a relative loss of approximately 15%.

Table 6

Absolute and relative losses

	Alternatives			
	I	II	III	IV
Loss	0.85	0.99	0.97	5.29
Relative loss (%)	–	16.20	14.00	521.40

The similar performance of the first three alternatives is a surprising result. We expected alternative I to present a visibly better performance for year-end inflation, because it ignores inflation outcomes in the first three quarters of the year, while alternative II was expected to yield the worst outcome, since it forces monetary policy to react to large deviations of inflation from the target in the previous year. The presence of output gap and interest rate variation in the loss function in all quarters may have contributed to making the three alternatives more similar. Another possible explanation is related to the backward-looking component of inflation. To meet the year-end inflation target, the monetary authority needs to put a high weight on the inflation outcomes of the interim quarters. Therefore, the effect of changing the accountability frequency may have been mild.

These findings, however, do not imply that the BCB should be indifferent in choosing among the first three alternatives. If the Bank is in fact concerned only with the year-end accumulated inflation, then setting a quarterly target path for inflation is not likely to severely alter the behaviour of macroeconomic variables. Should monetary policy be evaluated on a quarterly basis, however, there is a high probability that unnecessary false alarms would be triggered in the course of the year. In the context of the current agreement, an informal consultation with the IMF is triggered if inflation deviates from the target path by more than 1 percentage point, and a formal consultation is required if the deviation exceeds 2 percentage points. The probability of inflation deviating from the target by more than 1 percentage point falls significantly as the year progresses (see Table 5). This is a particularly delicate issue for an emerging economy, because false alarms may trigger a confidence crisis and thus make the conduct of monetary policy more difficult. A compromise solution to this problem would be to increase the tolerance interval for the first three quarters of the year; this would preserve the quarterly accountability frequency while reducing the probability of triggering false alarms.

7. Conclusions

The relative success of economic policy in Brazil since the 1999 devaluation stems from a variety of factors, including the initial macroeconomic conditions, strong international support, and the inflation targeting regime that provided an adequate and timely anchor for expectations. The most important factor, however, was the long-awaited fiscal reversal, which was a necessary (but obviously not sufficient) condition for the sustainability of the inflation targeting framework.

Despite the huge devaluation in early 1999, the year ended with single digit consumer price inflation, which fell within the target set by mid-year, and with near 1% GDP growth, which was well above the

[20] It is possible, however, that the performance of the Taylor rule could dramatically improve if a different set of parameters were chosen.

preliminary prospects. Inflation behaviour showed a very low pass-through, which can be in part attributed to the output gap in the period, the overvalued *real* just before the float, and the low initial inflation. The inflation targeting regime guided expectations in line with the multi-year disinflation targets, allowing the relative price realignment after the devaluation to be processed without igniting overwhelming pressures on consumer prices.

However, the large swing in relative prices poses some idiosyncratic challenges for the monetary authority. The evolution of backward-looking prices is of particular concern. Such prices correspond to around 25% of the IPCA and increased by 36.6% in 1999-2000, while all other prices taken together rose by only 8.8% in the same period.

The results of simulations using different assumptions regarding the adjustment rule and the weight of backward-looking prices in the IPCA show that when the adjustment of these prices is based on past inflation, the degree of inertia increases and forces the BCB to be more restrictive in order to disinflate the economy. Nominal and real interest rates are 0.5 to 1 percentage point higher when the Bank faces a Phillips curve with backward-looking prices. When inflation is closer to its steady state value, however, the presence of administered prices in the IPCA does not alter the behaviour of monetary policy significantly.

We presented a brief description of the Brazilian experience showing how monetary policy has reacted to different shocks. In the inflation targeting period, all the shocks that hit the economy propagated their effects mainly through the supply side and financial markets. Although the shocks displayed some common features, such as rising oil prices, the rapidly changing overall economic conditions demanded different responses.

We confronted the theoretical policy prescriptions with estimated impulse responses to different kinds of shocks in a simple empirical model. As expected, the results showed that a central bank should be fairly restrictive when countering aggregate demand shocks, but it should partially accommodate supply and financial shocks by contemporaneously increasing nominal interest rates while allowing real interest rates to fall. Real interest rates eventually rise with the subsequent fall in inflation. This pattern, suggested by the impulse response functions, was observed in recent episodes in Brazil. When facing supply and financial shocks in the last two quarters of 1999, the BCB kept nominal interest rates constant at a level above long-run equilibrium and allowed real interest rates to fall. With inflation under control, real interest rates rose again in the following quarter, and the Bank resumed the trend of reducing interest rates.

Finally, the paper addressed the issue of how to monitor inflation targeting under agreements with the IMF. We used a simple structural model to show that, except in the case of a Taylor rule, the behaviour of relevant macroeconomic variables does not change significantly when the frequency at which monetary policy is evaluated increases from yearly to quarterly. However, a central bank should not be indifferent when choosing between year-end accountability only and quarterly monitored accountability such as that established in recent Brazilian agreements with the IMF. The reason is simple: if the relevant macroeconomic variables are initially out of equilibrium, then the probability of meeting the target by year-end may be high, while the probability of breaching the tolerance bands in the intermediate quarters is also high. Monitoring quarterly inflation figures under such circumstances can send unnecessary false alarms, introducing unwarranted noise into the conduct of monetary policy by affecting expectations.

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Price and wage inflation in Chile

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Abstract

Price and wage equations based on a model of imperfect competition were estimated using data from 1986:1 to 2000:4. From the estimations we can conclude: (i) as expected, productivity reduces unit labour costs and inflation and increases real wages; (ii) the findings of other studies are confirmed in the sense that the output gap and unemployment have a low impact on inflation due to widespread indexation; (iii) inflation imposes substantial costs on firms and workers; (iv) the exchange rate pass-through depends positively on economic activity and the inflation level, explaining why pass-through has been so low in recent years. Since inflation has been stabilised at around 3%, pass-through should be permanently lower than in the 1990s.

The estimation includes the first difference of the dependent variable following the literature on the estimation of linear quadratic adjustment cost (LQAC) models when the target and some of the driving variables follow I(2) processes. Given that it is a markup model, the price index fitted is narrower than the CPI to reflect the fact that these prices are formed where there is monopolistic competition. In order to model wages, we assume that a fraction of wages is negotiated, while the other fraction is adjusted according to past inflation. The nominal wages negotiated are determined following the theory of efficiency wage and bargaining model. The equations are used to generate out-of-sample inflation forecasts closer to actual inflation than before.

1. Overview

This article estimates equations for price and wage inflation using Chilean data from 1986:1 to 2000:4. Several issues crucial for understanding and anticipating the behaviour of inflation - which are at stake in the Phillips curve - motivate such estimation, for instance: (i) elasticity of inflation to the output gap, (ii) the permanent and cyclical movements of markups, (iii) effects of labour productivity growth on inflation, (iv) credibility, indexation and rationality, and (v) the size of the exchange rate pass-through.

Even though we touch on all these subjects in this paper, we take a closer look at the effect of exchange rate changes on domestic inflation because apparently this factor has substantially changed in recent years. Despite the fact that Chile is a small open economy, exchange rate pass-through has been low recently. In fact, there has been significant peso depreciation since 1997 without a strong impact on inflation. Why is this? Is a low pass-through a new permanent characteristic of the Chilean economy? Will the depreciation impact on inflation take place as soon as demand takes off again? The answer to these questions is crucial to defining monetary policy.

In order to tackle at least part of this research agenda, we present below a model of the Phillips curve based on some microfoundations and time series econometrics. Thus, we address these issues by estimating a structural equation for price inflation that considers explicitly a model of staggered nominal price setting by imperfectly competitive firms. In doing this, we use the quadratic price adjustment cost model of Rotemberg (1982), where the representative firm chooses a sequence of prices for solving its intertemporal problem. As a result, inflation can be represented as an error correction equation (Euler equation), relating this variable to expected inflation as well as to the gap between the "equilibrium" and actual price level.

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The views expressed in this paper are those of the authors and should not be attributed to the Central Bank of Chile. We would like to thank Pablo García, Esteban Jadresic and seminar participants at the Bank for International Settlements and the Central Bank of Chile for their comments and suggestions.

In addition, an I(2) analysis of inflation and the markup is undertaken. We find that the price level is best described as an I(2) process. To deal with I(2) processes, we incorporate inflation as an additional component of the "equilibrium" price in the Euler equation (Engsted and Haldrup (1999)). Having this variable in the cointegration equation reflects the existence of a long-run relationship between markups and inflation. In the estimations this relationship is negative, which may be interpreted as the cost to firms of overcoming missing information when adjusting prices in an inflationary environment (Banerjee et al (2001)). Different versions of the price equation are estimated (Gruen et al (1999)) by using a limited-information approach due to McCallum (1976).

Since there is a clear connection between prices and wages, we also estimated a model to explain wage dynamics. The model assumes that a fraction of wages is negotiated every period, while the other fraction is adjusted according to past inflation (Jadresic (1996)). The negotiated nominal wages are determined following the theory of efficiency wage and bargaining model. Thus, expected real wages depend on labour productivity, unemployment and past real wages (Blanchard and Katz (1997)). In order to incorporate the fact that nominal wages are also I(2), we included the inflation rate as a cost for workers when wages are negotiated. Since indexation is never perfect, the higher the inflation level, the lower real average wage each period.

The results show, as expected, that labour productivity reduces unit labour costs and inflation. In addition, a negative relationship between inflation and both markups and real wages indicates that inflation imposes substantial costs on firms and workers, fully justifying the stabilisation programme followed by the Central Bank since 1990. Moreover, the results confirm what was found in other studies in the sense that the output gap and unemployment have a low impact on inflation due to widespread indexation. Therefore, a gradual monetary policy is perfectly adequate in this case.

Finally, since pass-through is related to economic activity and the level of inflation, it should be smaller than in the 1990s given that the level of inflation has been stabilised at around 3%. Taking the estimated price and wage equations simultaneously, the exchange rate pass-through is analysed by simulating an exchange rate shock, with and without output gap. Had not a negative output gap existed after 1997, exchange rate pass-through would have been higher.

This article is organised as follows. The second section shows several stylised facts and introduces some imperfect-competition theoretical frameworks for the Phillips curve and the exchange rate pass-through. The third presents the markup model for prices. The next section has a wage model based on indexation, efficiency wage and bargaining models. The fourth section presents the estimations for the price and wage equations. Finally, there are some conclusions and policy recommendations.

2. Inflation: stylised facts and theoretical considerations

Figure 1 shows that inflation has had a positive correlation with the output gap and foreign inflation (considering the depreciation rate as well). Meanwhile, inflation has a negative correlation with labour productivity growth. The strong relation between price and nominal wage inflation indicates the key role indexation plays in the Chilean economy. In addition, it is important to point out that there is a negative correlation between inflation and the markup.[2] This reveals that, contrary to what we initially expected, in periods of higher inflation it is much harder for firms to increase the markup.

The negative correlation between real wages and inflation also indicates that workers suffer substantial costs from the latter, expressed in lower real wages. Furthermore, both labour productivity and unemployment are important in wage setting. As seen in Figure 1, both variables have a strong correlation with real wages but with different signs.

These graphs seem to indicate that there is a Phillips curve with a small slope while other variables, such as labour productivity and foreign inflation, also play an important role in explaining inflation.

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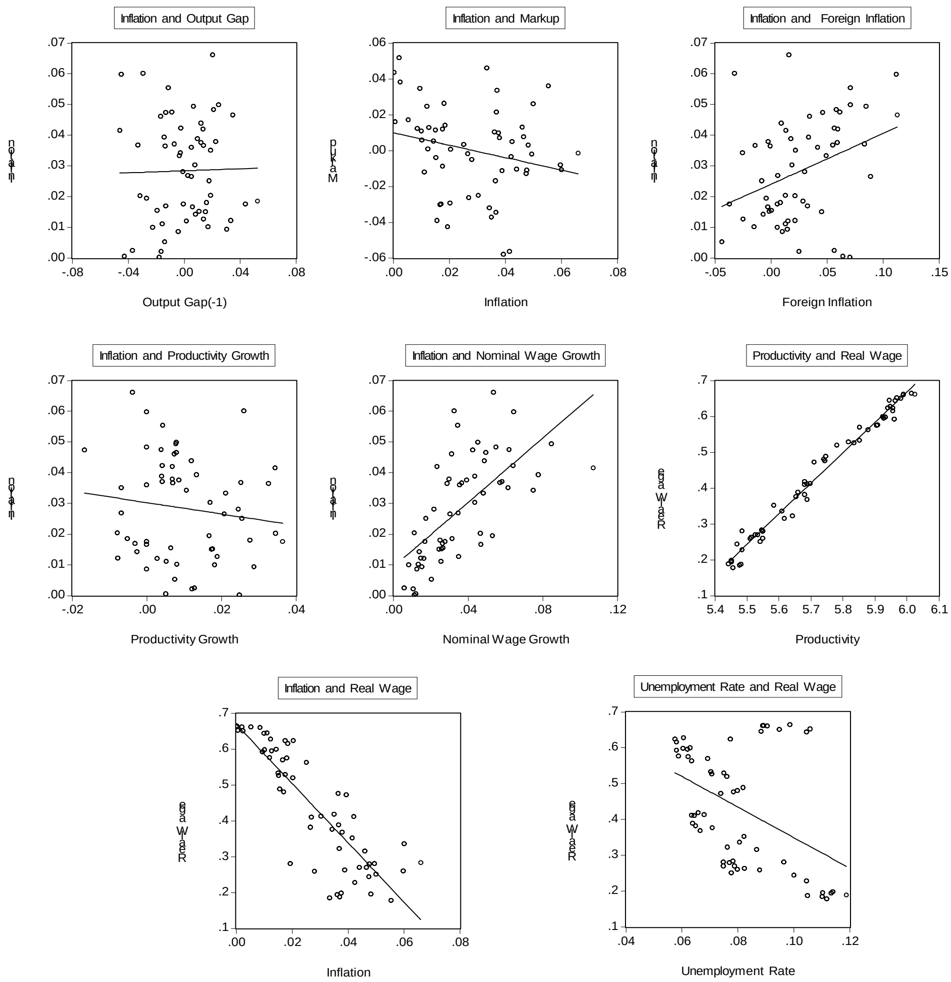
[2] Markup is obtained as the error term of the equation $p_t = a_0 + a_1(w_t - q_t) + a_2 p^*_t + \varepsilon_t$. p_t is the price level, w_t is the nominal wage and p_t^* is the foreign price (adjusted for the exchange rate, tariffs and taxes).

Figure 1

Inflation in Chile: stylised facts



2.1 Phillips curve

A convenient and widely used setup to describe the behaviour of the short-run trade-off between the change in inflation and output is an expectations-augmented Phillips curve like the one shown in equation 1.

$$\pi_t = \beta_1 * \pi_{t-1} + \beta_2 * E\pi_{t+1} + \beta_3 * \Delta_4 ep^* + \beta_4 * gap + \beta_5 * \Delta mk_t + \beta_6 * R_t + \varepsilon_t \tag{1}$$

where $E\pi_{t+1}$ = expected inflation, $\Delta_4 ep^*$ = annual imported price inflation, *gap* = output gap, Δmk = mark-up, *R*=raw materials, supply shocks or relative price changes (Romer (1996), Ball and Mankiw (1995)).

Equation 1 is also useful to summarise some of questions, already mentioned above, in which we are interested, since the coefficients are associated for instance with: (i) β_1: inertia and β_2: how forward-looking price formation is; (ii) β_3: the size of the exchange rate pass-through; (iii) β_4: elasticity of inflation to the output gap; (iv) β_5: the effect of markups on inflation; (v) β_6: effects of raw material shocks on inflation.[3]

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[3] β_1 and β_2 coefficients are usually restricted to add up to 1.

Similar versions or variations of equation 1 have been estimated for Chile (García et al (2000)). Nonetheless, it is useful to pursue further research on Phillips curves since, first, there is uncertainty about the β parameters, second, they do not have a structural interpretation and, finally, some of those equations have consistently overpredicted Chilean inflation during the recent past.

We will follow a different approach: instead of estimating a reduced-form relation between the change in inflation and the unemployment rate, we will estimate separate price and wage equations based on a model of imperfectly competitive firms in error correction form. Thus, the error correction in the price equation ensures that in the steady state the price level is a markup on unit labour costs.

Besides the issues cited above, estimating price and wage equations will also allow us to say something about the relationship between labour productivity and inflation, and the effects inflation has on markups and wages. The non-competitive setting is also appropriate to analyse the low exchange rate passthrough experienced in recent years. Obtaining the right size of this coefficient is instrumental in implementing an appropriate monetary policy. In the next section, we introduce the non-competitive theoretical framework by relating the exchange rate pass-through to markups and imperfect competition.

2.2 Pass-through from depreciation to inflation

i. Theory

Although the exchange rate directly affects the peso price of imported goods, this movement is not necessarily transferred to the end consumer immediately. When this transfer occurs and to what degree depends on several factors, some of which are described below.

As said above, the impact of changes in the exchange rate on domestic inflation is known as the "pass-through coefficient". The direct short-term effect of the exchange rate on inflation is related to the imported part of the basket of goods that make up the CPI. The larger the share of imported goods within the CPI basket, the greater the exchange rate effect on prices. In Chile, about 48% of CPI goods are considered importable. The exchange rate also directly affects the cost structure of companies using imported inputs. Thus, the greater the proportion of imported inputs making up the costs, the more depreciation will affect these companies' prices. In a regime based on inflation targets, pass-through ultimately depends on monetary policy and agents' expectations. Although in the short-term inflation may rise due to depreciation, in the medium- and long-term inflation should fall back to the target level or range defined by the central bank.

The behaviour of demand determines whether or not companies can transfer to final prices any changes in their costs resulting from fluctuations in the exchange rate. For example, if the economy is in the midst of a recession, companies will find it difficult to pass on higher costs due to depreciation. Furthermore, movements in the exchange rate can influence both the level of aggregate demand and wages as well as the composition of demand. For instance, a depreciation in the exchange rate that tends to produce a contraction in aggregate demand could also end up reducing prices by an amount equivalent to the upward pressures generated by the same depreciation.

Currency devaluation brings with it a change in relative prices. Assuming that income is constant, when the prices of imported goods rise, consumers' real income falls. If demand for these imported goods is inelastic, the purchase of other goods and services will have to fall and, as a result, so will the prices of the latter, assuming that prices are perfectly flexible. However, prices are often rigid due to market imperfections. In this case, faced with currency depreciation, CPI inflation will rise. This is why many pass-through analyses are based on aspects related to industrial organisation (Dornbusch (1987)). This analysis emphasises, for example, the degree of import penetration, market structure in terms of greater or lesser concentration, and the differentiation and degree of substitution between domestic and imported products.

A greater concentration in a productive sector increases the producing company's control over price and therefore over profit margins (markups). The same occurs if there is a small degree of substitution between the domestic and imported products. This degree of control over the price could vary with the cycle (Small (1997)). In these situations, producers evaluate the costs of modifying their prices and when these are higher than the benefits, they accept transitory fluctuations in their profit margins, causing prices to react less to shifts in the exchange rate.

As a result, in the presence of imperfect competition, aggregate demand movements, combined with fluctuations in the exchange rate, affect importers' markups. More volatile aggregate demand would be associated with a reduced pass-through of exchange rate fluctuations to final prices. In this case, importers will be less willing to raise their prices for fear of losing market share.

The entry of new firms could have an impact similar to a demand reduction. For instance, during the 1990s the retailing sector in Chile went through a restructuring process. Huge superstores and supermarkets distributing a wide variety of products proliferated. These megastores are usually able to reduce costs because of their ability to negotiate with suppliers. At the same time they fight for their market share by holding sales and introducing different marketing strategies. Sometimes these sales imply markup reduction, particularly when demand is weak.

The volatility of the exchange rate is another factor influencing transfers affecting domestic inflation. The more volatile the exchange rate, the less its impact on domestic prices should be, because importers will be more cautious when it comes to changing prices, especially when the costs of an adjustment are high. As a result, expectations about the duration of a currency depreciation affect the speed and size of pass-through of a higher exchange rate to prices.

The level of inflation also affects the pass-through coefficient. In general, the magnitude of the transfer should decrease as the annual inflation rate declines. In a low-inflation economy, the price change of a good is more easily perceived as a modification of relative prices, which has more impact on demand for the good and its market share. Thus, the cost of increasing prices could be high for a company if its market share plays a decisive role in its margins and total profits (Taylor (2000)).

International evidence indicates that the pass-through from the exchange rate to prices is lower in developed countries than in Latin America and Asia.[4] In one panel estimate with 71 countries, Goldfajn and Werlang (2000) found a depreciation-to-inflation pass-through coefficient of 0.73 at the end of 12 months. When the sample was divided into OECD members and emerging economies, at the end of 12 months pass-through coefficients of 0.6 and 0.91 respectively were observed. When this sample was sorted by region, the 18-month coefficient for Europe was 0.46, while in America it was 1.24. Finally, as a result of an exercise based on their estimates, the authors found a bias towards predicting higher inflation than that actually observed in several well known cases of large depreciation.

ii. Rolling correlation

The simplest exercise one can perform is to compute the correlation between inflation and exchange rate depreciation. In this case, two rolling correlation statistics were computed (Figure 2). The first (black line) has its start date fixed (1986:1) and the correlation coefficient is calculated each time a new observation is added, starting in 1990. Therefore, each computation has a larger sample than the last. Even though this coefficient is rather stable, it has some movement. It decreases at the beginning of the 1990s, grows again from 1994 to 1996 and has steadily fallen since 1998.

The second statistic in Figure 2 (grey line) has a fully moving sample. Thus, both the start and end dates move each time the correlation coefficient is computed. In this case, the statistics fluctuate much more. This coefficient moves closely in line with the first coefficient up to 1996. Thereafter, it falls dramatically to even become negative, showing an important change in the relationship between these two variables.

It is worth pointing out that such a simple exercise shows that decision-making based exclusively on the pass-through coefficient used in the small structural model, or based on the first correlation statistics computed, could lead to policy mistakes. One could easily overestimate forecast inflation, missing the significant change that took place from 1997 to 1999 in the relationship between inflation and currency depreciation.

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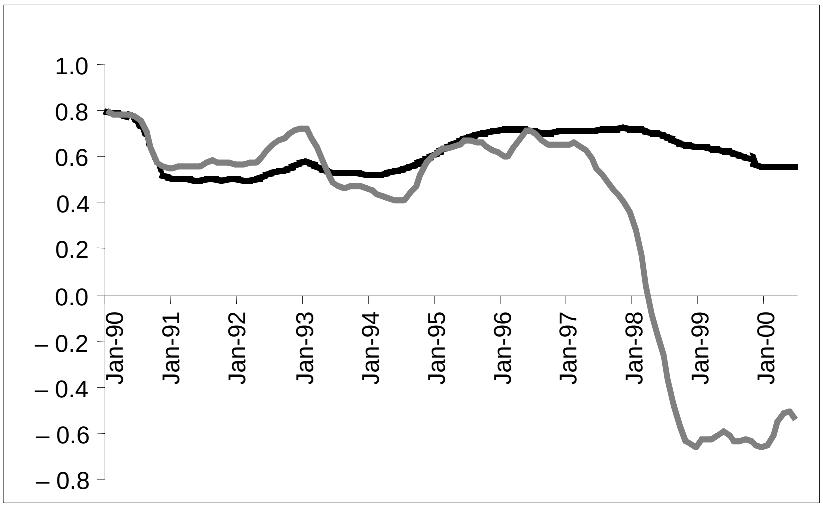
4 A great many articles have been written on pass-through over the years. Most of them try to estimate the extent to which exchange rate fluctuations are responsible for the behaviour of inflation. Some use CPI inflation, others producer price inflation. There is also a wide range of estimation techniques used to obtain a quantitative result, ranging from ordinary least squares (Woo (1984)), to panel data (Goldfajn and Werlang (2000)), vector auto regression (McCarthy (1999)), cointegration analysis and error correction models (Beaumont et al (1994), Kim (1998), Kim (1990)), and state-space models (Kim (1990)).

Figure 2

Rolling correlation coefficient between annual inflation and depreciation

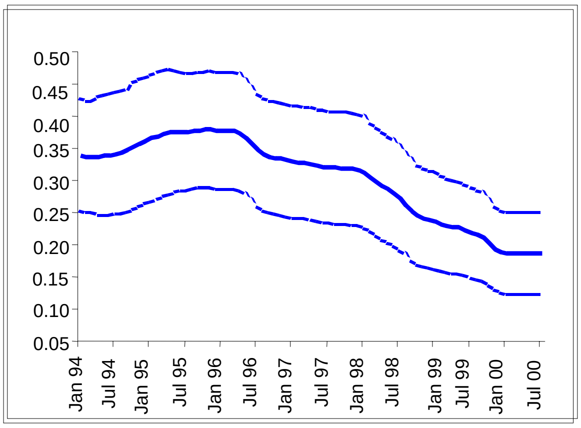


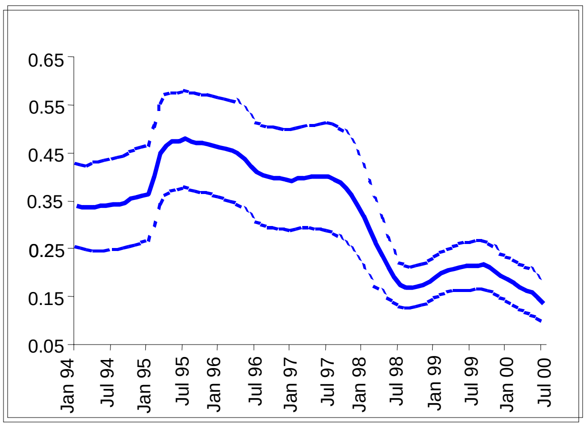
iii. Rolling regression and pass-through in a small model

A rolling regression was estimated for annual inflation with exchange rate depreciation and a trend as right-hand variables using monthly data between 1986 and 2000 (Figure 3).[5] Again, the two types of rolling samples were used. The left-hand panel in Figure 3 shows the regression coefficient obtained when the initial date of the sample does not change. Conversely, the sample used to estimate the right-hand panel in Figure 3 has both the initial and the last date moving. The left-hand panel of Figure 3 shows that the coefficient's fall started earlier in 1996. As one would expect, the coefficient is less stable with both dates moving.[6]

Figure 3

Rolling regression





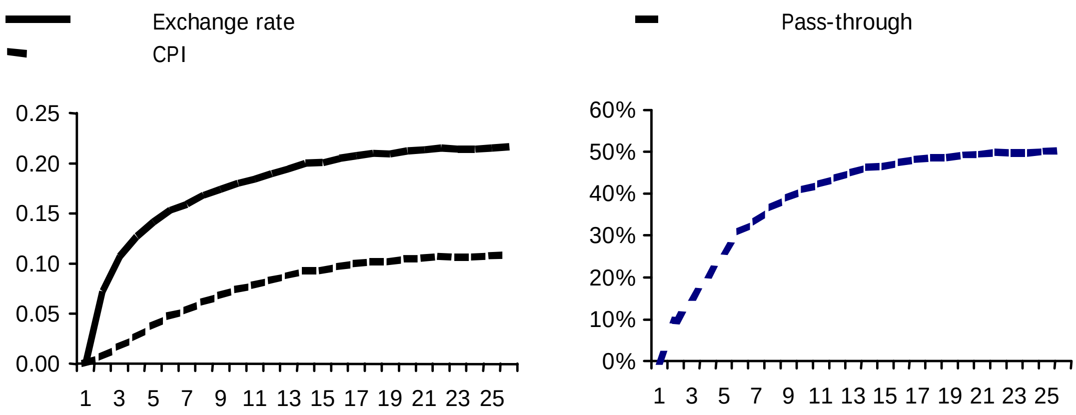
5 Annual CPI inflation was found to be trend-stationary using monthly data.

6 In fact, it matches some stylised facts of the economy during the last decade. It is well known that there was a consumption boom between 1995 and 1997, which coincides with a rebound of this coefficient.

Missing variables such as the output gap may cause the instability problem. We also simulated a (five-equation) small structural model, similar to the one in García et al (2000). The impact of the exchange rate on inflation is controlled by the output gap. The pass-through obtained with this simulation amounts to 50% over five to six years (Figure 4), meaning that the period over which the full impact of a depreciation is felt is rather long. However, Figure 4 shows that after the first three years most of the effect has already taken place. It is important to point out that this model includes a monetary rule consistent with the behaviour of a central bank in an inflation targeting regime. Therefore, it explains why pass-through is never complete in Figure 4.[7]

Figure 4

Pass-through in a small model



3. A price setting model

3.1 Optimal price in the long run

In this section, we derive a Phillips curve from the quadratic price adjustment cost model developed by Rotemberg (1982). Thus, firms weigh the cost of changing prices against the cost of being away from the price the firm would choose if there were no adjustment cost (Roberts (1995)). The latter price is called the "optimal price" and is determined following Beaumont et al (1994) and Layard et al (1991). The firms are identical and obtain an output *y* by using labour *l* and an imported input *z*:

$$y_i = a_1 + a_2 \, l_i + (1 - a_2) z_i \tag{2}$$

Each firm's demand is $y_d - f$, where f is the log of the number of identical firms. The demand curve faced by each firm would be:

$$y_{di} = -\eta \left(\tilde{p}_i - p \right) + y_d - f \tag{3}$$

where p_i is the firm's price, *p* is the price level and η is the elasticity of demand. Therefore, the price that maximises benefits in the long run is given by:

$$\tilde{p}_{di} = -\log \left[\frac{n}{n-1} \right] + MC = m + MC = m + a_1 + a_2 w_t + (1 - a_2) \, p_t^* \tag{4}$$

[7] Pass-through never reaches 100% because no traded good has a major share of all inputs and consumer goods.

where the price p_{di} is fixed by charging a margin *m* over the marginal cost *MC*.[8] A pricing model based on a markup over costs is inappropriate when applied to markets close to perfect competition like the ones for agricultural products (Woo (1984)). Since the price index to be explained should be the one reflecting monopolistic markets, core or underlying inflation, IPCX2, is used here.[9]

We now examine the margin. It is assumed that in the long term firms desire a constant markup, *m*. However, in the short run firms could postpone price adjustments and accept deviations of their markup from the desired level. In doing so, firms could be motivated by both market share and the actual cost of changing prices, or menu cost (Ghosh and Wolf (2001)). Therefore, demand fluctuations and anything affecting market power could have an impact on the markup (Barnerjee et al (2001)). On the other hand, margins and inflation may also be either positively or negatively related because there are two opposite effects. First, one would expect this coefficient to be positive since, as noted above, it is harder for employers to pass on cost increases to customers in a low-inflation environment (Taylor (2000)). In Taylor's words, "firms in low inflation economies will appear to have less pricing power than firms in high inflation economies". Second, one would also expect that inflation imposes costs on firms and therefore the markup net of inflation is reduced (Banerjee et al (2001)). We rely on the econometric estimation to determine its sign, ie which effect is greater.

We follow Banerjee et al (2001), Benabou (1992), Russell et al (1997) and others arguing that high inflation, which usually leads to higher volatility and uncertainty, is associated with lower markups. Therefore, we write the markup equation as a function of labour productivity, the output gap and inflation:

$$m = c_1 + c_2 q_t + c_3\left(y_t - \bar{y}_t\right) + c_4 \Delta p_t \tag{5}$$

Following Beaumont et al (1994) and Banerjee et al (2001), one can approximate equation 4 by this expression:

$$\tilde{p}_{di} = (a_1 + c_1) + a_2(w_t - q_t) + (1 - a_2)p_t^* + c_3\left(y_t - \bar{y}_t\right) + c_4 \Delta p_t \tag{6}$$

Where p* is equal to foreign input prices adjusted by the nominal exchange rate and taxes and $w_t – q_t$ is wages minus labour productivity (unit labour cost). Here we are imposing $a_2 = –c_2$, which implies that income shares are independent of the level of productivity in the long run. We drop the output gap from the long-run price equation (6) on the basis that it is a stationary variable with a zero steady state level. In the short run (12), markup depends on economic activity. However, economic theory is not conclusive regarding this issue and it could be either pro- or countercyclical. Therefore, this question should be solved empirically.[10]

3.2 Optimal price in the short run

The structural equation for inflation is in the spirit of the new Phillips curve literature. It is derived explicitly from a setting of imperfectly competitive firms where nominal prices are rigid. In doing this, we propose a (Rotemberg (1982)) LQAC model of the representative firm, which minimises the loss of charging for its product a different price from the optimal one weighted against the cost of changing its price. This intertemporal problem is solved by choosing a sequence of *pt*, the decision variable, such that:

$$\min_{\{p_{t+i}\}} E_t \sum_{i=0}^{\infty} \beta^i \left[\theta \left(p_{t+i} - \tilde{p}_{t+i}\right)^2 + \left(p_{t+i} - p_{t+i-1}\right)^2\right] \tag{7}$$

---

8 Note also that w_t can be separated into private (wpr_t) and public wages (wpu_t).

9 IPCX excludes perishable food as well as gas, fuels and regulated services. Throughout the article, we also call it core inflation.

10 The theory about the relationship between margins and the cycle is ambiguous. Some models predict procyclical margins (Kreps and Scheinkman (1983)). Others predict that they are countercyclical (Rotemberg and Saloner (1986), Rotemberg and Woodford (1991)).

where E_t is the expectations operator conditional on the full public information set, β is the subjective discount rate, θ is the relative cost parameter and $\tilde{p}_t$ denotes the optimal price of p_t. After rearrangement, the Euler equation from the minimisation problem can be written as:

$$\Delta p_{t+i} = \beta \Delta p^e_{t+i+1} - \theta \left[p_{t+i} - \tilde{p}_{t+i} \right] \tag{8}$$

Where Δp^e_{t+i+1} denotes expected inflation. One could think of it as an error correction equation relating the rate of inflation to the gap between the equilibrium and actual price levels. In order for this to be a useful theory of inflation, the optimal price level needs to be defined as in (6).

The second step is to reparameterise equation (8) to carry out the I(2) analysis. Following Haldrup (1995), the optimal price can be parameterised as:

$$\tilde{p}_t = \gamma_1 x_{1,t-1} + \gamma_1 \Delta x_{1,t} + \gamma_2 x_{2,t-1} + \gamma_2 \Delta x_{t-1} + \gamma_2 \Delta\, x_{2,t-1} + \gamma_2 \Delta^2 x_{2,t}$$

where x_1 denotes the I(1) variables $\{q_t, \Delta p_t\}$ while x_2 are the I(2) ones $\{w_t\}$.

Therefore we transform the optimal price:

$$\tilde{p}_t = (1-a_2) p^*_{t-1} + a_2 (w_{t-1} - q_{t-1}) + c_4 \Delta p_{t-1} + a_2 \Delta\, w_{t-1} + (1-a_2) \Delta p^*_t + a_2 (\Delta^2 w_t - \Delta q_t) + c_4 \Delta^2 p_t$$

Now we transform $\theta \left[p_t - \tilde{p}_t \right]$ to obtain the cointegration error correction term.

In order to do this, we add and subtract Δp_{t-1}, and we also use two identities $p_t \equiv p_{t-1} + \Delta p_t$ and $\Delta p_{t-1} \equiv \phi \Delta p_{t-1} + (1-\phi) \Delta p_{t-1}$ where $\phi = \dfrac{\beta}{1+\theta}$. Thus, equation (8) can be written in acceleration form:

$$\begin{aligned} \Delta^2 p_t &= k_1 (\Delta p_{t+1} - \Delta p_{t-1}) + k_2 (1-a_2) \Delta p^*_t + k_2 a_2 (\Delta^2 w_t - \Delta q_t) + \psi \left(y_{t-1} - \bar{y}_{t-1} \right) \\ &- k_2 \left(p_{t-1} - \left[(1-a_2) p^*_{t-1} + a_2 (w_{t-1} - q_{t-1}) + a_2 \Delta w_{t-1} + \left(c_4 + \frac{(1-\phi)(1+\theta)}{\theta} \right) \Delta p_{t-1} \right] \right) + \varepsilon_t \end{aligned} \tag{12}$$

Where $k_1 = \dfrac{\beta}{1+\theta(1-c_4)}$ and $k_2 = \dfrac{\theta}{1+\theta(1-c_4)}$

Even though the model is overidentified and we need to impose some restrictions to identify all parameters, the parameters β, γ_{12} and θ can be obtained from the same number of equations:

$$\hat{k}_1 = \frac{\beta}{1+\theta(1-c_4)}, \quad \hat{k}_2 = \frac{\theta}{1+\theta(1-c_4)}, \quad \hat{k}_3 = \hat{k}_2 * \left(c_4 + \frac{(1-\phi)(1+\theta)}{\theta} \right) \tag{13}$$

Where k_1, k_2 and k_3 are parameters obtained from the unrestricted estimations.

Equation (12) is what we refer to as the price equation. This equation relates inflation to expected inflation, wage growth, the output gap and average cost. In addition, there is an error correction term which ensures that in steady state the price level is set by adding a markup on the unit labour cost and imported-input prices. If one wants to obtain the expectations-augmented reduced-form Phillips curve, one should substitute $\Delta^2 w_t$ for a wage curve (Blanchard and Katz (1997) and Gruen et al (1999)).

Finally, it is important to note that expected inflation matters because prices are sticky. What happens with prices next period affects current prices. Note that expectations can be rational or adaptive. When expectations are rational, we will have a price curve similar to the New Phillips curve proposed by Galí (2000) and Roberts (1995). The inflation rate can jump. However, usually inflation shows a great amount of inertia.[11] This distinction is crucial when designing a successful stabilisation programme.

[11] In Chile, inflation is highly persistent to the extent that it is best described as being an I(1) process.

For example, in the case of sticky inflation a more gradual stabilisation programme is called for, in order to reduce the risk of causing a sharp fall in the rate of output growth.

3.3 Private wage equation

We have assumed that indexation is complete and there is uniform staggering in order to study wage behaviour. This implies that a proportion α of the wages is negotiated, while (1-α-δ) are adjusted according to past inflation (Jadresic (1996)). The remainders, δ, cannot adjust their wages with past inflation and suffer a loss with it.

$$\Delta wpr_t = (1-\alpha-\delta)\Delta\, p_{t-1} + \alpha\Delta x_t \tag{14}$$

The negotiated wages are set as in Blanchard and Katz (2001):

$$x_t - p^e_{t+1} = \mu b_t + (1-\mu)q_t - \beta u_t + \varepsilon_t \tag{15}$$

The expected real wage depends on the reservation wage b_t, labour productivity q_t and the unemployment rate u_t, where $0 \leq \mu \leq 1$. The reservation wage is related to non-labour income. However, Blanchard and Katz (2001) argue that labour productivity increases "in the informal and home production sectors are closely related to those in the formal market economy". Therefore, the reservation wage depends on past real wage and labour productivity.

$$b_t = a + \sigma(wpr_{t-1} - p_{t-1}) + (1-\sigma)q_t \tag{16}$$

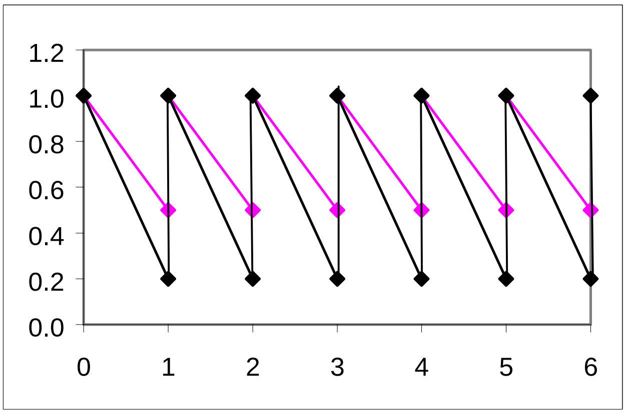
Substituting equation (16) into (15) and performing some algebra, we obtain equation (17):

$$\Delta x_t = \left[\, p^e_{t+1} - p_{t-1}\right] + \mu a - (1-\sigma\mu)(wpr_{t-1} - p_{t-1} - q_{t-1}) + (1-\sigma\mu)\Delta q_t - \beta u_t \tag{17}$$

where p_t is the consumer price level, which includes all goods,[12] and q_t is labour productivity.

Figure 5

Average real wage and inflation



By substituting equation (17) into equation (14) and performing a reparameterisation yields the aggregate wage acceleration:

$$\begin{aligned}\Delta^2 wpr_t &= \alpha\,\left[\Delta\, p^e_{t+1} - \Delta\, p_{t-1}\right] + (\Delta p_{t-1} - \Delta wpr_{t-1}) + \alpha\mu a - \alpha(1-\sigma\mu)(wpr_{t-1} - p_{t-1} - q_{t-1}) + \\ &\alpha(1-\sigma\mu)\Delta q_t - \alpha\beta u_t - \delta\Delta p_{t-1} + D_t + Z_t + \varepsilon_t\end{aligned} \tag{18}$$

12 Indexation is based on CPI.

where α, μ, λ and δ are all greater than zero. D_t represents variables such as seasonal dummies. Variables such as minimum wages and public wages are included in Z_t. Thus, in the absence of an adjustment cost, an increase in either the price level or labour productivity will cause an increase in the desired nominal wage. We have also incorporated the rate of inflation to consider the negative effect this variable has on real wages. Since indexation is never perfect, the higher the inflation level, the lower average real wage each period. This loss is equal to $\delta\Delta p$ (Figure 6).

Some parameters of interest can be obtained from this specification. For instance, the impact of unemployment on wage acceleration for workers who are changing their wage contracts can be calculated as $\alpha\beta$.

4. Results

We present here the estimation results. Instead of applying the two-step method proposed by Engle and Granger (1987) and Haldrup (1995), we estimated the long-run relationship together with the dynamics, as in equation 12, following Harris (1995).[13] As this author puts it, when estimating a long-run equation, superconsistency ensures that it is asymptotically valid to omit the stationary I(0) terms, however the long-run relationship estimates will be biased in finite samples (see also Phillips (1986)). Therefore, Harris cites Inder (1993) to conclude that in the case of finite samples, "the unrestricted dynamic model gives ... precise estimates (of long-run parameters) and valid t-statistics, even in the presence of endogenous explanatory variables". At the same time, it is also possible to test the null hypothesis of no cointegration.

In addition, an I(2) analysis of inflation and the markup is performed as in Haldrup (1995). We find that the levels of prices and unit labour costs are best described as I(2) processes.

4.1 Unit roots and cointegration

We begin the empirical section by testing the estimation variables for unit roots. Table 1 indicates that price level and wage are I(2). This confirms that the price equation can be estimated in acceleration form. In general, one can say that Chilean inflation deviates from any given mean in the period considered here. Moreover, Chilean inflation has traditionally been very persistent due to generalised indexation. In addition, variables such as the output gap and the nominal exchange rate are I(0) and I(1) respectively.

In order to test for cointegration, Phillips-Perron and Dickey-Fuller tests were applied to the residuals obtained in the regression: $p_t = c + \beta_1 w_t + \beta_2 q_t + \beta_3 p^*_t + \beta_4 \Delta p_t + \varepsilon_t$. The unit root is rejected at standard critical values.

However, when using I(2) variables the appropriate critical values are tabulated in Haldrup (1994). In this case, the Phillips-Perron statistic is high enough to reject the null hypothesis. On the other hand, the Dickey-Fuller statistic roughly matches the 10% Haldrup critical value (Table 2). We consider that with these results it is possible to reject the null of no cointegration, especially when the Z test is considered.

[13] Cf pp 60-61. See also Phillips and Loretan (1991) for a comparison of several one-step (uniequational) cointegration methods used to estimate long-run economic equilibria.

Table 1
Unit root test

Variables	Level	First differences[1]	Second differences[2]
Price	– 0.02	– 0.68[3]	– 2.92
Wage	1.13	– 2.68	– 8.56
Labour productivity	– 2.38	– 7.80	– 12.72
Nominal exchange rate	– 2.16	– 6.13	– 10.18
Foreign price	– 1.59	– 4.07	– 9.02
Output gap	– 4.26	– 5.40	– 9.87
Private unit labour cost	– 0.22	– 2.40	– 4.60
Public wage	0.72	– 1.00	– 7.00
Unemployment rate	– 2.41	– 2.22	– 3.55
1% Critical value[4]	– 3.56	– 3.56	– 2.61
5% Critical value	– 2.92	– 2.92	– 1.95
10% Critical value	– 2.60	– 2.60	– 1.65

[1] Test includes a constant. [2] Neither a constant nor a trend is included. [3] We also tested inflation including a constant and a trend. In this case, the statistic (– 2.7) does not allow us to reject the unit root hypothesis either. [4] MacKinnon critical value for rejection of a unit root hypothesis.

Table 2
Cointegration test for prices[1,2]

Test	Value	Critical value	5%	10%
Phillips-Perron	– 5.90	PP Haldrup	– 2.60 – 4.30	– 1.95 – 3.90
ADF	– 4.20	ADF Haldrup	– 2.60 – 4.30	– 1.95 – 3.90

[1] The equation for obtaining the error term was the following: $p_t = c + \beta_1 w_t + \beta_2 q_t + \beta_3 p*_t + \beta_4 \Delta p_t + \varepsilon_t$. [2] Each test was estimated with four lags. Serial correlation LM and ARCH tests do not indicate autocorrelation or heteroskedasticity.

4.2 Price equation

As stated in equation (12), price acceleration was run on wages, productivity, the output gap, lagged prices, foreign prices and several difference terms.[14] We have estimated two versions of equation (12).

- Model 1

  In this estimation, we imposed $\beta_6 = -\beta_7$, which implies that we can introduce unit labour costs instead of private wages and labour productivity. Cost homogeneity (the various costs add up to prices) was also imposed: $-\beta_4 = \beta_5 + \beta_6 + \beta_7 + \beta_8 + \beta_9$.

  $$\Delta^2 p_t = \beta_1 + \beta_2 (\Delta p^e_{t+1} - \Delta p_{t-1}) + \beta_3 (y_{t-1} - \overline{y}_{t-1}) + \beta_4 p_{t-1} + \beta_5 (wpr_{t-1} - q_{t-1}) + \beta_6 (wpu_{t-1} + taxes) + (-\beta_4 - \beta_5 - \beta_6) p^*_{t-1} + \beta_7 \Delta p_{t-1} + \beta_8 \Delta^2 w_{t-1} + \beta_9 \Delta q_t + \beta_{12} \Delta e_{t-1} + \beta_{10} \Delta e_{t-3}$$

  where *wpr* denotes private wages and *wpu* corresponds to public wages.

[14] Even though the oil price was included in these regressions to take into account short-run shocks to the system, it was not significant. Therefore we dropped it.

- Model 2

Model 2 includes exchange rate terms multiplied by inflation, besides also having the unit labour cost restriction.

$$\Delta^2 p_t=\beta_1 + \beta_2 (\Delta p^e_{t+1}-\Delta p_{t-1})+\beta_3 \frac{1}{2}\left[(y_{t-1}-\bar{y}_{t-1})+(y_{t-2}-\bar{y}_{t-2})\right]+\beta_4 p_{t-1}+\beta_5 (wpr_{t-1}-q_{t-1})+\beta_6 wpu_{t-1}+ [\beta_7+\beta_8 (p_{t-1}- p_{t-4})/4)]\, p^*_{t-1}+ \beta_9\Delta p_{t-1}+\beta_{10} \Delta^2 wpr_{t-1}+\beta_{11} \Delta^2 wpu_{t-1}+\beta_{12}\Delta q_t +\beta_{13}\Delta e_t + \beta_{14}\Delta p_t\Delta e_t + \beta_{15}D883 + \beta_{16}D911$$

where $p^* = e + pext + taxes$

The results are presented in Table 3.

Table 3

Price equation (dependent variable: $\Delta^2 p_t$)

Sample 1987.4 2000.4

Variables[1]	**Model 1**	**Variables**	**Model 2**
Const	0.57 (2.80)	*Const*	0.58 (3.30)
$\Delta pe_{t+1}-\Delta p_{t-1}$[2]	0.34 (2.30)	$\Delta p^e_{t+1}-\Delta pt-1$[2]	0.19 (2.00)
$(y_{t-1}-\bar{y}_{t-1})$	0.08 (3.40)	$(y_{t-1}-\bar{y}_{t-1})$	0.08 (2.60)
p_{t-1}	– 0.23 (– 5.20)	p_{t-1}	– 0.25 (– 10.00)
$wpr_{t-1}-q_{t-1}$	0.15 (4.70)	$wpr_{t-1}-q_{t-1}$	0.13 (6.20)
wpu_{t-1}	0.05 (3.40)	wpu_{t-1}	0.08 (8.30)
p^*_{t-1}	0.23 – 0.15 – 0.05 = 0.03	p^*_{t-1}	0.02 (1.70)
Δp_{t-1}	– 0.30 (– 1.80)	$p^*_{t-1}{}^*(p_t-p_{t-4})/4$	0.05 (3.60)
$\Delta^2 w_{t-1}$	0.17 (3.90)	Δp_{t-1}	– 0.61 (– 4.70)
Δq_t	– 0.23 (– 3.20)	$\Delta^2 wpr_{t-1}$	0.15 (4.30)
Δe_t	0.04 (1.70)	$\Delta^2 wpu_{t-1}$	0.02 (1.80)
Δe_{t-3}	0.04 (2.30)	Δq_t	– 0.11 (– 2.10)
		Δe_t	– 0.05 (– 3.10)
		$\Delta e_t \bullet \Delta p_t$	3.10 (3.50)
		D883	– 0.012 (– 8.70)
		D911	– 0.009 (– 4.70)

Table 3 (cont)

Variables[1]	Model 1	Variables	Model 2
R^2	0.70		0.87
DW	2.06		2.34
ARCH(4)[3]	0.60 (66%)		1.20 (32%)
LM(4)[3]	0.80 (52%)		4.90 (0%)
Jarque Bera[3]	5.40 (6%)		0.40 (82%)
β	1.20		
θ	0.80		
c_4	– 2.04		
assuming $\beta = 1$			
c_4	[– 2.40, – 1.80]		
θ	[0.7,1]		

[1] *pt* is core inflation and each variable is in logs. [2] Δpe_{t+1} is estimated by instrumental variables. We use contemporaneous values and three lags of domestic inflation, external inflation, rate of depreciation, wage growth, labour productivity growth, output gap, and the rate of growth of oil price. We also include seasonal dummies. [3] Probabilities are reported in brackets.

Table 3 shows the estimation of equation (12).[15] The various diagnostic residual tests indicate that the models have the desired properties for OLS estimation.[16] Multivariate tests are satisfactory, as can be seen from the lower part of the table. In general, the econometric fit is satisfactory with high R-squareds and highly significant variables. Moreover, the results presented in Table 3 provide evidence of the existence of I(2) data trends and cointegration because Δp_{t-1}1 is significant and the error terms are stationary.

We tested the two restrictions of Model 1 using an unrestricted version of it. First, we tested the hypothesis of the coefficient for private wages being equal to that for labour productivity, though of opposite sign. If this is the case, we can include unit labour cost (w-q) as a variable in the model. As shown in Table 4, the Wald test indicates that we fail to reject the null hypothesis at a 89% of significance. Second, we tested in Model 1 the hypothesis of cost homogeneity, or that the various costs add up to prices. We also fail to reject this null hypothesis at a 35% level of significance (Table 4). As a result, we imposed both restrictions in Model 1. The third estimated model, which generates the best out-of-sample inflation forecast, includes only the unit labour cost restriction. This model is also different in the sense that it has two dummy variables and the exchange rate terms are multiplied by the rate of inflation: $\beta_8 \bullet \Delta p_t \bullet p^*_{t-1}$ $\beta_{14} \bullet \Delta e_t \bullet \Delta p_t$. The out-of-sample forecast of this model is better as can be seen in the second row of Figure 6.

A major outcome of these econometric estimations is that the parameters have the expected signs and the restrictions of the model hold. The coefficient for the output gap (y_{t-1}-$\bar{y}_{t-1}$) is positive but small, indicating that a 10% output gap will accelerate the inflation rate by 0.8%. Thus, these results confirm what was found in other studies in the sense that the output gap and unemployment have a small impact on inflation due to widespread indexation. Therefore, a gradual monetary policy is perfectly appropriate in this case.

[15] Instead of using the contemporaneous acceleration of nominal wages, we included its first lag because the former was not significant and had the wrong sign.

[16] However, the second model may have some autocorrelation. Standard errors were obtained with the Newey-West heteroskedasticity and autocorrelation consistent procedure.

Table 4

Restriction tests

Wald test hypothesis	Model 1
Unit labour cost	89%
Linear homogeneity	35%

The results also show, as expected, that labour productivity reduces unit labour costs and inflation. In addition, a negative relationship between inflation and both markups and real wages indicates that inflation imposes substantial costs on firms and workers, fully justifying the stabilisation programme put in place by the central bank since 1990.[17] On the other hand, expected inflation acceleration Δpe_{t+1}-Δp_{t-1} is significant, confirming that expectations matter in determining inflation.

The parameters β, $c12$ and θ can be obtained from equation (13). This implies that the long-run relationship between markup and inflation is negative, ie, $c12$ is around (– 2). On the other hand, θ is 0.8. This parameter is the weight firms place on costs associated with deviations from the optimal price. Notice that inflation imposes a high cost on firms: a 1 percentage point increase in annual steady state inflation (0.25) reduces markups on average by 0.5% (0.25*2).[18]

In order to compare the models, we estimated them up to 1997:4 and generated out-of-sample inflation forecasts (Figure 6). We find that the restrictions imposed on Model 2 reduce the error when compared to a fully unrestricted estimation (first row in Figure 6). On the other hand, the second model is better at forecasting inflation. This confirms that pass-through is positively related to inflation and, at the same time, that inflation overprediction in the recent past is linked to mis-measurement of the pass-through coefficient.

4.3 Wage equation

Regarding wages, Table 5 indicates that, using the error term from the regression $w_t = c + \beta_1 p_t + \beta_2 q_t + \beta_3 \Delta p_t + \varepsilon_t$, the Phillips-Perron statistic does reject the null of no cointegration at a 10% Haldrup critical value. On the other hand, Table 6 shows that the wage model replicates the dynamics of wage inflation remarkably well (the out-of-sample forecast confirms this as well, see Figure 7). The regressors explain most of the movements of the dependent variable since the adjusted R-squared is around 80%. In addition, the ARCH test and LM test on the residuals allow us to reject the presence of significant heteroskedasticity and autocorrelation respectively.

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17 Banerjee et al (2001) obtained a similar result for Australia.

18 One problem with estimation is that β is far above what is theoretically reasonable. In empirical studies, it is common to obtain imprecise estimates of the discount factor, hence it may be preferable to fix it. Nevertheless, the model is overidentified when β is fixed and it is only possible to obtain a range of values for c_{12} and θ. Fixing $\beta = 1$, we obtain a range between 0.7 and 1.0 for θ. In the case of c_{12}, in equation (12), it is negative and similar to the value obtained without fixing $\beta = 1$ (see Table 3).

Figure 6
Out-of-sample inflation forecast

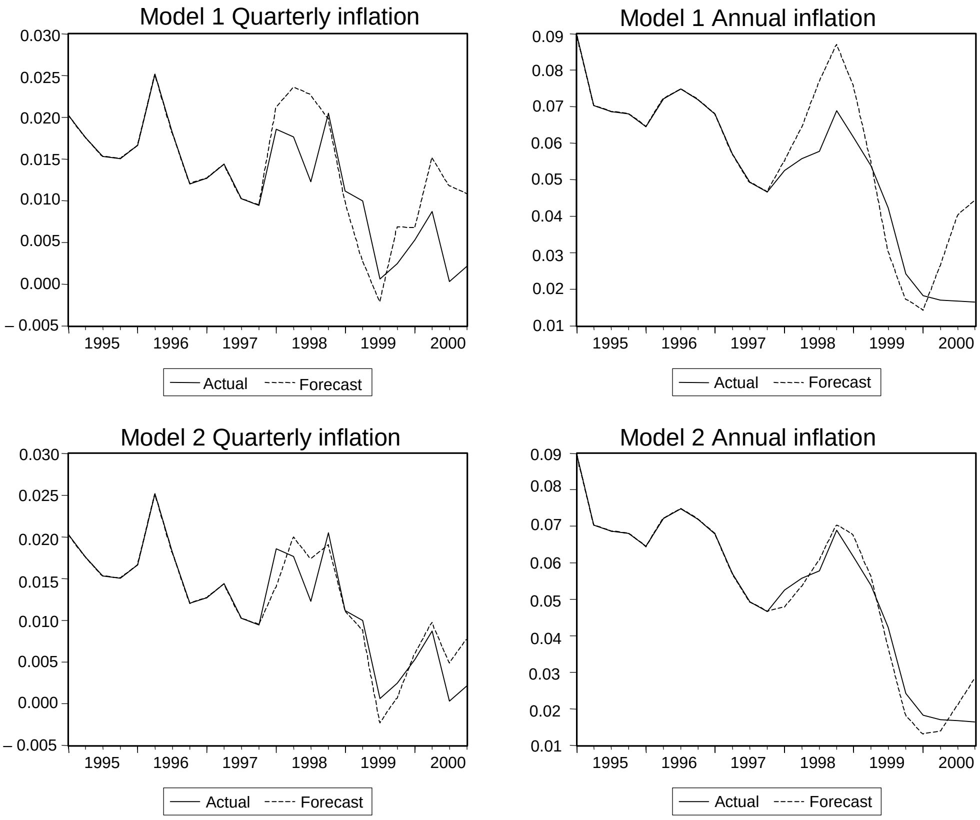


Table 5
Cointegration test for private wages[1,2,3]

Test	Value	Critical value	5%	10%
Phillips-Perron	– 4.15	PP	– 2.6	– 1.95
		Haldrup	– 4.3	– 3.9
ADF	– 2.7	ADF	– 2.6	– 1.95
		Haldrup	– 4.3	– 3.9

[1] The equation to obtain the error term was $wpr_t = c + \beta_1 p_t + \beta_2 q_t + \beta_3 \Delta p_t + \varepsilon_t$. [2] Each test was estimated with four lags. Serial correlation LM and Arch tests do not indicate autocorrelation and heteroskedasticity. [3] A Hodrick-Prescott filter is used to calculate productivity.

As shown in Table 6, the data confirms a negative relationship between the acceleration of wage inflation $\Delta^2 w_t$ and unemployment U_t, with a – 0.15 parameter. This is a Phillips curve itself. It is worth pointing out that there is a close relation between wage and CPI inflation due to widespread indexation (the term $\Delta p_{t-1} – \Delta w_{t-1}$). Our estimation indicates that a 10% increase in inflation above wages will lead to a 7% acceleration of wage inflation next period.[19]

[19] It is worth noting that expected inflation was not significant and was thus dropped.

Table 6

Private wage equation (dependent variable: $\Delta^2 w_t$)
Sample 1987.4–2000.4

$\Delta^2 wpr_t = \beta_1 + \beta_2 \Delta q_t + \beta_3(\Delta p_{t-1} - \Delta wpr_{t-1})\ \beta_4\ w_{t-1} + \beta_5\ p_{t-1} + \beta_6\ q_{t-1} + \beta_7 \Delta p_{t-1} + \beta_8 u_t + \beta_9 d2 + \beta_{10} d3 + \beta_{11} d4$

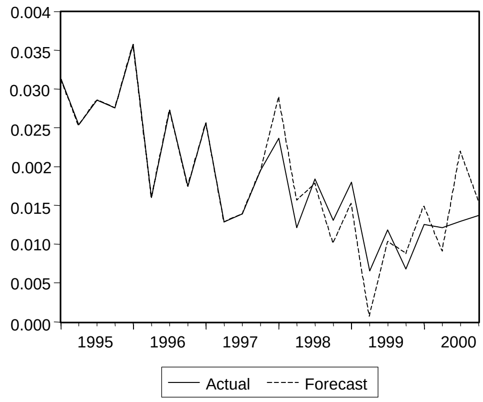
	Variables[1]	**Coefficient**[2] (*t*-statistic)
β_1	c	– 0.8 (– 2.8)
β_2	Δq_t	0.1 (1.3)
β_3	Δp_{t-1} -Δwpr_{t-1}	0.68 (7.6)
β_4	wpr_{t-1}	– 0.35 (– 3.4)
β_5	p_{t-1}	0.37 (3.4)
β_6	Q_HP_{t-1}	0.15 (2.7)
β_7	Δp_{t-1}	– 0.33 (– 2.7)
β_8	u_t	– 0.15 (– 1.84)
β_9	*Seas_d*2	– 0.006 (– 2.2)
β_{10}		0.001 (0.5)
β_{11}	*Seas_d*4	– 0.003 (– 1.3)
R^2		0.79
DW		2.17
ARCH (4)[3]		0.67 (61%)
LM(4)[3]		0.43 (78%)
Jarque-Bera[3]		1.3 (51%)

[1] Log values, except for the unemployment rate. [2] A Hodrick-Prescott filter is used to calculate the level of productivity. However, the first difference is calculated without using this filter. [3] Probabilities are reported in brackets.

On the other hand, the parameters of productivity confirm that it has a positive effect on wages. In addition, the negative parameter of lagged inflation indicates that this variable imposes a cost for workers. Even though the sign of this variable can be derived from the model (inflation is multiplied only for positive parameters), the overidentification does not allow us to determine its exact magnitude.

Figure 7

Out-of-sample forecast for private wage growth



4.4 Pass-through

Finally, we analyse in detail the implications of our estimations on exchange rate pass-through. We have incorporated second-round effects of wages on prices. Thus, we have a simultaneous system for prices (Model 2) and wages, which depends on productivity, the exchange rate, foreign prices and lagged variables. In the first round, the nominal exchange rate directly affects prices. Subsequently, wages, through indexation, impact prices again. We generated out-of-sample inflation forecasts with both equations simultaneously.[20] The results are shown in Figure 8.

Figure 8

Simultaneous equation inflation forecast

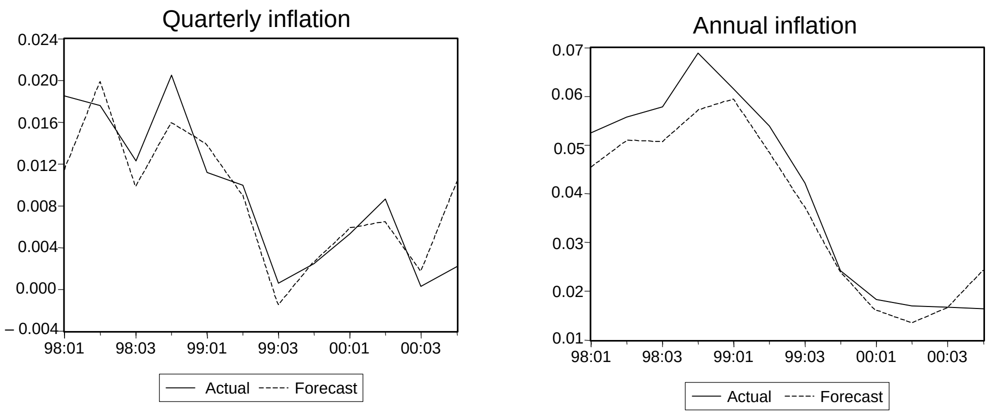


Figure 9 shows pass-through when the nominal exchange rate increases. First, we incorporated both equations in the García et al (2000) five-equation model - instead of their Phillips curve. Next, we hit both real and equilibrium real exchange rates with a 10% shock. We then followed the nominal exchange rate and price paths.

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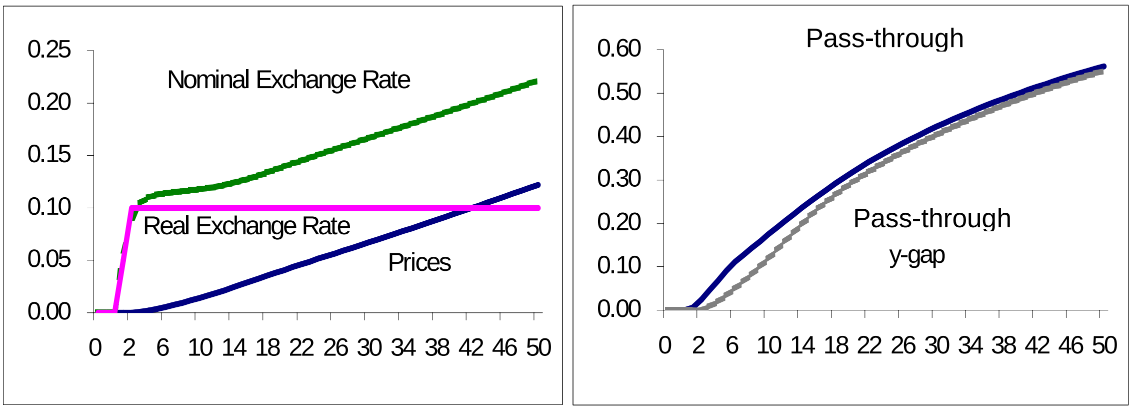
[20] This exercise was performed with our restricted price index IPCX2, instead of CPI, affecting wages. We consider that it is the origin of the underestimation of the inflation forecast shown in Figure 8.

Figure 9 indicates that after a 1% rise in the real exchange rate, the nominal exchange rate also increases, producing an accumulated impact on prices of around 0.16% after three years.

Figure 9



Next, we explore how the effect of an exchange rate shock depends on economic activity. Evidence suggests that there is a pass-through decrease when the economy is in a "recession". Figure 9 shows what happens in our artificial environment with prices, and the pass-through effect, if we have a temporary increase of 10% in the exchange rate in two alternative scenarios. The first scenario has an endogenous output gap. The second has an exogenous 2% negative output gap which fades linearly in three years. The accumulated inflation effect of depreciation is higher when the economy is at potential (zero output gap). A negative output gap tends to offset the inflationary effect of a nominal depreciation. The negative output gap reduces margins and hence a fraction of the depreciation is not passed on to consumers.[21]

Finally, Model 2 in Table 3 suggests that the size of exchange rate pass-through is positively related to the inflation level. This effect is captured in the variables where the nominal exchange rate is multiplied by inflation. In both cases, the coefficients are positive and strongly significant. Therefore, one could conclude that the low pass-through from the exchange rate to inflation observed in recent years is permanent since inflation has been stabilised at around 3%. It also suggests, as stated above, that inflation overprediction in the recent past is probably related to mis-measurement of the pass-through coefficient.

5. Conclusions

Price and wage equations based on a model of imperfect competition were estimated and used to generate out-of-sample inflation forecasts. From the estimations we can conclude:

The findings of previous studies are confirmed in the sense that the output gap and unemployment have a small impact on inflation due to widespread indexation. Therefore, a gradual monetary policy is called for.

Despite the fact that generalised wage indexation is one of the major elements explaining price and wage behaviour, expectations of future inflation matter. This is a very important variable to consider in an inflation targeting regime, since credibility could substantially reduce the sacrifice ratio.

We empirically found that productivity reduces unit labour costs and inflation, affecting real wages positively. In addition, a negative relationship between inflation and both mark ups and real wages

[21] In this exercise, output calculation was performed assuming a zero unemployment rate because unemployment was not linked to the output gap. Considering this second-round effect in this particular exercise would probably generate a lower pass-through.

indicates that inflation imposes substantial costs on firms and workers. This result emphasises the benefits of stabilising the inflation rate. This cost rises even more when the impact of inflation on real wages is considered.

Finally, the exchange rate pass-through depends positively on economic activity and the inflation level, explaining why pass-through has been so low in recent years. Therefore, one could conclude that pass-through would be permanently lower than in the 1990s, given that inflation has been stabilised at around 3%.

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The role of asset prices in Indian inflation in recent years: some conjectures

Partha Ray and Somnath Chatterjee[1]

Consequent upon the external payments crisis of 1990-91, a process of structural reforms has been set in motion in India, encompassing inter alia the financial, fiscal and external sectors. Against this backdrop, we made an attempt to analyse the impact of stock prices on commodity price inflation in India in the recent period (1994-2000). We constructed a vector autoregression (VAR) model comprising the call money rate, broad money growth, output gap, stock price inflation and commodity price inflation. We found that while stock price inflation did not Granger cause an output gap, it seemed to have Granger caused commodity price inflation. The results remained unaltered even if the output gap was replaced by output growth in the model. In other words, this implies that while stock prices may not have much significance for the growth of output, they contain important information about commodity prices and may thus serve as a leading indicator of inflation. We also considered gold as an alternative asset in the household portfolio. Gold price inflation, however, failed to emerge as a leading indicator of inflation. Similar results followed even after the introduction of the exchange rate as an additional variable in our basic VAR model.

1. Introduction

The relationship between asset price inflation and commodity price inflation, and more generally the significance of asset prices for monetary policy formulation, has been the subject of intense debate amongst academics and policymakers, particularly in the context of industrialised economies. While the asymmetric impact of asset price movements on the real economy as well as their implications for financial stability have been well recognised, a clear consensus on the precise extent to which monetary policy needs to take cognisance of their "leading indicator properties" for the inflation process, enigmatic as they usually are, has yet to emerge. The financial crises in Japan during the early 1990s and, more recently, in Southeast Asia have only served to reinforce the concerns relating to asset prices, an upsurge in which had coexisted with low levels of commodity price inflation in those economies, apparently masking their impending and virulent collapse. More recently, the concerns relating to the sharp downturn in technology, media and telecommunications (TMT) stocks across the globe after their spectacular run-up, as well as evidence of the existence of *strong* links between asset (stock) prices and the real economy even in emerging market countries, have fuelled the ongoing debate.

Such developments evoked some curiosity about the role of asset price inflation in the general inflation process in a country like India that is undergoing financial liberalisation and rapid structural transformation and is being increasingly integrated with the global economy, abetted by wide-ranging market-oriented reforms initiated in the previous decade.

Asset prices have until recently, and quite understandably given the nascency of the reform process, been somewhat ignored in the traditional explanations of the inflation process in India, viz the monetarist and structuralist schools. Consequent upon the external payments crisis of 1990-91, a process of structural reforms was set in motion in India. With the advent of reforms, financial markets, including capital markets, have undergone significant liberalisation, mainly reflected in the deregulation of interest rates, the progressive latitude accorded to private sector entities, including foreign players,

[1] The authors are with the Reserve Bank of India. This paper reflects their personal views and not those of the institution to which they belong. The authors are indebted to the participants in the Workshop and in particular to M S Mohanty, Palle Andersen and Miguel Messmacher for their insightful comments. They are also grateful to S Pattanaik, M K Saggar and D Ajit of the Reserve Bank of India for their comments on an earlier version of the paper. The usual disclaimer applies.

institutional changes and the development of new products. These changes have not only resulted in the rapid growth of financial markets but have also strengthened their interlinkages. At the same time, a distinct moderation in the commodity price inflation rate was witnessed during the second half of the 1990s, from its relatively high average level of 8 to 9% in the past, reflecting to some extent the salutary impact of the reform process. What is the role of asset prices in Indian inflation in this changing scenario? Do we need to incorporate their information content in order to gauge the inflation process in India? More specifically, are asset prices indicative of future inflationary trends? These are some of the questions that we attempt to address in this paper.

The paper is organised as follows: Section 2 presents a select resumé of the relevant issues that are raised in the literature. In addition to a survey of studies on Indian inflation, trends in select macro variables are discussed in Section 3. Sections 4 and 5 are devoted to the methodology and empirical results on the relationship between stock prices and inflation, respectively. Some robustness tests are looked into in Section 6. Section 7 concludes the paper.

2. Role of asset prices in inflation: an overview of the literature[2]

Broadly speaking, the transmission from asset price inflation to commodity price inflation could be gauged in terms of the impact of asset prices on aggregate demand as well as on the expectations of the future trends in output and inflation - given that the current price of an asset is the discounted value of the future income stream generated by it - that are implicit in them. The nature and speed of the transmission would not only depend upon the share of assets in private sector wealth but also the level of development of the economy, particularly its financial markets. In general, with increasing market integration, imbalances in one asset market could be easily transmitted to other markets. For instance, excess liquidity would tend to reduce short-term interest rates (the opportunity cost of holding money), which could show up in an excess demand for stocks and a consequent increase in their prices and so on. As the range of assets (stocks, money, government bonds, gold, real estate, foreign exchange and the like) increases, their interactions, amongst themselves as well as with real variables, could, however, render the transmission process more nebulous. It is also recognised that asset prices are inherently volatile and are highly susceptible to changes in investor sentiments, quite independent of any change in the "fundamentals". Consequently, extracting the "right" information from any observed movement in asset prices is near impossible [Bernanke and Gertler (2000)]. Against this backdrop, let us turn to two specific issues that have been raised in the literature on asset price inflation.

2.1 Transmission channels from asset prices to real activity and inflation

While stock prices and property prices are found to have significant predictive power for the real GDP growth rate and the output gap, respectively, of many industrialised countries, views have differed on the causal relationships between the changes in the prices of these assets and output growth (and, in turn, inflation).[3] One view relegates stock markets to mere "sideshows" since they do not cause real output, but the information implicitly contained in their prices is indicative of the future rate of growth of dividends/income/output. Another view underscores the causal impact of asset prices on private consumption and investment. Rising asset prices affect private consumption by raising lifetime wealth, signalling higher expected wage incomes (as a result of growth of real incomes) and increasing the value of collateral, which influences the borrowing capacity of private agents. Vickers (2000), however, points out that higher housing prices may cause people who do not own houses or those whose housing needs are not fully satiated to reduce their non-housing expenditures, and therefore the impact of housing prices on consumption expenditure could be equivocal.

An increase in asset prices affects investment by lowering the cost of new capital relative to existing capital (Tobin's q theory), providing an impetus to current investment based on expected future growth

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2 See Gertler et al (1998) for an overview of the various issues relating to asset prices and monetary policy.

3 See International Monetary Fund (2000) for a discussion and survey of various views on this.

of output (the “flexible accelerator” model) and improving the banks’ balance sheet and thus inducing them to lower interest charges on loans. Second round effects of these changes in aggregate demand on asset prices are also evident.

Empirical evidence confirms the impact of stock and property prices on private consumption and investment in industrialised countries, although the magnitude of the effect varies, depending upon, inter alia, the share of the assets in national wealth and the nature of corporate and banking laws. Kent and Lowe (1997) particularly highlight the asymmetric impact of changes in asset prices on (output and) commodity prices in that the indirect effect of falling asset prices on consumer prices via banking and financial system instability is significantly larger than the direct effect. This occurs mainly because the erosion of the value of certain assets used as collateral for loans, following a sharp dip in their prices, results in large losses to banks and financial institutions, discouraging, if not coercing, them to reverse their liberal lending policies and leading to a protracted slowdown in economic activity and a deflationary environment. On the other hand, against the backdrop of the low (consumer price) inflation environment that coincided with the run-up in asset prices in Japan and Southeast Asian economies in the 1990s, Browne et al (1998) have highlighted the importance of taking cognisance of rising asset prices and the surge in investment spending in policy formulation. In Japan for instance, while rising asset prices were facilitated by financial deregulation and liberalisation, consumer price inflation remained low partly because the appreciation of the domestic currency lowered the cost of imported products. Moreover, it may be recognised in this context that the transmission of asset prices to consumer prices may be incomplete and may occur with a lag. Similarly, Christoffersen and Slok (2000) show that, in the case of six transition economies (the Czech Republic, Russia, Poland, Hungary, Slovenia and Slovakia) over the period 1994-99, lagged values of asset prices (real stock returns, real three-month money market interest rates and changes in the real exchange rate) contain significant signals of changes in real economic activity, particularly industrial production.

The composition of the assets is also found to be an important factor determining the magnitude and nature of the impact on the real economy.[4] It has also been highlighted that the ultimate impact of stock price movements on the real economy may have to be gauged not only in terms of their “wealth effects” but also in terms of their effects on consumer and business confidence in the economic environment.

2.2 Information content of asset prices with respect to expected inflation

A conventional starting point for assessing the information content of financial asset prices as embodied in nominal interest rates is the Fisher equation: $i = r + \pi^e$, where i, r and π^e denote the nominal interest rate, the real interest rate and the expected inflation rate, respectively. In the absence of risk premia and money illusion and assuming r to be a constant, the equation portrays a one-to-one relationship between nominal interest and expected inflation. In other words, since the “returns” from the financial asset would be obtained over a time period in the future, according to the Fisher equation, the investors would like to be fully compensated for the likely/expected inflation rate that would prevail during that period, so as to earn a specified constant real rate of return. Given a real rate of return, nominal interest rates or the current price of a financial asset, therefore, reflect the inflation rate expected to prevail in the future. Assuming a relationship can be drawn between the expected future inflation rate and the actual future inflation rate, the current financial asset price, conceptually, contains information about the future inflation rate.[5] Smets (1997), in fact, argues that even if the

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[4] It has been observed that the relatively high share of telecommunications in Asia, Latin America and Europe makes these regions less susceptible to changes in perceptions regarding the new economy, and that, given the small size of the TMT sectors in Asia and Latin America, the impact on aggregate consumption and investment would be relatively smaller. Empirical analyses showed that both TMT and non-TMT stocks have a significant impact on consumption and investment in North America and the United Kindom, while non-TMT stocks were not found to have a large impact in continental Europe. Furthermore, TMT stocks were found to be a leading indicator of economic activity in the major regions of the world; see IMF (2001) for details.

[5] An important issue in this context is the appropriateness of the conventional price indices. Attempts have been made to reconstruct these price indices so as to account for the full impact of changes in asset prices. The central argument in such endeavours is that since conventional consumer price indices focus on changes in the price level of consumption goods in the current period, they fail to capture the import of lifetime utility, which basically reflects a choice between present and future consumption. Drawing upon the Inter-temporal Cost of Living Index (ICLI) developed by Alchian and Klein (1973), Shibuya (1992), for example, constructed a Dynamic Equilibrium Price Index (DEPI) as a weighted geometric mean of the

impact of asset prices on aggregate demand is limited, they may contain useful information about the current and future economic environment, which could be utilised to improve the efficacy of monetary policy.

Some empirical studies have generally confirmed that current asset prices/nominal interest rates provide reliable forecasts of future inflation up to a certain period, to some (but not a great) extent.[6] For instance, Mishkin (1990) reports that the yield spread, an asset price based indicator, provides a reliable forecast of inflation up to three years in the future but explains only 3 to 7% of the total variation in inflation.[7] Goodhart and Hoffmann (2000) in their study of 16 industrialised countries over the period 1973-98, however, did not find the yield spread to be a very useful predictor, in general, for future changes in the inflation rate (four, eight and 12 quarters ahead) although it turned out to be a significant predictor for future real GDP growth in the case of a greater number of countries.[8] It has further been pointed out that the nature of the association between the expected inflation rate and nominal asset prices depends on the correlation between inflation and the income from the asset and, in turn, on the relationship between inflation, real output and interest rates. This suggests that the predictive power of asset prices would be contingent upon the macroeconomic environment: for instance, asset prices would be more likely to predict inflation if such an inflationary situation was brought about by accommodative monetary policy that facilitated output growth and a decline in interest rates, rather than an inflationary environment created by negative shocks to the productive potential of the economy [Borio et al (1994)].

The broad messages that emerge from the foregoing discussion are that (certain) asset prices have information regarding the future course of real output and inflation, though with different degrees of success; the outcome has been largely shaped by the prevailing macroeconomic environment, household portfolio preferences and the nature of institutional arrangements. Moreover, asset prices such as interest rates and property/land and stock prices have predominantly figured in the empirical exercises to gauge the impact of asset price inflation.

3. Nature of Indian inflation and role of asset prices

3.1 Indian inflation: a select resumé

There has been a plethora of studies on inflation in the Indian economy.[9] Broadly speaking, the aggregate price or inflation behaviour in India followed two distinct, but not necessarily mutually

current price index (P: GDP deflator) and asset price (AP) changes (changes in the value of the national wealth), DEPI = $1[P^1/P^0]^{\alpha}\,[AP^1/AP^0]^{(1-\alpha):}$, where $\alpha = \rho/(1+\rho)$ and ρ is time preference. Apart from the intractability of such an index, there is a contrary view too; see Kent and Lowe (1997), who aver that central banks target the future expected (path of) inflation and not the current rate of inflation. Moreover, asset price increases resulting from say, productivity growth and improved corporate outlook are likely to be associated with a decline in future expected inflation. For both these reasons, they argue that it is not necessary to include asset prices in an index of prices for central banks to target. Vickers (2000) points out that the retail price index includes prices of durable goods (such as refrigerators) whose services may be reaped over the future and that, therefore, to say that the retail price index is the money cost of a basket of goods and services for current consumption is not exactly true; see also Filardo (2000). Recently, however, Cecchetti et al (2000) extracted the core component from equity, housing and consumer prices and suggested bestowing a higher weight on housing prices in the index of consumer prices.

6 See, for example, Fama (1977) and Mishkin (1990).

7 The yield spread is the difference between long-term and short-term nominal interest rates. According to the expectations theory of term structure, long-term nominal interest rates reflect expected future short-term interest rates. Assuming constant real interest rate risk premia, the yield spread, therefore, is indicative of the expected future inflation rate.

8 Notwithstanding the Fisher hypothesis, a number of studies have documented an inverse relationship between the rates of return on assets and the expected rate of inflation. This "puzzling" result has usually been attributed to "proxy effects" (ie a positive association between asset returns and real activity and a negative association between real activity and inflation imply a negative relation between stock returns and inflation) or to irrationality/money illusion and market inefficiency; see, for example, Fama and Schwert (1977), Marshall (1992), Boudoukh and Richardson (1993) and Santoni and Moehring (1994).

9 See Bhattacharya and Lodh (1990) for a survey of studies on Indian inflation.

exclusive, paths, viz monetarist and structuralist. Typically, monetarist models attempted to explain inflation primarily in terms of excess money growth and, given the fact that in India excessive monetary growth reflected profligacy on the part of the Union Government, particularly during the 1980s, held it responsible for Indian inflation.[10] In specific terms, most of these studies attempted to estimate a long-run relationship between money, output and prices. The major determinants of Indian inflation to emerge from the recent studies are M3, output and the call money rate [see, for example, Callen and Chang (1999)]. In the case of the manufacturing sector, the exchange rate and import prices are also found to be useful.

Conversely, in the structuralist approach, sectoral prices are determined first and then the overall aggregate level is seen as a weighted average of the sectoral prices. In the structuralist tradition, Balakrishnan (1991) modelled Indian inflation in terms of a mark-up, raw material cost and wage cost, along with an index for capacity utilisation. Agricultural prices, on the other hand, had been modelled in terms of per capita output, per capita income of the non-agricultural sector and the government procurement of food grains. Results from his non-nested tests revealed that the structuralist model of Indian inflation outperformed the monetarist model.

As alluded to earlier, the impact of the stock market on commodity prices and real activity has not attracted much attention in the Indian context. There have been some attempts, nevertheless. Mukherjee (1988), using annual data for the period 1949 to 1981, found that while consumption Granger causes stock prices, in the case of investment the causality is from stock prices to investment. He found that stock prices Granger caused GDP during this period. For a shorter period using monthly data from 1970 to 1981, however, he found unidirectional causality from the index of industrial production (IIP) to stock prices. Recently, Pethe and Karnik (2000) examined the relationship between stock prices and IIP. Using monthly data over the period April 1992 to December 1997, they found no evidence of cointegration between stock prices and IIP on the basis of the Engle-Granger two-step procedure; they inferred that "… there is no evidence to suggest that a revival of the stock market, in the sense of rising share price, could be a leading indicator of the economy" (p 355). We felt that Mukherjee's (1988) finding could be critically specific to the time period he had chosen, when the stock market was not really sufficiently developed in India. Moreover, as the relationship between stock prices and output does not exist in isolation, one may question the selection of just two variables, viz IIP and stock prices in Pethe and Karnik (2000). In addition, we found that Pethe and Karnik's result is sensitive to the choice of methodology. In fact, when we ran the Johansen cointegration routine between IIP (manufacturing) and stock prices over the same period (ie April 1992 to December 1997), we found the variables to be cointegrated.[11] However, we felt that any attempt to obtain a cointegrating relationship between stock prices and IIP over such a short period could be inappropriate. Besides, irrespective of the technique, existence of any cointegrating relationship between these variables in such a bivariate setup may not have much exploratory content because of the combined effect of the omitted variables.

3.2 Recent trends in select Indian macro variables

The Indian economy has witnessed significant changes over the past decade. Unsustainable macroeconomic policies in the 1980s coupled with the adverse impact of the Gulf war culminated in an external payments crisis in 1990-91. Structural reforms launched in the wake of the crisis,

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[10] See Chand (1996) for a discussion on the fiscal determinants of Indian inflation.

[11] Assuming unrestricted intercepts and no trends, the results from the Johansen cointegration procedure are as follows (where r is the number of cointegrating vectors):

Test	Null hypothesis	Alternative hypothesis	Statistics in the model		95% critical value
			Without seasonal dummies	With seasonal dummies	
Eigenvalue	$r = 0$	$r = 1$	22.90	23.85	14.88
	$r \leq 1$	$r = 2$	0.05	0.00	8.07
Trace	$r = 0$	$r \geq 1$	23.00	23.76	17.86
	$r \leq 1$	$r = 2$	0.05	0.00	8.07

encompassing the fiscal, monetary, banking, financial and external sectors and essentially aimed at liberalising the economy, inducing competition and instilling macroeconomic discipline, have been the hallmark of developments in the 1990s. In the present paper, our concern is the second half of the 1990s, when the reform process began to get firmly entrenched. What happened on the output and inflation fronts during these years? How did the money and equity markets behave? As a prelude to our understanding of the relationship between stock price inflation and commodity price inflation in India, we present a rundown of the trends in select macro variables (Appendix Table 1).

The inflation rate in India, as measured by the wholesale price index (WPI), has been lower and relatively less volatile than in most developing countries, particularly during the last two decades.[12] After remaining at around 8 to 9%, on average, during the 1970s and 1980s, the inflation rate increased sharply during the first half of the 1990s, reflecting a myriad of factors, including intermittent domestic agricultural supply shocks and exogenous shocks such as the oil price increase and the Gulf war as well as passive monetary accommodation of past fiscal excesses. There was a distinct moderation in the average rate of inflation during the second half of the 1990s, with the inflation rate declining to below 4% in 1999-2000. Such a deceleration in the price level was facilitated by reforms gaining momentum, particularly the institutional arrangements that have greatly improved the implementation of monetary policy and liberalisation-led internal restructuring, technological innovation and the environment of price competitiveness. Moreover, the rate of increase in prices of manufactured products (which are most affected by price competitiveness and which constitute around 60% of the WPI) has not only been more stable but has also generally remained below that of the overall rate of inflation; part of the decline, at least in recent years, has, however, been on account of the industrial slowdown. Notwithstanding the general improvement in the price situation, the inflation rate has continued to reflect occasional pressures from supply shocks and increases in administered fuel prices.

The ongoing process of economic reforms and liberalisation has invigorated the capital market as well. The Indian capital market ranks as one of the largest in the world in terms of the number of investors and the number of listed companies [Patil (1999)]. The market capitalisation of the Bombay Stock Exchange (BSE) (the focus of our empirical analysis), for instance, was placed at 47% of GDP in 1999-2000.[13]

The year-on-year growth rate of the monthly 30-scrip index at the BSE, called the SENSEX, over the period 1994-95 to 1999-2000 shows a rough W-shaped movement, reflecting marked volatility (coefficient of variation of 253%).[14] The uptrends have been attributed to a combination of factors such as an improvement in corporate earnings, foreign institutional investment (FII) inflows, favourable legislative changes and, more recently, the global upsurge in infotech stocks. The downward movements have coincided with the prevalence of high domestic interest rates resulting from intervention to even out high volatility in the foreign exchange market (1995-96), uncertainties related to the financial crises in Southeast Asia, the imposition of economic sanctions, downgrading by international rating agencies and the industrial slowdown (1998-99).

Monetary policy in India has been guided by the twin objectives of price stability and the provision of adequate credit to the productive sectors of the economy, with the emphasis between the two objectives being dictated by year-specific considerations. The rate of growth of money supply was placed significantly above the long-run rate of growth of 17% during 1994-95 and 1998-99. The increase in money supply during 1994-95 reflected partly the substantial increase in credit to the commercial sector and partly a sustained rise in capital inflows, both facilitating the initial upsurge in industrial production and the increase in stock prices. The large monetary expansion during 1998-99 reflected surges in non-resident inflows. The deceleration in money supply during 1995-96 was partly attributable to the drying-up of liquidity following exchange market intervention to stem speculative

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12 The WPI is the main measure of the rate of inflation used in India. The basic advantage of the WPI is that it is class-independent and available at high frequency (ie weekly) in a timely manner. This index, however, does not cover the non-commodity producing sector, eg services and non-tradables; see Reddy (1999) for details on issues related to various measures of price indices in India.

13 The Indian securities market consists of 22 stock exchanges. Currently, there are about 9,000 listed companies, of which, however, only about 1,500 company stocks, on average, are traded on a daily basis.

14 The trends in the rates of change in the SENSEX and the broader BSE national index are more or less similar.

pressures. Reflecting this development, the average call money rate jumped sharply to over 17% from its usual range of 7 to 9%. It is often expected that a developing country like India will be marked by market segmentation. Interestingly, trends in call rates and the SENSEX since the mid-1990s are symptomatic of increasing market integration.[15]

So far we have only looked into financial variables and prices. What happened on the output front during these years? By the mid-1990s it had become clear that the Indian economy was out of the shackles of low growth rates and had started operating on a higher growth trajectory. After a high growth phase of above 7% per annum from 1994-95 to 1996-97, the pace of real GDP growth in India has, however, slackened somewhat to around 6 to 6.5% more recently. The trend in the overall rate of growth has been affected by the increasing share of the services sector and occasional agricultural supply shocks (during 1995-96, 1997-98 and 1999-2000). Following an initial surge, industrial (manufacturing) production generally remained subdued up to 1998-99 but recovered substantially during 1999-2000. The output gap, as measured by the deviation of the index of industrial production (manufacturing) and its Hodrick-Prescott filtered value, showed wide fluctuations.[16] After an initial downturn during 1995-96, it was on an upswing during the next year and a half, followed by further downward movement. It is apparent that this fluctuating movement of the output gap was not in tune with the downward movement of commodity price inflation.

4. Asset price and Indian inflation: methodology and data

4.1 Methodology

The importance of asset prices for commodity price inflation is explored by means of an unrestricted reduced form vector autoregression (VAR) model, in the tradition of Sims (1980). Accordingly, we construct a VAR model of the form:

$$X_t = B_0 + C(L)\, X_{t-1} \qquad (1)$$

where X is the vector of variables, and C(L) is a lagged polynomial operator of order N, ie $C(L) = 1+L+L^2+ \ldots + L^N$, with $L^k X_t = X_{t-k}$.

We preferred the reduced form non-cointegrated VAR technique to its two standard rivals: (a) cointegrated VAR and (b) structural VAR.

As far as cointegrated VARs are concerned, as we see below, our choice of period is extremely short, viz six years. Over such a short period, we felt that any pre-testing of a long-run relationship may not be very meaningful. Thus, we took the variables in the form in which we expect them to be stationary.[17]

Our preference over structural VAR also needs some justification. As far as the theoretical literature is concerned, we did not find an unambiguous stance that gave an idea about the underlying structural relationship between asset prices, inflation, money, output and, perhaps, interest rates. Therefore, we preferred the Sims-type (1992) reduced form VAR, and tried to discern the impulse responses through a Choleski-type identification scheme. A major critique against such reduced form VARs is that structural inferences from the impulse responses of such VAR models are sensitive to the ordering of the variables. Often the solution is offered in the form of theoretically meaningful restrictions on the

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[15] It is often found that there is a tendency for the peaks of the call rate to coincide with the troughs of the SENSEX. There seems to be a similar tendency between stock price *inflation* and the call rate, *albeit* with some lags. There are exceptions to these trends too.

[16] As we have monthly data, we have taken λ = 14,400.

[17] This is contrary to the works of Sims and his associates [eg Sims (1992)], whereby a reduced form VAR is run in terms of the level variables. The justification came from Sims et al (1990), who, in developing Fuller's (1977) results, showed that coefficients were consistently estimated independent of the order of integration of the variables. Furthermore, as Hamilton (1994) has pointed out, even if the true model is a VAR in differences, certain functions of the parameters and hypothesis tests based on VAR in levels have the same asymptotic distribution based on differentiated data.

innovations of the VAR process. While such structural VARs have been quite popular in recent years, unless they have proper theoretical foundations there could be a tendency to adopt "incredible identifying restrictions". Besides, we have reasons to believe that the ordering has some justification a priori. However, to take care of the sensitivity of the impulse responses to the ordering of the variables, we employed Pesaran et al-type (1997) generalised impulse response functions.[18] In the context of the above N-ordered VAR, the notion of a generalised impulse response function (GIR) is as follows.

The VAR can be written in the infinite moving average form as $X_t = A + \sum_{i=0}^{\infty} B_i e_{t-i}$, where A is a vector of constants, and e_ts are unobserved vectors of shocks, which are jointly normally distributed with zero mean and a constant variance-covariance matrix Ω with a typical element ρ_{ij}. Following Pesaran et al (1997), the conditional expectation of e_t can be written as $E[e_t \mid e_{jt} = k] = (\rho_{ij})^{-1} k \, \Omega \, e_j$, where e_j is a selection vector with element j equal to unity and zero elsewhere. Then, the GIRs of the jth disturbance term on X_{t+M} are $B_M \, \Omega \, e_j \, (\sqrt{\rho_{ij}})^{-1}$, and the GIRs of X_{t+M} are, following a unit shock to the jth variables, $(\Sigma_p B_p) \, \Omega \, e_j \, (\sqrt{\rho_{ij}})^{-1}$.

4.2 Data

The choice of variables in our empirical investigation is quite eclectic, and follows from the basic idea of Hoffmaister and Schinasi (1995) that asset price inflation can affect commodity price inflation via its interaction with the nominal interest rate, real output (or the output gap) and monetary growth. Thus, in estimating (1), X, the vector of variables, includes a proxy for commodity price inflation (π), a proxy for asset price inflation (π^A), the real output gap (ie Y - Y*), a nominal interest rate (i), and a variable capturing monetary growth (m). We have taken equity as the chosen asset. While it could be argued that a meaningful analysis of recent trends of the Indian economy should have been extended to the beginning of the reform period (ie 1991-92), because of the irregularities in the stock market the numbers for 1992-93 are to a fair extent outliers. Besides, screen-based trading in the stock exchanges started much later. Hence we opt for the six-year period, April 1994 to March 2000, as our sample (the financial year of the Indian economy being April-March).

Because of the small sample, we take all the data at a monthly frequency. It may be mentioned that we have incorporated all the basic level data in deseasonalised form, using the census X-11 method. While the literature is quite ambiguous as regards the use of seasonal filters in taking the variables of the VAR, it is quite a normal practice to use the data in deseasonalised form in the case of a reduced form VAR, as against a cointegrated VAR, where centred seasonal dummies are introduced.[19] The theoretical justification for using seasonally adjusted data comes from Sims (1993), who showed that seasonally unadjusted data tended to overemphasise the fit at the seasonal frequencies; conversely, use of seasonally adjusted data would produce a small bias.[20]

Thus, the following variables have been taken into consideration.

– Output gap (Y - Y*): GDP numbers in India have been available at a quarterly frequency only in the recent period. Hence, we use the monthly index of industrial production (IIP) as the proxy for the activity variable. Since we have confined our analysis to the stock market, a much narrower notion of industrial activity has been adopted, namely IIP on account of manufacturing (Y). In order to construct an index of potential output, we have taken Hodrick-

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18 Pesaran et al's (1997) generalised impulse response analysis builds on the earlier work by Koop et al (1996). It has been shown that generalised impulse responses are unique and fully take account of the historical pattern of correlations observed among the different shocks. Furthermore, the generalised and Choleski-type impulses coincide when the variance-covariance matrix of error process of the underlying VAR is a diagonal one. However, we are unable to construct the standard error bounds for these generalised impulse responses.

19 For example, Sims (1980) and Sims (1992) both use seasonally adjusted data for a large number of variables. Lütkepohl (1993) too uses deseasonalised data.

20 To quote from Sims (1993), "Use of (seasonally) unadjusted data and a correctly specified model of seasonal variation is always the best option. But treating seasonality casually, as a "nuisance" component of the model, can lead to worse errors than those produced by use of adjusted data" (p 19).

Prescott filtered values of Y (denoted by Y^*), and taken the deviation of Y from Y^* as a measure of the output gap [Hodrick and Prescott (1997)].

– Inflation (π): Corresponding to the measure of output, we take the wholesale price index (WPI) for manufactured products as the relevant price index and its rate of change as the measure of inflation.

– Stock price inflation (π^S): This is taken as the rate of change in the BSE sensitive index (SENSEX).

– Interest rate (i): The call money rate in the Bombay market is taken as the interest rate.

– Monetary growth rate (m): The growth rate of broad money, or M3, is taken as the monetary growth rate.

Thus, we estimate a VAR of the following form (with $a_{ij}(L)$ as the lag operator):[21]

$$\begin{bmatrix} i_t \\ m_t \\ (Y_t - Y^*) \\ \pi_t^S \\ \pi_t \end{bmatrix} = \begin{bmatrix} a_{11}(L) & a_{12}(L) & a_{13}(L) & a_{14}(L) & a_{15}(L) \\ . & . & . & . & . \\ . & . & . & . & . \\ . & . & . & . & . \\ a_{51}(L) & a_{52}(L) & a_{53}(L) & a_{54}(L) & a_{55}(L) \end{bmatrix} \begin{bmatrix} i_t \\ m_t \\ (Y_t - Y^*) \\ \pi_t^S \\ \pi_t \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \\ e_{4t} \\ e_{5t} \end{bmatrix} \quad (1)$$

5. Asset price and Indian inflation: empirical results

5.1 Time series properties of the variables

Before we proceed to estimate the VAR, it is necessary to test for the time series properties of the variables. We employed the standard Dickey-Fuller (DF) and augmented Dickey-Fuller (ADF) test (Appendix Table 3). All the variables - interest rate, M3 growth, output gap, stock price inflation, gold price inflation, and manufacturing price inflation - appear to be stationary. This is in consonance with the relevant studies on the order of integration of related Indian macro variables.[22] Since we have taken the data in deseasonalised form, the power of the unit root tests could have been reduced [Ghysels and Perron (1993)]. Hence, we reworked the DF and ADF tests using non-deseasonalised data; the results on the order of integration of the variables were found to be invariant.

5.2 Relationship between the variables: correlation coefficients

To begin with, we looked at the simple correlations between the variables. As we have already shown that all the variables are I(0), one can expect the simple correlation coefficients to be indicative of some association and not the underlying spuriousness due to the presence of a time trend. It is interesting to note that stock price inflation is significantly negatively correlated with the interest rate. The correlation between stock price inflation and commodity price inflation is, however, insignificant.[23] Considering that these are contemporaneous correlations, one need not read too much into these findings. Nevertheless, the correlation coefficients between current values of commodity price inflation and lagged values of stock price inflation turned out to be significantly positive.[24] This gives us a

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21 All the rates of change or growth rates are taken as annualised, ie $(x_t - x_{t-12})/x_{t-12}$.

22 For example, Parikh (1997) found IIP, M3 and WPI to be I(1) and the call rate to be I(0).

23 The significance of the correlation coefficient (r) is tested through the t-statistic $[r \sqrt{(N-2)}] / [\sqrt{(1-r^2)}] \sim t_{N-2}$.

24 For example, the coefficients between commodity price inflation and lagged values of stock price inflation, with lags 0 to 10, respectively, turned out to be –0.123, –0.038, 0.070, 0.182, 0.279, 0.360, 0.437, 0.493, 0.565, 0.613 and 0.634, respectively.

hunch about the appropriateness of considering stock price inflation as a leading indicator of commodity price inflation.

Table 1

Contemporaneous correlation coefficients between the variables

(period of estimation: April 1994 to March 2000)

Variables	Interest rate	M3 growth	Output gap	Stock price inflation	Commodity price inflation
Interest rate	1.000	– 0.303[1]	0.178[1]	– 0.259[1]	0.297[1]
M3 growth		1.000	– 0.623[1]	0.092	0.221
Output gap			1.000	0.042	– 0.084
Stock price inflation				1.000	– 0.123
Commodity price inflation					1.000

[1] Denotes significance at the 5% level.

5.3 Block exogeneity of asset price inflation in the VARs

After determining the lags for the respective VARs, we estimated the VAR described above.[25] To begin with, we tested for the block exogeneity pattern of various variables in order to determine the extent to which these variables selected for the VAR are significant (Table 2). All the variables in both the VARs appear to be block endogenous (as revealed by the respective χ^2 values), implying thereby that their exclusion from the system would lead to loss of information.

Table 2

Block exogeneity tests for the variables in the VAR

(period of estimation: April 1994 to March 2000)

Variables	χ^2
Interest rate	105.22 [1]
M3 growth	161.62 [1]
Output gap	108.09 [1]
Stock price inflation	168.53 [1]
Commodity price inflation	133.37 [1]

[1] Denotes significance at the 1% level. The χ^2 values for VAR have 40 degrees of freedom.

5.4 Granger causality patterns

Nevertheless, our primary concern is to see whether asset prices matter for inflation in India. In order to check that, we looked at the joint significance of various independent variables in the commodity price inflation equation using the standard F test. As can be seen from Table 3, all the variables, including stock price inflation, are significant in the commodity price inflation equation in the VAR.

[25] The lags are determined through Schwarz Information criteria, and through sequential testing using Sims' (1980) Modified LR tests. The optimal lags of the VAR turned out to be 10 months.

Table 3

Granger causality patterns in the VAR

(period of estimation: April 1994 to March 2000)

Independent variables	Dependent variable: commodity price inflation		Dependent variable: output gap	
	F-statistic	Significance	F-statistic	Significance
Interest rate	2.09	0.07	0.69	0.72
M3 growth	2.36	0.05	1.65	0.16
Output gap	2.16	0.07	2.13	0.07
Stock price inflation	3.52	0.01	1.17	0.36
Commodity price inflation	238.69	0.00	0.65	0.76

Thus, stock price inflation is seen to be Granger causing commodity price inflation. However, when it comes to the output gap, apart from its own past values, all the variables fail to Granger cause an output gap. There could be two possible explanations for this. First, this may be indicative of the lack of output effect on the part of stock price inflation and, from that standpoint, would be in line with earlier evidence such as Mukherjee (1988) and Pethe and Karnik (2000).[26] Alternatively, this could be due to the failure of the output gap to emerge as an important determinant of Indian inflation.[27] Thus, despite the failure of stock price inflation to influence the output gap, it is found to have an effect on inflation. Granger causality, however, refers to incremental predictability. Hence, what we can infer is that stock price inflation contains important information on future commodity price inflation. In other words, stock price inflation may turn out to be a leading indicator of inflation.

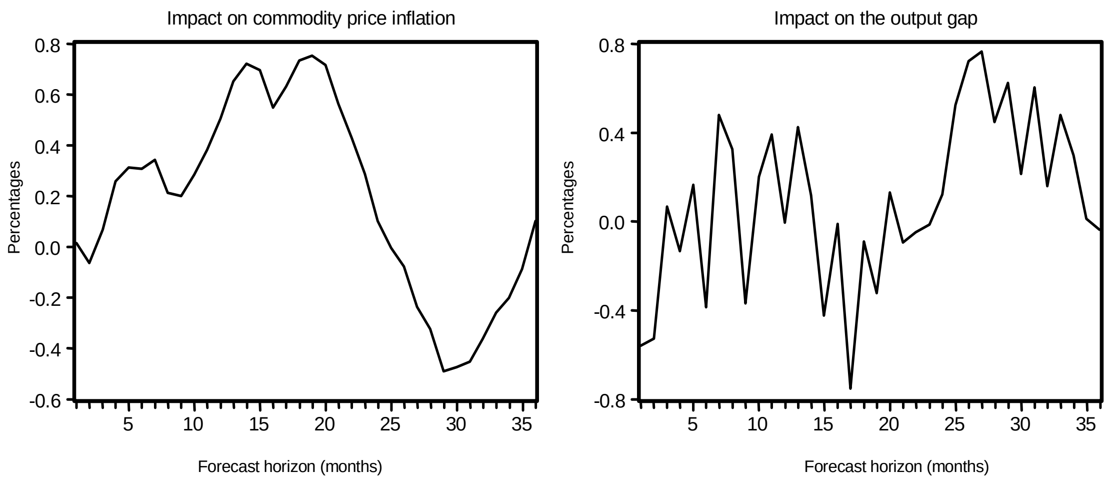
5.5 Impact of asset price inflation shock on commodity price inflation

How does stock price inflation influence commodity price inflation? We looked into the generalised impulse response of commodity price inflation to a unit standard deviation shock to stock price inflation (Chart 1). It appears that, in the initial 20 months, there is a general upward trend in commodity price inflation as a result of a unit standard deviation shock in stock price inflation (and not in the stock price level). This upward impact, however, does taper off and exhibits a downward tendency up to nearly 30 months. The impact on the output gap is more uncertain, reflecting perhaps the fluctuations in the index of industrial production. It needs to be noted in this connection that in the absence of any structural model it may not be at all appropriate to give a structural interpretation of these generalised impulses. Furthermore, since we are unable to construct the standard error bands, it would be difficult to gauge the reliability of the impulses [Runkle (1987)].

[26] This result occurs typically with respect to stock prices. The outcome with respect to market capitalisation could be quite different. In fact, in a preliminary bivariate exercise, we found that real market capitalisation Granger causes manufacturing output growth.

[27] Coe and McDermott (1997) found that for India the output gap model did not work.

Chart 1
Impulse responses of stock price inflation in a VAR with the output gap



5.6 Variance decomposition

How much of the forecast errors of commodity price inflation and the output gap is explained by stock price inflation? To this end, Table 4 reports the generalised forecast error variance decomposition of commodity price inflation and the output gap. It is evident that although, in the initial periods, stock price inflation explains only a small proportion of commodity price inflation, the ratio increases after six months and reaches as much as 60% after one and a half years. In fact, the contribution of stock price inflation in explaining the variance of commodity price inflation surpasses all other variables (including M3 growth) after a year. On the other hand, as expected, the contribution of stock price inflation in explaining the variance of the output gap seems to be limited.

Table 4
Variance decomposition of commodity price inflation and the output gap

Months	Proportion of variance of commodity price inflation explained by					Proportion of variance of the output gap explained by				
	interest rate	M3 growth	output gap	stock price inflation	commodity price inflation	interest rate	M3 growth	output gap	stock price inflation	commodity price inflation
1	2.5	8.3	1.0	0.3	100.0	11.5	17.1	100.0	8.4	0.9
6	20.9	31.8	3.3	23.4	22.8	13.9	37.3	53.1	10.6	7.0
12	19.3	24.5	3.8	44.3	17.2	18.5	33.1	37.2	12.1	7.0
18	9.2	12.0	11.7	64.0	7.5	27.0	28.0	29.7	14.8	8.4
24	17.8	11.3	12.6	60.7	5.8	33.0	26.7	26.1	12.2	8.7
30	16.7	18.3	9.4	49.8	4.6	29.6	23.9	22.8	18.2	9.1
36	22.1	16.2	8.4	41.8	6.3	31.6	21.7	20.7	17.9	8.9

These findings indicate that while stock prices fail to Granger cause the output gap, they seem to contain information on inflation. Granger causality, however, does not have any ontological connotation; hence, the above results would indicate that past knowledge of asset price inflation helps to predict commodity price inflation but fails to do so in the case of output growth. This is, however, not an unexpected outcome. Despite financial liberalisation and an increase in market capitalisation, equity is yet to emerge as the major repository of private sector wealth in India and hence a prime determinant of private consumption. In fact, the bulk of equity holdings in India are in the hands of various financial institutions, many of which are in the public sector. A restrictive policy on the part of the banks towards lending for stock market investment may have further attenuated the linkage between stock prices and output growth. Yet another reason could be that, due to their very nature, extant industrial output statistics failed to take cognisance of stock market developments, which occurred primarily in the services-related segments in recent years. This apart, even in the case of output growth it is the services sector that has become the major source of activity in India in recent years.[28] Besides, as already pointed out, the insignificant impact of the stock market on the real economy could be due to our choice of stock price inflation as the asset price indicator; with indicators capturing stock market activities (such as market capitalisation), the outcome could be entirely different. It may be highlighted in this context that, even in the case of a number of developed countries, stock prices failed to emerge as a leading indicator of the output gap.[29] Nevertheless, given the information base and related market efficiency, stock price inflation seems to have information content as regards the inflationary expectations of economic agents. As a result, even if it fails to Granger cause growth, it seems to have predictive content about inflation. Similar findings have been arrived at for a number of developed economies such as Denmark, Finland, Norway and the United States [Borio et al (1994)].

6. Some robustness tests

How far are the results presented above robust? In this context, the present section will relax some of the assumptions of the above analysis. In particular, we will replace the output gap with output growth and use alternative definitions of asset prices.

6.1 Using output growth instead of the output gap

It may be noted that our measure of the output gap is somewhat crude in the absence of any structural model. Furthermore, Coe and McDermott (1997) have pointed out that the output gap model does not work for India. Hence, in the above VAR we replaced the output gap with growth of manufactured IIP. Even after this substitution, all the variables turned out to be block endogenous.[30] In this case too, stock price inflation is seen to be Granger causing commodity price inflation; the impact of stock price inflation on output growth seems to be insignificant (Table 5).

Table 5

Granger causality in the VAR with output growth

(period of estimation: April 1994 to March 2000)

Independent variables	Dependent variable: commodity price inflation	Dependent variable: output growth
Interest rate	1.10	1.16
M3 growth	2.31[1]	0.71
Output growth	1.61	1.73
Stock price inflation	3.45[2]	0.68
Commodity price inflation	79.12[2]	2.52[2]

[1] Denotes significance at the 5% level. [2] Denotes significance at the 1% level.

[28] A possible solution to this problem could be to run the whole exercise in terms of GDP growth. However, as already indicated, due to the low frequency of GDP statistics we are unable to do so.

[29] See, for example, IMF (2000), p 96.

[30] The $\chi 2$ values for the interest rate, M3 growth, output growth, stock price inflation and commodity price inflation turned out to be 82.89, 130.69, 109.13, 160.52 and 134.31, respectively. All of these are significant at the 1% level.

The generalised impulse response functions of a unit standard deviation shock to asset price inflation, as reported in Chart 2, indicate some positive impact on commodity price inflation for nearly a year and a half. The impact on output growth, however, is much more erratic - after the initial expansionary phase up to six months, there is a downturn up to nearly a year and a half. Thus, the impulses do not seem to be sensitive to definition of the output gap. Similar results are obtained from the forecast error variance decomposition (Table 6).

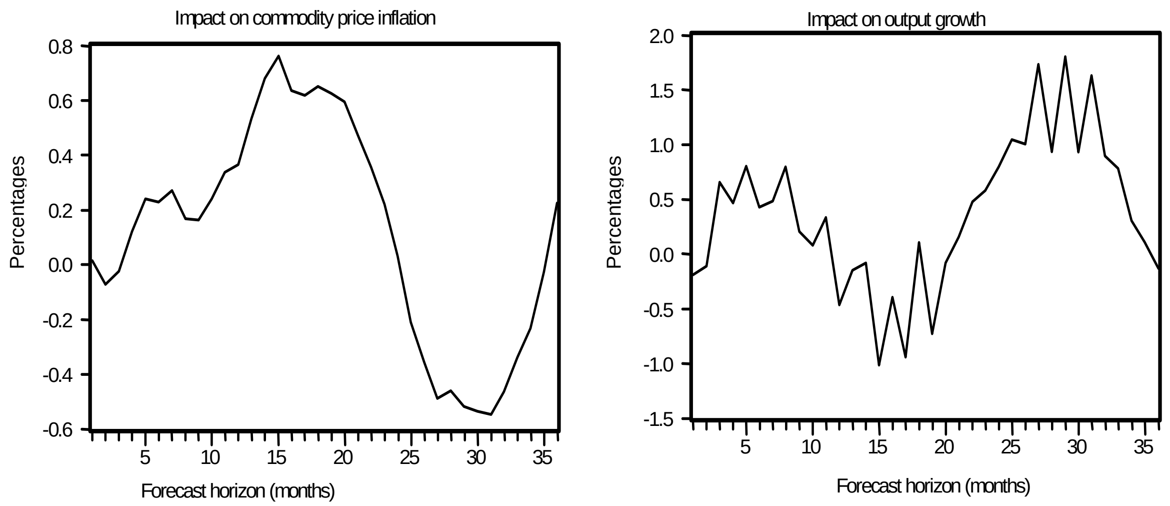
Table 6

Variance decomposition of the VAR with output growth

Months	Proportion of variance of commodity price inflation explained by					Proportion of variance of output growth explained by				
	interest rate	M3 growth	output growth	stock price inflation	commodity price inflation	interest rate	M3 growth	output growth	stock price inflation	commodity price inflation
1	0.7	1.4	1.2	0.2	100.0	1.2	29.9	100.0	0.8	1.2
6	6.7	51.8	25.3	11.7	25.7	4.9	23.1	55.2	15.5	12.6
12	7.7	42.0	26.7	29.8	17.6	11.8	20.5	46.8	16.7	10.2
18	3.3	17.9	22.9	61.7	6.8	16.2	27.8	35.7	19.0	7.1
24	9.1	15.8	34.7	53.0	4.4	23.4	25.1	27.5	19.6	6.9
30	9.6	16.3	30.8	52.2	3.7	19.0	21.7	19.3	33.4	5.2
36	8.5	15.5	34.0	49.2	5.1	17.7	17.6	25.8	30.8	4.7

Chart 2

Impulse responses of stock price inflation in a VAR with output growth



6.2 VAR with alternative asset prices

So far our analysis has been couched only in terms of one asset, viz equity. The menu of assets in the household portfolio could, however, be much larger. In fact, the choice set could be somewhat different for a developing country to enable it to take care of the rather special preferences of agents. For example, in the Indian case, apart from equity, land and gold could perhaps be important alternative assets in the household investment portfolio.[31] Despite the fact that in rural credit transactions land could be seen as an interlinked asset, in the Indian case there is an absence of systematic and reliable statistics on land price. This apart, due to urban land ceiling legislation, during the period covered by our study real estate prices in urban areas could have had a lot to do with scarcity rent rather than economic fundamentals. Thus, we did not consider land as an alternative asset in our analysis.

The story of gold in the Indian case is, however, different.[32] It is well known that Indians have an enormous propensity for holding the yellow metal. There could be several motives behind this. Apart from social demands, gold could also act as an important form of collateral in the case of an informal money market.[33] The movement in domestic gold prices (as proxied by the gold price in the Bombay market) reflects not only seasonal demand (with peaks occurring a number of times in the month of February) and exchange rate movements but also the impact of periodic liberalisation measures that have facilitated a closer alignment of domestic prices with international prices. During the period under review, gold price inflation showed an undulating trend, with a massive downturn witnessed during 1996-98, largely reflecting subdued international prices. When we reworked our basic model in terms of gold price inflation, all the variables, including gold price inflation, turned out to be block endogenous. Nevertheless, gold price inflation failed to Granger cause either commodity price inflation or the output gap (Table 7). Hence, we inferred that the gold price failed to have much information content about commodity price inflation.

Table 7

Granger causality pattern in the model with gold price inflation

(period of estimation: April 1994 to March 2000)

Independent variables	Dependent variable: commodity price inflation		Dependent variable: output gap	
	F-statistic	**Significance**	**F-statistic**	**Significance**
Interest rate	1.84	0.11	0.68	0.72
M3 growth	0.65	0.74	1.36	0.26
Output gap	0.73	0.68	1.53	0.19
Gold price inflation	1.26	0.31	0.97	0.49
Commodity price inflation	205.84	0.00	0.65	0.75

6.3 VAR with the exchange rate as an additional variable

As is well known, the VAR results could be sensitive to the choice of the variable vector. Is there a specification problem in our VAR? Several such variables could be cited in this context, such as credit availability, the exchange rate, capital flows, energy prices, foreign interest rates and foreign asset prices.[34] Since we do not have a structural model of inflation in the Indian economy, many of these variables could be quite unmanageable to incorporate in our rather simplified reduced form VAR model. Nevertheless, we thought there is at least one crucial variable that could have some bearing on this issue, namely the exchange rate. This is essentially because the progressive liberalisation measures initiated as part of the ongoing reform process have not only opened up the external sector

[31] In fact, in Hoffmaister and Schinasi's (1995) model, land price is taken to be the representative asset price. They note that " ... although stock prices are notoriously difficult to model empirically, real estate prices generally move in response to fundamental economic factors, including business cycles and monetary factors" (p 63).

[32] See Garner (1995) for a discussion on taking the gold price as a leading indicator of inflation.

[33] The National Accounts of India treat gold as a consumption good and do not include it under saving; see Central Statistical Organisation (1980) for details. This is, however, contrary to the popular perception of Indian people, who often see gold as an investment avenue. See Sarma et al (1992) for details on gold stock in India.

[34] We are indebted to Miguel Messmacher for drawing our attention to this issue.

but also resulted in a greater degree of integration between the various segments of financial markets, viz money, capital and forex.[35] In order to take cognisance of this issue, we introduced the rupee/dollar exchange rate as an additional variable in our basic VAR model (1).

At this point, a rundown on the Indian exchange rate might be useful. The Indian rupee has, since September 1975, been pegged to a basket of currencies of India's major trading partners. The external payments crisis in 1990-91 and the subsequent initiation of structural reforms brought about significant changes to exchange rate management. After two successive downward adjustments in the external value of the rupee in July 1991, there was a gradual transition to a system of EXIM scrips, then to a dual exchange rate system, and finally to a fully market-based exchange rate regime in March 1993. India's exchange rate policy focuses upon "…managing volatility with no fixed rate target while allowing the underlying demand and supply conditions to determine the exchange rate movements over a period in an orderly way…" [RBI (2001b)]. Reflecting this, occasional exchange market pressures (see Appendix Table 1 for broad trends in the exchange rate), such as those which emanated in the wake of the Southeast Asian financial crises, have been addressed with a combination of timely policy measures, including interventions and monetary policy actions.

Even after the introduction of the exchange rate in our VAR model, we found that stock price inflation continued Granger causing commodity price inflation. On the other hand, as earlier, the exchange rate failed to influence the output gap.

Table 8

The Granger causality pattern in the basic model with the exchange rate

(period of estimation: April 1994 to March 2000)

Independent variables	Dependent variable: commodity price inflation		Dependent variable: output gap	
	F-statistic	**Significance**	**F-statistic**	**Significance**
Interest rate	2.61	0.07	0.99	0.50
M3 growth	2.36	0.09	1.20	0.39
Output gap	2.91	0.05	1.03	0.48
Stock price inflation	2.69	0.06	0.98	0.51
Commodity price inflation	25.21	0.00	0.42	0.91
Exchange rate	1.39	0.30	1.11	0.43

7. Conclusions

We looked into the role of asset prices in Indian inflation in recent years. Taking equity as an asset variable, we found that although stock price inflation failed to have any impact on the output gap or output growth, it has predictive content regarding commodity price inflation. In other words, stock prices seem to have information about the inflationary expectations in the economy. Some other assets such as gold, notwithstanding its importance in the household portfolio, failed to emerge as a leading indicator of commodity price inflation. Similar results followed even after the introduction of the exchange rate as an additional variable in our basic VAR model. Due to the short period of our analysis and in the absence of any structural model that could have incorporated the behavioural relationships of agents, this finding, however, is in the nature of a conjecture and needs to be substantiated with further research. Despite these limitations, the result of the paper - that the information content of equity price inflation is indicative of the future expected path of commodity price inflation - has important implications for monetary policy formulation.

[35] See RBI (2001a), Chapter 6, on this issue.

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Appendix

Appendix Table 1

Select macro indicators of India

(in percentages)

		1994-95	1995-96	1996-97	1997-98	1998-99	1999-2000
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	Real GDP	7.8	7.3	7.5	5.0	6.8	6.4
2	Industrial growth	8.5	12.8	5.8	6.6	4.0	8.1
3	Manufacturing growth	9.1	13.8	7.0	6.7	4.3	9.1
4	Commodity price inflation	10.9	7.8	6.3	4.8	6.9	3.0
5	Commodity price inflation (manufacturing)	10.5	9.1	4.0	4.1	4.5	1.7
6	Stock price inflation (based on BSE national index)	47.7	– 19.2	1.4	7.0	– 10.7	58.3
7	Stock price inflation (based on BSE sensitive index)	45.5	– 16.7	5.1	10.7	– 12.7	43.5
8	Gold price Inflation	3.0	6.2	2.7	– 14.3	– 1.3	2.9
9	Growth of reserve money	22.4	16.5	6.4	10.3	12.2	11.9
10	Growth of M3	19.8	15.7	16.2	17.0	19.8	17.1
11	Call rate	9.4	17.1	7.4	8.0	7.8	9.1
12	Center’s GFD/GDP	– 5.7	– 5.1	– 4.9	– 5.9	– 6.4	– 5.6
13	CAD/GDP	– 1.0	– 1.6	– 1.2	– 1.3	– 1.0	– 0.9
14	Exchange rate (INR/USD)	31.40	33.45	35.50	37.16	42.07	43.33

Note: The yearly rates of change are calculated as averages of annualised monthly rates of change.

Appendix Table 2

Select indicators of the Indian capital market

		1994-95	1995-96	1996-97	1997-98	1998-99	1999-2000
1	BSE SENSEX (1978-79 = 100)	3,974.91	3,288.68	3,469.24	3,812.86	3,294.78	4,658.63
2	P/E ratio	41.24	19.92	15.34	14.51	12.86	19.76
3	Yield (% per annum)	0.75	1.25	1.54	1.53	1.82	1.23
4	Turnover (INR billions)	677.49	500.64	1,242.84	2,078.45	3,119.99	6,850.28
5	Turnover/GDP (%)	6.7	4.2	9.1	13.7	17.7	35.1
6	Market capitalisation (INR billions)	4,688.37	5,637.48	4,639.15	5,603.25	5,429.42	9,128.42
7	Market capitalisation/GDP (%)	43.1	44.5	34.1	37.0	30.9	46.8
8	Capital raised through public and rights issues	276.32	208.03	148.76	45.7	55.86	72.89

Note: Excepting item 8, all data pertain to the Bombay Stock Exchange.

Sources: Annual Report, Reserve Bank of India, various issues; Survey of Indian Industries, SEBI-NCAER

Appendix Table 3

Time series properties of the variables: Dickey-Fuller and augmented Dickey-Fuller statistics without a trend

(period of estimation: April 1994 to March 2000)

	Interest rate	M3 growth	Output gap	Stock price inflation	Gold price inflation	Manufacturing price inflation
1. Without a time trend						
DF	–4.974	–2.381	–4.192	–2.030	–1.549	–0.925
ADF(1)	–3.740	–1.720	–2.241	–2.182	–1.771	–1.286
ADF(2)	–2.831	–1.624	–1.845	–3.120	–1.735	–1.335
ADF(3)	–2.055	–1.568	–1.721	–3.099	–1.885	–1.311
ADF(4)	–2.037	–1.317	–1.948	–3.212	–1.761	–1.022
ADF(5)	–1.802	–2.146	–2.481	–3.588	–1.876	–1.000
ADF(6)	–1.922	–3.462	–2.730	–3.495	–1.907	–1.597
ADF(7)	–2.129	–3.412	–2.506	–3.941	–1.907	–1.492
ADF(8)	–2.166	–2.920	–2.215	–3.128	–1.722	–2.302
ADF(9)	–2.046	–2.392	–2.246	–3.045	–2.039	–2.234
ADF(10)	–2.141	–2.241	–2.068	–2.530	–2.648	–2.246
ADF(11)	–2.078	–2.845	–2.183	– 2.872	–2.299	–1.694
ADF(12)	–2.018	–1.784	–1.597	–2.084	–1.499	–2.126
2. With a time trend						
DF	–5.198	–2.349	–4.157	–2.026	–1.391	–1.311
ADF(1)	–4.021	–1.688	–2.179	–2.170	–1.717	–1.979
ADF(2)	–3.154	–1.591	–1.747	–3.107	–1.674	–2.036
ADF(3)	–2.430	–1.543	–1.599	–3.158	–1.869	–1.902
ADF(4)	–2.434	–1.279	–1.864	–3.269	–1.696	–1.940
ADF(5)	–1.990	–2.168	–2.519	–3.664	–1.709	–2.118
ADF(6)	–2.220	–3.687	–2.814	–3.671	–1.768	–2.382
ADF(7)	–2.465	–3.798	–2.555	–3.999	–1.824	–2.338
ADF(8)	–2.567	–3.316	–2.244	–3.209	–1.685	–2.836
ADF(9)	–2.462	–2.644	–2.120	–3.064	–2.051	–2.690
ADF(10)	–2.589	–2.304	–2.041	–2.576	–2.781	–2.838
ADF(11)	–2.514	–3.444	–2.760	–2.939	–2.366	–2.002
ADF(12)	–2.558	–1.638	–1.805	–2.237	–1.029	–1.520

Note: 95% critical value for the ADF statistics without a time trend is –2.90 and with a time trend is –3.47.

On price level stability, real interest rates and core inflation[1]

Sándor Valkovszky and János Vincze, National Bank of Hungary, April 2001

Abstract

The paper addresses several issues pertaining to the problem of monetary policy, inflation measurement and relative prices. After some preliminary empirical analysis showing that the problem must be relevant, we set out to conduct a mainly theoretical investigation. If the per period utility function is not homothetic in the commodity vector, empirical price aggregates do not have exact theoretical counterparts, and their properties, as well as those that are calculated from them (such as real interest rates), must be interpreted with care. We examine the consequences of goods heterogeneity in the framework of a stochastic dynamic equilibrium model without a steady state. To solve the model we posit specific, though we think plausible, assumptions concerning fiscal policy in a small open economy. Conclusions are obtained with important policy implications to the effect that inflation variability may be tolerated, and that the correct meaning and interpretation of real interest rates may run counter to accepted ideas. Our general conclusion is that neglecting goods heterogeneity may, in certain circumstances, grossly mislead policymakers and analysts.

1. Introduction

We start from a few propositions related to monetary (exchange rate) policies and inflation, which are applied, though not restricted, to transition countries in central and eastern Europe.

1. CPI inflation must be stable and low.
2. While the real exchange rate must be relatively stable, strict pegs should be avoided because they do not give monetary policy the opportunity to control inflation via control of the real interest rate.
3. The conduct and/or evaluation of monetary policy must rely on a core, or underlying, inflation concept.

These propositions are not unanimously upheld, but each of them musters a significant degree of endorsement. The first can be derived from the Maastricht criteria that are to be satisfied by countries wishing to join the European Union in the foreseeable future. The second has acquired wide currency in general, and the third has sneaked into central bank practice and has held and gained ground among financial analysts and in academic circles.

In this paper we develop arguments to the effect that none of the above claims is unquestionable. We focus on transition countries, but many of our arguments have broader validity. The main novelty of our approach lies in discarding the assumption of homothetic consumer preferences. We model an economy where consumers buy several goods (one of them durable) and services, and where their preferences are represented by the addilog utility function. This functional form has been used, for instance, by Clarida (1996) to estimate demand for imported durables, and by Bils and Klenow (1998) to test competing business cycle theories. One important empirical conclusion of these papers is that the non-homothetic preference specification seems to be confirmed. If we take this for granted then

[1] This paper was presented at the BIS workshop “Modelling aspects of the inflation process and the monetary transmission mechanism in emerging market countries”, Basel, 15-16 January 2001. Helpful remarks by workshop participants and by Péter Benczúr are gratefully acknowledged. The views expressed herein are those of the authors and do not necessarily reflect the social views of the National Bank of Hungary.

the observation that large and non-transitory relative price changes occur in reality raises the possibility that this can be important when we interpret CPI inflation as defined by the usual Laspeyres indices. The present study offers an initial contribution in this direction by building a dynamic general equilibrium model for a small open economy.

We are faced with methodological difficulties in carrying out the proposed approach. As the model contains several types of goods and we assume both non-homothetic preferences and permanent productivity improvement, there is neither a non-stochastic steady state nor a balanced growth path in this model. Linear approximation methods, or non-linear techniques that assume stationarity, are therefore not available options. Also, we want to model a wide variety of shocks which make the state space too large for the easy application of discrete non-linear approximation methods. We generate (almost) exact formulas for price indices, which are obtained by making specific behavioural assumptions concerning government (fiscal) policy. Essentially, it is assumed that fiscal policy is set with a view to controlling aggregate demand in a way that ensures the economy's solvency and observes the rationality of individual decisions.

Section 2 reviews the story of relative and absolute price changes in 1990s Hungary. This is then supplemented with evidence from transition and developed countries, showing that the Hungarian experience can be generalised. In Section 3, a stochastic general equilibrium model serving as a framework for the discussion in subsequent sections is set up and solved in two versions. In the light of these solutions, Section 4 addresses the propositions described in the introduction. First, we explore the consequences of our utility specification for the long-term variability of prices. Second, we ask about the consequences of stabilising prices when monetary policymakers are facing different kinds of shocks. Third, the meaning of real interest rates is analysed. Finally, the various methodologies used to calculate core inflation indices are examined. Section 5 summarises and draws conclusions for further research.

2. The experience with inflation and relative prices in Hungary

Inflation in transition has generated a substantial literature.[2] Here we describe some "internal" features of the inflationary process, having to do with relative price developments. We do not concern ourselves with the reasons for the ups and downs or with the speed of disinflation, etc. The focus will be on Hungary and salient features of price formation will be pointed out. Then the more general transition literature will be invoked to show that these salient features are probably not peculiar to Hungary.

2.1 Relative consumer prices in Hungary

This subsection is based on Valkovszky and Vincze (2001). The following is a short summary of relevant findings.[3]

The investigation was based on a database including the price indices of the 160 items making up the Hungarian consumer price index. First, we tried to identify "tradable" prices. We followed a statistical approach and came to the conclusion that all the goods classified as durable could pass as tradables when this concept is defined as being well explained by nominal exchange rate changes in the long run. In other words, the foreign exchange price of these goods seemed to be stable in the longer term. However, significant short-run deviations could be observed, especially when unexpected changes occurred in the path of the nominal exchange rate. Then we proceeded to investigate relative price changes. We could identify six subaggregates. First, there are non-energy administered (regulated) prices, characterised by infrequent changes. Relative administered prices have exhibited a positive trend and have grown substantially. They show a zigzag picture, undergoing short periods of large hikes, and more protracted periods of almost no change. Clearly, the upward trend was due to the initial "underpricing" of public services, but the exact timing and size of the catching-up process was

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[2] For summaries see Begg (1998), Cottarelli and Boyle (1999) and Wyplosz (1999).

[3] On this topic and in general on the Hungarian CPI, see also Ferenczi et al (2000). On the behaviour of relative prices in transition, see Coorey et al (1998) and, in the case of Slovenia, Cufer et al (1998).

politically motivated. Second came energy prices, which have partly been regulated, but also exposed to world price developments, ie supply shocks from our point of view. The relative energy price was declining at a mild pace until 1995, when it rose steeply, followed by a continued upward trend. This shape was due to deliberate policies, which had checked energy price increases before 1995 for social reasons, while the correction of the relative energy price was part of the fiscal adjustment package of that year. The third category consisted of excisable goods. Their relative prices do not show a zigzag pattern, but certain substantial changes have occurred. On the whole they exhibited a slightly negative relative price trend, which was notably reversed for some time in 1995. Again, political motives were apparently behind the timing of changes. The fourth group included non-processed food prices. These seem to be relatively stable in the long term, but have had cycles, exhibiting not just very large short-term fluctuations, but fluctuations that have apparently been persistent. Fifth, we distinguished processed food prices that have been fairly stable in relative terms. Finally, we could see, as a different subcategory, the remaining service prices. Their development almost mirrored that of durables, exhibiting a slight, but consistently positive, upward trend. This trend, and temporary variations, appeared to be related to wage changes. Thus when the foreign exchange value of wages increased, the relative price of services became temporarily higher, suggesting that a Balassa-Samuelson type hypothesis can be invoked to explain the upward trend as well.

Similar features of price formation are very likely to characterise the inflationary processes of other transition economies. In fact, relative administered public utility and energy prices exhibited the very same pattern in the Czech and Slovak Republics, with the difference that an important upward adjustment of almost 50% took place in 1998-99 and 1999-2000 respectively, while in Hungary and Poland relative prices in this group have followed a rather stable 2-3% per annum upward trend throughout the last five years. The excisable goods group revealed large relative price swings all over the central and eastern European countries (CEECs), admittedly in accordance with the hectic fiscal measures taken. In the second half of the 1990s one can observe, however, a slight upward trend in the relative price of alcoholic beverages and tobacco in many of the CEECs. Unfortunately, due to the lack of comparative databases, we were not able to repeat our study exactly with respect to other transition countries. Even if we cannot reproduce the distinction between processed and non-processed foodstuffs, on the basis of the Eurostat database the whole group of foodstuffs featured as a very volatile part of the CPI basket, not only in the short, but also in the long run. In comparison, the relative price of foodstuffs in the United Kingdom has had a variance roughly one third of that in Hungary in the same period. It is important to mention that the relative food price movements of the countries concerned showed remarkable correlations. This suggests that not only (international) energy prices, but also food prices delivered symmetric external shocks to the region.

Though the following cannot do justice to the whole set of observations, the above description can be summarised in five important stylised facts.

1. A substantial part of the CPI in transition economies, and especially those items that are relatively “durable”, behaves like “textbook” tradables. There is evidence that short-run unpredictable exchange rate changes are not passed on to domestic prices immediately, suggesting that at least a certain degree of nominal rigidity exists.

2. Prices that contain a substantial non-tradable component and are non-regulated seem to conform with the Balassa-Samuelson hypothesis.

3. Agricultural prices impart substantial volatility to the CPI and are heavily influenced by supply shocks. Supply shocks must be broadly understood, including not just changes in weather conditions, but the actions of politicians as well.

4. Public service and household energy prices have generally showed upward trends, with infrequent large changes. This suggests that both political considerations and the costs of changing prices must have played a substantial role in the catching-up process of these prices.

5. There seems to be evidence that the income elasticities and intertemporal substitutabilities of the different subgroups are different. The expenditure share of durables has shown very large variations.

3. The model

Our goal is to build a model for a small open economy where consumers purchase four types of goods:

1. A tradable and durable good;
2. A non-tradable and non-durable good;
3. A non-durable good with rigid but uncertain supply (called "food" hereafter); and
4. A public service.

These goods have different income elasticities of demand, which, in a growing economy, implies that no convergence to stable ratios, ie stationary solution in growth rates, is available. To study the behaviour of aggregate price indices, real interest rates and possible "core inflation" measures, we must construct a dynamic general equilibrium model. In order to focus on the above-mentioned problems, this model economy contains many simplifications. However, they are probably not crucial to the problems at hand and mainly serve to make the exercise manageable. The simplifications include the following: there is no money or physical capital in the model, foreign demand plays only an indirect role via the terms-of-trade effect, labour is supplied in a fixed quantity, international capital markets are passive, and the supply of "food" is exogenous. We also make a shortcut to fiscal policy determination.

3.1 Household behaviour

Households decide at the beginning of each period on how to divide their wealth among two financial assets (domestic government bonds (BH_t) and foreign bonds (BF_t)) and four consumption goods (non-tradable consumption (CN_t), food (CA_t), a publicly provided service (CPI_t) and a durable good (D_t)). Labour supply is rigid and normalised to 1. Disposable wealth includes assets carried over from the previous period, interest earned on them, profits distributed by firms owned by households, and wages paid out by the non-tradable and tradable sectors.

The representative household has a Houthakker (addilog) type per period utility function

$$U\left(CN_t,CA_t,CP_t,D_t\right)=\frac{CN_t^{1-\vartheta^N}}{1-\vartheta^N}+\frac{D_t^{1-\vartheta^D}}{1-\vartheta^D}+\frac{CA_t^{1-\vartheta^A}}{1-\vartheta^A}+\frac{CP_t^{1-\vartheta^P}}{1-\vartheta^P} \tag{1}$$

Thus we assume that services derived from possessing the durable good are proportional to its stock. We assume that $\vartheta^N,\vartheta^D,\vartheta^A$ and ϑ^P are definitely higher than 1, but that $\vartheta^N,\vartheta^D<\vartheta^A,\vartheta^P$, implying that the public service and foodstuffs have lower income elasticities than non-tradables and durables. This statement is a consequence of a fundamental fact about addilog preferences.

Proposition 1: *If preferences belong to the addilog family, i and j are two goods, φ_i and φ_j are income elasticities of demand, and ϑ_i and ϑ_j are utility function parameters, then $\frac{\varphi_i}{\varphi_j}=\frac{\vartheta_j}{\vartheta_i}$ (see Chari and Kehoe (1999)).*

This is the reason why Bils and Klenow (1998) call $\frac{1}{\varphi_i}$ an index of luxuriousness. It must be noted that their empirical results imply that luxuriousness and durability are positively correlated.

Then the household's programme can be written as

$$\max E_t\left[\sum_{r=t}^{\infty}\beta^{T-t}U\left(CN_t,CA_t,CP_t,D_t\right)\right] \tag{2}$$

subject to

$$BH_t + S_t BF_t + PN_t CN_t + PA_t CA_t + PP_t CP_t + T_t +$$
$$PI_t \left(D_t - \left(1-\delta^D\right) D_{t-1}\right) = I_{t-1} BH_{t-1} + S_t I^*_{t-1} BF_{t-1} + W_t + \Pi T_t + \Pi A_t \quad (3)$$

By definition

$$D_t = ID_t + \left(1-\delta^D\right) D_{t-1} \quad (4)$$

where ID_t is the purchase of the durable good.

Let NW_t denote nominal wealth denominated in the home currency in period t. Then one can define the optimal value function in the usual way

$$V(NW_t) = \max_{CN_s, CA_s, CP_s, D_s, BF_s} E_t \left(\sum_{s=t}^{\infty} \beta^s U\left(CN_s, CA_s, CP_s, D_s\right) \right) \quad (5)$$

where

$$NW_t = I_{t-1} NW_{t-1} + \left(S_t I^*_{t-1} - I_{t-1}\right) S_{t-1} BF_{t-1} + W_t + \Pi T_t + \Pi A_t +$$
$$\left(1-\delta^D\right) PI_t D_{t-1} - I_{t-1}\left(PN_{t-1} CN_{t-1} + PA_{t-1} CA_{t-1} + PP_{t-1} CP_{t-1} + PI_{t-1}\left(D_{t-1} - \left(1-\delta^D\right) D_{t-2}\right)\right) - T_t \ . \quad (6)$$

Under certain conditions this exists, and the maximum principle can be written as

$$V\left(NW_t, \ldots\right) = \max_{CN_s, CA_s, CP_s, D_s, BF_s} \left(U\left(CN_t, CA_t, CP_t, D_t\right) + \beta E_t\left(V\left(NW_{t+1}, \ldots\right)\right)\right). \quad (7)$$

The set of first-order conditions for this problem can be derived by differentiating (5) with respect to the decision variables, making the first derivatives equal to zero, and using the envelope condition applied to (7).

Let us define the auxiliary variable Λ_t (the marginal indirect utility of nominal wealth in t).[4]

The following is the standard dynamic first-order condition:

$$\Lambda_t = I_t \, \beta E_t\left(\Lambda_{t+1}\right) \quad (8)$$

It can be proved that

$$\Lambda_t = \frac{CN_t^{-\vartheta^N}}{PN_t} \quad (9)$$

Then we can obtain the following intratemporal first-order conditions:

$$\frac{PN_t}{PA_t} = \frac{CN_t^{-\vartheta^N}}{CA_t^{-\vartheta^A}} \quad (10)$$

$$\frac{PN_t}{PP_t} = \frac{CN_t^{-\vartheta^N}}{CP_t^{-\vartheta^N}} \quad (11)$$

$$\frac{PI_t}{PN_t} = \frac{D_t^{-\vartheta^D}}{CN_t^{-\vartheta^N}} + \beta\left(1-\delta^D\right) E_t \left(\frac{PI_{t+1}}{PN_{t+1}} \frac{CN_{t+1}^{-\vartheta^N}}{CN_t^{-\vartheta^N}} \right). \quad (12)$$

One can also derive, from the optimal choice between domestic and foreign bonds, the portfolio choice equation

[4] This is the partial derivative of the value function associated with the consumer's maximisation problem with respect to nominal wealth.

$$E_t\left(\Lambda_{t+1}\left(I_t - I_t^* \frac{S_{t+1}}{S_t}\right) = 0\right) \tag{13}$$

The transversality condition may be written as

$$\lim_{T\to\infty} E_t\left[\frac{\beta^{T-t}\Lambda_{t+T}}{\Lambda_t} NW_{t+T}\right] = 0$$

for all *T.*

3.2 Production

Production has a hierarchical structure. Differentiated producers produce a continuum of tradable goods using homogenous labour with diminishing returns to scale technology. We assume that tradable producers are distributed on $(0, 1)$ uniformly. This output can be sold domestically or exported. If sold domestically, a competitive sector aggregates these differentiated products into a domestically produced tradable aggregate. Then another competitive sector produces, via a CES technology, an intermediate input-capital good aggregate of this domestic tradable aggregate and of an imported good. Non-tradables are made from this latter good and by homogenous labour via a Cobb-Douglas technology. In addition, the food product is produced randomly and a public good service is provided at zero cost.

3.2.1 The tradable sector

We assume that the production function is

$$QT_{jt} = \theta_t LT_{jt}^{\alpha} \tag{14}$$

where QT_{jt} is the quantity of output, LT_{jt} labour, and θ_t and α are production function parameters.

Output can be sold either domestically or abroad (exports).

$$QT_{jt} = X_{jt} + Z_{jt} \tag{15}$$

where X_{jt} is domestic purchases, and Z_{jt} exports.

First, let us assume that prices are flexible and that firms set period *t* prices based on current information. Firms are assumed to be price-takers in international markets and price-makers at home. A firm entering period *t* + 1 has to decide on how much to produce and what price to charge at home. This assumption implies the ability to price discriminate and leads to a higher domestic price at home than abroad. Thus if the firm produces a certain amount of its product and faces the problem of dividing it between domestic sales and exports, it will first satisfy domestic demand and then export the rest. The possibility of international price discrimination can be explained by the presence of transportation and other transaction costs (tariffs, etc) that make perfect arbitrage impossible. This problem can be written as

$$\max_{PQ_{jt}, LT_{jt},} PX_t\left(\theta_t LT_{jt}^{\alpha} - X_{jt}\right) + PQ_{jt}X_{jt} - W_t LT_{jt} \tag{16}$$

where PQ_{jt} is the domestic price, and W_t the nominal wage. Moreover

$$PX_t = PX_t^* S_t \tag{17}$$

is the (common) export price expressed in domestic currency, PX_t^* is the export price in foreign currency and S_t is the nominal exchange rate. To carry out maximisation the firm must take into account the demand function (see below), which is supposed to be known by the seller and has a price elasticity ϕ which is identical across firms. Then profit maximisation implies the following formula for domestic tradable prices:

$$PQ_{jt} = PX_t \frac{\phi}{\phi - 1}. \tag{18}$$

The role of marginal cost is assumed by the exchange rate, which is the marginal opportunity cost of selling in the domestic market.

Labour demand can be explicitly expressed from the other first-order condition as

$$LT_{jt} = \left(\frac{\alpha \theta_t PX_t}{W_t} \right)^{\frac{1}{1-\alpha}} \tag{19}$$

Now we can consider nominal rigidity in price setting, by assuming that period $t + 1$ prices must be set based on period t information. Only one equation changes, namely the equation determining home-produced tradable prices. The new formula is the following:

$$PQ_{t+1} = \frac{\phi}{\phi - 1} \frac{E_t \left(S_{t+1} PX^*_{t+1} \Lambda_{t+1} \right)}{E_t (\Lambda_{t+1})} \tag{20}$$

Thus the marginal opportunity cost, the variable to be marked up, is modified by taking uncertainty into account. The effective marginal opportunity cost $\left(\frac{E_t \left(PX^*_{t+1} S_{t+1} \Lambda_{t+1} \right)}{E_t (\Lambda_{t+1})} \right)$ is higher (lower) than the expected export price if the export price and the marginal utility of nominal wealth are positively (negatively) correlated, since

$$\frac{E_t \left(PX^*_{t+1} S_{t+1} \Lambda_{t+1} \right)}{E_t (\Lambda_{t+1})} = E_t \left(PX^*_{t+1} S_{t+1} \right) + \frac{\mathrm{cov}_t \left(\Lambda_{t+1}, PX^*_{t+1} S_{t+1} \right)}{E_t (\Lambda_{t+1})}.$$

As usual, if shocks are small in the sense that $PX^*_{t+1} S_{t+1} \leq PQ_{j,t+1}$ it is surely ex post rational to satisfy domestic demand at the predetermined prices. In the following, this is always assumed to be the case.

Assuming tradable firms are uniformly distributed on the interval (0, 1), the aggregate input demand functions are exactly the same as that of the individual demand functions, with the superscripts omitted.

To derive the demand elasticity we start with the Dixit-Stiglitz technology for the aggregate home tradable good

$$X_t = \left(\int (X_{jt})^v \, dj \right)^{\frac{1}{v}} \tag{21}$$

Then the aggregate domestic tradable price index PQ_t can be written as

$$PQ_t = \left(\int (PQ_{jt})^{\frac{v}{v-1}} \, dj \right)^{\frac{v-1}{v}} \tag{22}$$

and the demand for the jth good as

$$X_{jt} = \left(\frac{PQ_{jt}}{PQ_t} \right)^{\frac{1}{v-1}} X_t \tag{23}$$

Thus $\phi = \frac{1}{v - 1}$

To complete our description of the intermediate-capital good (tradable) sector, we define a Cobb-Douglas technology as follows:

$$Y_t = X_t^{\rho} M_t^{1-\rho} \quad (24)$$

Then price and demands can be derived as

$$PI_t = \rho^{-\rho}(1-\rho)^{1-\rho} PM_t^{\rho} PQ_t^{1-\rho} \quad (25)$$

$$X_t = (1-\rho)\frac{PI_t}{PQ_t} Y_t \quad (26)$$

$$M_t = \rho \frac{PI_t}{PM_t} Y_t \quad (27)$$

where

$$PM_t = PM_{t^*} S_t \quad (28)$$

is the import price in domestic, and PM_t^* the import price in foreign currency.

3.2.2 The non-tradable sector

When the Cobb-Douglas technology is written as

$$QN_t = LN_t^{\eta} YN_t^{1-\eta} \quad (29)$$

prices and demand satisfy

$$PN_t = \eta^{\eta}(1-\eta)^{1-\eta} W_t^{\eta} PI_t \quad (30)$$

$$LN_t = (1-\eta)\frac{PN_t}{W_t} QN_t \quad (31)$$

$$YN_t = \eta \frac{PN_t}{PI_t} QN_t \quad (32)$$

3.2.3 Food sector

Here we assume that food products cannot be both exported and imported and that decisions are taken one period in advance, before the realisation of technological uncertainty. (Alternatively, technological uncertainty can be reinterpreted as involving quotas). Output is purely stochastic, and it is equal to consumption.

$$QA_t = CA_t \quad (33)$$

3.2.4 Public service sector

Provision of the public service (QP_t) requires tradable input proportionally, and is supplied elastically to satisfy household demand for it.

$$YP_t = QP_t \quad (34)$$

$$QP_t = CP_t \quad (35)$$

where YP_t is input demand for tradables, and CP_t household demand for the public service.

3.3 Market equilibrium

3.3.1 Goods markets

There is a non-trivial goods market for the intermediate-capital good and a trivial one for the non-tradable good. Market clearing requires

$$Y_t = YN_t + ID_t + YP_t \tag{36}$$

and

$$QN_t = CN_t \tag{37}$$

3.3.2 Labour market

Labour market equilibrium is equivalent to

$$1 = LN_t + LT_t \tag{38}$$

3.4 Exogenous variables

Exogenous variables of the model include the (euro) import price $\left(PM_t^*\right)$, the (euro) export price $\left(PX_t^*\right)$, the (euro) interest rate $\left(I_t^*\right)$, productivity in the home tradable sector (θ_t) and food supply (CA_t).

3.5 Policy

Government policy has three interrelated aspects. Policy is generically defined in the following way:

$$f_P\left(PM_t^*, PX_t^*, I_t^*, \theta_t, CA_t, \Omega_{t-1}\right)$$

where Ω_{t-1} is the set of period t – 1 variables. In other words, the government can set these variables based on past information as well as on the current realisation of shocks.

3.5.1 Pricing of the public service

Efficiency would require setting

$$PP_t = PI_t \tag{39}$$

However, we assume that public service prices must be predetermined and cannot adjust to shocks immediately. We also allow for the possibility that the government may wish prices to deviate from marginal costs for reasons of taxation. Thus we assume the existence of a general relationship such as

$$PP_{t+1} = F_{PP}\left(\Omega_{t-1}\right)E_t\left(PI_t\right) \tag{40}$$

Here $F_{PP}\left(\Omega_{t-1}\right)$ is assumed to be a stationary mark-up. One can see that the government can affect the price level by changing mark-up unless monetary policy strives to dampen it. However, this should not involve conditional variability, ie price level uncertainty, whatever the nominal exchange rate policy.

3.5.2 Demand management

Let us define the marginal utility of nominal euro wealth as

$$\Lambda_t^e = S_t \Lambda_t \tag{41}$$

The government is supposed to be able to set the marginal utility of nominal euro wealth as

$$\Lambda_t^e = f_{PD}\left(\Omega_{t-1}, PM_t^*, PX_t^*, I^*{}_t, \theta_t, CA_t\right) \tag{42}$$

under the implementability constraints:

$$\Lambda_t^e = \beta I_t^* E_t\left(\Lambda_{t+1}^e\right) \tag{43}$$

Our shortcut to policy determination means that via these instruments the government can, to a certain extent, control the marginal utility of euro wealth in the economy. Euro wealth is a real variable for a small open economy and it is generally believed that domestic spending is an important concern for governments in countries where foreign debt is not insignificant. The exogeneity of foreign interest rates makes the debt process of small open economies inherently unstable. Thus some feedback regulation by the government may indeed be necessary (see below for details on the feasibility of this policy formulation).

3.5.3 Monetary (exchange rate) policy

Monetary policy has two varieties:

Fixed exchange rate:

$$S_t = 1, \tag{44}$$

and flexible exchange rates

$$S_t = F_{pM}\left(\Omega_{t-1}, PM_t^*, PX_t^*, I_t^*, \theta_t, CA_t\right) \tag{45}$$

Since, in this model, trends in the nominal exchange rate do not make sense, the exchange rate is supposed to be stationary. Identifying monetary policy with exchange rate policy in this model without money is more attractive than the alternative of identifying it with interest rate policy, since it avoids questions of indeterminacy. Defining exchange rate flexibility simply by allowing for its response to shocks also seems plausible.

3.6 Solution of the model

The endogenous part can be solved in the following order. A first set of equations can be solved from the exogenous and policy processes directly.

$$PM_t = PM_t^* S_t \tag{46}$$

$$PX_t = PX_t^* S_t \tag{47}$$

For the fully flexible price version

$$PQ_t = PX_t \frac{\phi}{\phi - 1} \tag{48}$$

whereas in the version with nominal price rigidity

$$PQ_t = \frac{\phi}{\phi - 1} \frac{E_{t-1}\left(PX_t^* \Lambda_t^e\right)}{E_{t-1}\left(\dfrac{\Lambda_t^e}{S_t}\right)} \tag{49}$$

The expectations on the right-hand side depend only on exogenous and policy variables and can thus be calculated if those processes are known. The next block of equations includes

$$PI_t = \rho^{\rho}\left(1-\rho\right)^{1-\rho} PM_t^{\rho} PQ_t^{1-\rho} \tag{50}$$

$$PA_t = \frac{CA_t^{-\vartheta^A} S_t}{\Lambda_t^e} \tag{51}$$

$$CP_t = \left(\frac{\Lambda_t^e}{S_t} PP_t\right)^{-\frac{1}{\vartheta^P}} \tag{52}$$

$$I_t = \frac{I^*{}_t}{S_t} \frac{E_t\left(\Lambda_{t+1}^e\right)}{E_t\left(\frac{\Lambda_{t+1}^e}{S_{t+1}}\right)} \tag{53}$$

Again, the right-hand side expectations are computable from the exogenous variables and policy processes.

Then the labour market equilibrium can be used to determine nominal wages as a function of previously solved-for variables.

$$1 = \left(\frac{\alpha\theta_t PX_t}{W_t}\right)^{\frac{1}{1-\alpha}} + \frac{\left[\eta^{\eta}(1-\eta)^{1-\eta}(1-\eta)PI_t\right]^{\frac{\eta\vartheta^N-\eta}{\vartheta^N}} S_t}{W_t^{\frac{\vartheta^N-\eta\vartheta^N+\eta}{\vartheta^N}} \Lambda_t^e} \tag{54}$$

This is an implicit equation that cannot be solved explicitly. If it is solved for W_t, the rest of the system can be computed recursively. Regarding this equation as a function of W_t (the other variables are predetermined and positive) then $\frac{\vartheta^N - \eta\vartheta^N + \eta}{\vartheta^N} > 0$ implies that the right-hand side is monotonically decreasing. It approaches ∞ as W_t approaches 0 and approaches 0 as W_t approaches ∞. Thus there is a unique solution.

$$LT_1 = \left(\frac{\alpha\theta_t PX_t}{W_t}\right)^{\frac{1}{1-\alpha}} \tag{55}$$

$$QT_t = \theta_t LT_t^{\alpha} \tag{56}$$

$$PN_t = \eta^{\eta}(1-\eta)^{1-\eta} W_t^{\eta} PI_t \tag{57}$$

$$CN_t = \left(\frac{\Lambda_t^e}{S_t} PN_t\right)^{-\frac{1}{\vartheta^N}} \tag{58}$$

$$LN_t = (1-\eta)\frac{PN_t}{W_t} CN_t \tag{59}$$

$$YN_t = \eta \frac{PN_t}{PI_t} CN_t \tag{60}$$

$$D_t = \left[\frac{PI_t\Lambda_t^e}{S_t}\left(1-\beta\left(1-\delta^D\right)E_t\left(\frac{PI_{t+1}\Lambda_{t+1}^e S_t}{PI_t\Lambda_t^e S_{t+1}}\right)\right)\right]^{-\frac{1}{\vartheta^D}} \tag{61}$$

The expectation $E_t\left(\frac{PI_t\Lambda_{t+1}^e S_t}{PI_t\Lambda_t^e S_{t+1}}\right)$ can be computed again from the basic processes.

When the rental price of durables is defined as

$$PR_t = PI_t\left(1-\beta\left(1-\delta^D\right)E_t\left(\frac{PI_{t+1}\Lambda_{t+1}^e S_t}{PI_t\Lambda_t^e S_{t+1}}\right)\right) \tag{62}$$

the rest of the system may be written as

$$ID_t = D_t - \left(1 - \delta^D\right) D_{t-1} \tag{63}$$

$$Y_t = YN_t + ID_t + CP_t \tag{64}$$

$$X_t = (1 - \rho) \frac{PI_t}{PQ_t} Y_t \tag{65}$$

$$M_t = \rho \frac{PI_t}{PM_t} Y_t \tag{66}$$

$$Z_t = QT_t - X_t \tag{67}$$

3.6.1 Justifying the solution

The above formulas refer to a subset of the variables of the model. We have not imposed any feasibility constraints on the equilibrium processes. To make economic sense, the resulting equilibrium must satisfy transversality or no-Ponzi game conditions for both the private sector and the government. We also left open the problem of portfolio decisions; in other words the behaviour of capital markets. To argue for the validity of the (sub)solution obtained, we proceed via several steps.

1. How does the long-run financial position of the private sector behave for a given demand policy? It is clear that different demand policies would lead to quite different present values of net future spending. In other words, any randomly selected aggregate demand policy that satisfies the implementability condition is very unlikely to result in a feasible equilibrium.

2. Can the government make any private income spending plan feasible? The answer is yes, provided that the government has the ability to adjust (lump-sum) taxes appropriately. With no restriction on taxes, the government can make a transfer each period that balances private sector accounts so that no borrowing or lending by households occurs.

3. Is this enough to make the proposed equilibrium feasible for the whole economy? Even though transfers between the government and the private sector do not affect the overall budget constraint, an arbitrary (implementable) aggregate demand policy may still be non-feasible for the economy as a whole. However, the government has another instrument, namely real government spending. Suppose the government spends on importables, which may even enter the household utility function in an additive way and not influence the marginal utilities of privately purchased goods. Then the government can adjust its own spending so that the current account is balanced at each period.[5]

Thus one can prove that there are, and in fact must be many, government policies that support an equilibrium for a given (implementable) aggregate demand policy. These policies also imply zero asset trade in equilibrium. In fact, in equilibrium models with government spending it is obviously the case that government spending has an impact on private consumption. Thus, simply stated, our assumption is as follows: the government can control aggregate demand constrained by the implementability condition. If we were interested in optimal policy analysis we should specify the welfare consequences of fluctuations in government spending, or try to model a realistic tax structure. These considerations are not necessary for our present purposes. Also, it may be feared that some demand policies would have widely unrealistic consequences for the path of government spending and taxes. Therefore, if one wished to carry out numerical calculations with the model, attention should be restricted to policies that are reasonable in a vague sense; ie they are easily interpretable demand policies involving parameters that do not result in extreme fluctuations in either expenditures or taxes.

[5] Non-negativity constraints should of course be observed.

3.7 Price formulas

Above we showed how the model can be solved recursively. Here, we derive the formulas for prices expressed as functions of policy and exogenous variables as far as it is possible or convenient.

Food prices are

$$PA_t = \frac{CA^{-\vartheta_\alpha} S_t}{\Lambda_t^e} \tag{68}$$

or

$$pa_t = -\vartheta_a ca_t - \lambda_t^e + s_t \tag{69}$$

where lower case letters denote logs of the corresponding variable.

Thus, food prices are determined by monetary policy, demand policy and the agricultural supply shock, with the latter's impact depending on the ϑ_a parameter. When this is large (ie foodstuffs are less luxurious), supply shocks have larger impacts on both absolute and relative food prices.

Flexible durable prices can be expressed as

$$PI_t = \rho^\rho (1-\rho)^{1-\rho} PM_t^{*\rho} \left(\frac{\phi}{\phi-1} PX_t^* \right)^{1-\rho} S_t \tag{70}$$

or in logs

$$pi_t = \log\left(\rho^\rho (1-\rho)^{1-\rho}\right) + \rho pm_t^* + (1-\rho)\log\left(\frac{\phi}{\phi-1}\right) + (1-\rho) px_t^* + s_t \tag{71}$$

With full price flexibility, demand policy has no impact on durable prices, though exchange rates have a unitary elasticity. In this case, import and export prices contribute to durable price inflation with weights corresponding respectively to the import share and 1 minus the import share in the intermediate sector. The $(1-\rho)\log\left(\frac{\phi}{\phi-1}\right)$ term means that durable prices have a higher level when there is a larger domestic distortion as expressed by the mark-up term in the pricing formula for tradable production.

In the case of price rigidity, (70) becomes

$$PI_t = \rho^\rho (1-\rho)^{1-\rho} PM_t^{*\rho} \left(\frac{\phi}{\phi-1} \frac{E_{t-1}\left(PX_t^* \Lambda_t^e\right)}{E_{t-1}\left(\frac{\Lambda_t^e}{S_t}\right)} \right)^{1-\rho} S_t^\rho \tag{72}$$

A second-order approximation (exact in the case of log normality) gives

$$pi_t = \log\left(\rho^\rho (1-\rho)^{1-\rho}\right) + \rho pm_t^* + (1-\rho)\log\left(\frac{\phi}{\phi-1}\right) + \rho s_t +$$

$$(1-\rho)\left(E_{t-1}\left(px_t^* + s_t\right) + \frac{1}{2}\mathrm{var}_{t-1} px_t^* + \frac{1}{2}\mathrm{var}_{t-1} s_t + \mathrm{cov}_{t-1}\left(\lambda_t^e, px_t^*\right) - \mathrm{cov}_{t-1}\left(\lambda_t^e, s_t\right) \right) \tag{73}$$

The direct impact of the exchange rate is blunted, as it manifests itself only via the import price. However, both monetary and demand policy expectations matter. The expected exchange rate has a direct positive impact and exchange rate variability adds to the price level as well. We can call monetary and fiscal policies *parallel* if devaluations tend to be accompanied by expansionist aggregate demand policies. Parallelism means that $\mathrm{cov}_{t-1}\left(\lambda_t^e, s_t\right)$ is negative in our model. Thus tradables prices become relatively higher when policy exhibits parallelism.

The price that enters the first-order condition (the demand function) for durables involves the rental price. In the flexible case this may be written as

$$PR_t = \left(\rho^{\rho} (1-\rho)^{1-\rho} PM_t^{*\rho} \left(\frac{\phi}{\phi - 1} PX_t^{*} \right)^{1-\rho} S_t \right) x \tag{74}$$

$$\left(1 - \left(1 - \delta^D\right) E_t \left(\frac{\beta \Lambda_{t+1}^e}{\Lambda_t^e} \left[\frac{PM_{t+1}^{*\ \rho} PX_{t+1}^{*1-\rho}}{PM_t^{*\rho} PX_t^{*1-\rho}} \right] \right) \right)$$

If we use the notation $H_t = 1 - \left(1 - \delta^D\right) E_t \left(\frac{\beta \Lambda_{t+1}^e}{\Lambda_t^e} \left[\frac{PM_{t+1}^{*\ \rho} PX_{t+1}^{*1-\rho}}{PM_t^{*\rho} PX_t^{*1-\rho}} \right] \right)$, then taking logs yields

$$pr_t = \log\left(\rho^{\rho} (1-\rho)^{1-\rho}\right) + \rho pm_t^{*} + (1-\rho) \log\left(\frac{\phi}{\phi - 1} \right) + (1-\rho) px_t^{*} + s_t + h_t \tag{75}$$

The h_t term can be approximated as

$$-h_t \approx \log\left(1 - \delta^D\right) + \log \beta + E_t \left(\lambda_{t+1}^e - \lambda_t^e \right) + \rho E_t \left(pm_{t+1}^{*} - pm_t^{*} \right) + (1-\rho) E_t \left(px_{t+1}^{*} - px_t^{*} \right) +$$

$$\frac{1}{2} \left[\mathrm{var}_t \left(\lambda_{t+1}^e \right) + \rho\, \mathrm{var}_t \left(pm_{t+1}^{*} \right) + (1-\rho) \mathrm{var}_t \left(px_{t+1}^{*} \right) \right] + p\, \mathrm{cov}_t \left(\lambda_{t+1}^e, pm_{t+1}^{*} \right) + (1-\rho) \mathrm{cov}_t \left(\lambda_{t+1}^e, px_{t+1}^{*} \right)$$

$$+ \rho (1-\rho) \mathrm{cov}_t \left(px_{t+1}^{*}, pm_{t+1}^{*} \right), \tag{76}$$

where there is a factor (omitted) that is time-invariant if h_t is stationary as in Clarida (1996). Here, h_t is the deviation of the rental price from the purchase price. Interestingly, in the price flexibility case this deviation does not depend on exchange rate policy. However, it depends on demand policy. An expected contraction (ie a positive $E_t \left(\lambda_{t+1}^e - \lambda_t^e \right)$) depresses the rental price by making the possession of the durable good more valuable in the future. Expected increases in export and import prices have the same qualitative effect. In addition, the demand policies that depend on foreign prices make a contribution. Suppose, for example, that an increase in import prices is associated with a decline in aggregate demand (ie $\rho\, \mathrm{cov}_t \left(\lambda_{t+1}^e, pm_{t+1}^{*} \right)$ is positive). This decreases the rental price by making the purchase of the durable good a hedge against uncertainty. On the other hand, the plausible policy of an aggregate demand expansion following an export price increase would make the purchase a risky investment and would result in an increase in the rental price.

With price rigidity things get to be messy

$$PR_t = \left(\rho^{\rho} (1-\rho)^{1-\rho} PM_t^{*\rho} \left(\frac{\phi}{\phi - 1} \frac{E_{t-1}\left(PX_t^{*} \Lambda_t^e\right)}{E_{t-1}\left(\frac{\Lambda_t^e}{S_t} \right)} \right)^{1-\rho} S_t^{\rho} \right) x \tag{77}$$

$$\left(1 - \left(1 - \delta^D\right) E_t \left(\frac{\beta \Lambda_{t+1}^e S_t^{1-\rho}}{\Lambda_t^e S_{t+1}^{1-\rho}} \left[\frac{PM_{t+1}^{*\ \rho} \left(\frac{E_t\left(PX_{t+1}^{*} \Lambda_{t+1}^e\right)}{E_t\left(\frac{\Lambda_{t+1}^e}{S_{t+1}} \right)} \right)^{1-\rho}}{PM_t^{*\rho} \left(\frac{E_{t-1}\left(PX_t^{*} \Lambda_t^e\right)}{E_{t-1}\left(\frac{\Lambda_t^e}{S_t} \right)} \right)^{1-\rho}} \right] \right) \right)$$

Now the log of the rental prices may be written as

$$pr_t = \log\left(\rho^{\rho}(1-\rho)^{1-\rho}\right) + \rho pm_t^* + (1-\rho)\log\left(\frac{\phi}{\phi-1}\right) + \rho s_t + (1-\rho)E_{t-1}\left(px_t^* + s_t\right) + \frac{1}{2}\mathrm{var}_{t-1}px_t^* +$$

$$\frac{1}{2}\mathrm{var}_{t-1}s_t + \mathrm{cov}_{t-1}\left(\lambda_t^e, px_t^*\right) - \mathrm{cov}_{t-1}\left(\lambda_t^e, s_t\right) + h_t \ . \qquad (78)$$

The approximation of h_t yields

$$-h_t \approx \log\left(1-\delta^D\right) + \log\beta + E_t\left(\lambda_{t+1}^e + \rho pm_{t+1}^* - (1-\rho)s_{t+1}\right) -$$

$$\left(\lambda_t^e + \rho pm_t^* - (1-\rho)s_t\right) + \frac{1}{2}\mathrm{var}_t\left(\lambda_{t+1}^e + \rho pm_{t+1}^* - (1-\rho)s_{t+1}\right) +$$

$$(1-\rho)E_t\left(px_{t+1}^* + s_{t+1}\right) + \frac{1}{2}\mathrm{var}_t\, px_{t+1}^* + \frac{1}{2}\mathrm{var}_t\, s_{t+1}$$

$$+\mathrm{cov}_t\left(\lambda_{t+1}^e, px_{t+1}^*\right) - \mathrm{cov}_t\left(\lambda_{t+1}^e, s_{t+1}\right) - (1-\rho)E_{t-1}\left(px_t^* + s_t\right) + \frac{1}{2}\mathrm{var}_{t-1}px_t^*$$

$$+\frac{1}{2}\mathrm{var}_{t-1}s_t + \mathrm{cov}_{t-1}\left(\lambda_t^e, px_t^*\right) - \mathrm{cov}_{t-1}\left(\lambda_t^e, s_t\right) \qquad (79)$$

Here the main novelty is that both exchange rate and exchange policy expectations play some role. Different exchange rate policies may imply either an increase or a decrease in the riskiness of investing in durables.

Public service prices are set by policymakers as

$$PP_t = F_{PP}\left(\Omega_{t-1}\right)E_{t-1}\left(PI_t\right) \qquad (80)$$

The approximation results in

$$pp_t = f_{PP}\left(\Omega_{t-1}\right) + E_{t-1}\left(pi_t\right) + \frac{1}{2}\mathrm{var}_{t-1}\left(pi_t\right) \ . \qquad (81)$$

One can see that expected intermediate good prices play a role here, and that unexpected changes in the exchange rate have no effect. This pricing assumption thus gives another source of price rigidity, irrespective of the pricing behaviour of tradable producers.

For wages one cannot give an explicit expression, but can determine the sign of the partial derivatives unambiguously. The implicit equation to be solved is

$$\left(\frac{\alpha\theta_t PX}{W_t}\right)^{\frac{1}{1-\alpha}} + \frac{\left[\eta^{\eta}(1-\eta)^{1-\eta}(1-\eta)PI_t\right]^{\frac{\eta\vartheta^N-\eta}{\vartheta^N}} S_t}{W_t^{\frac{\vartheta^N-\eta\vartheta^N+\eta}{\vartheta^N}}\Lambda_t^e} - 1 = 0$$

in both the flexible and rigid cases. However, the comparative statics are different in the two cases. When tradable prices are flexible

$$\partial W_t/\partial S_t = 1 \qquad \partial\frac{W_t}{S_t}\Big/\partial\theta_t > 0 \qquad \partial\frac{W_t}{S_t}\Big/\partial PX_t^* > 0 \qquad \partial\frac{W_t}{S_t}\Big/\partial PM_t^* > 0 \qquad \partial\frac{W_t}{S_t}\Big/\partial\Lambda_t^e < 0 \ .$$

In other words, the exchange rate has a unitary elasticity, and the foreign price, productivity and aggregate demand variables influence the euro wage directly; ie independently of exchange rate policy. All signs are just as expected. The main difference in the price rigidity case is that $\partial W_t/\partial S_t < 1$. The other derivatives should be written in terms of the nominal wage.

$$\partial W_t/\partial\theta_t > 0 \qquad \partial W_t/\partial PX_t^* > 0 \qquad \partial W_t/\partial PM_t^* > 0 \qquad \partial W_t/\partial\Lambda_t^e < 0 \ .$$

These signs can be interpreted as incipient changes in the euro wage as well but, in contrast to the price flexibility case, exchange rate policy can undo any of these. In general one can make a log linearisation that results in the following formula.

$$w_t = a_0 s_t + a_1 \log \theta_t + a_2 px_t^* + a_3 pm_t^* - a_3 \lambda_t^e \,, \tag{82}$$

where a_1, a_2, a_3 and a_4 are positive, time-varying and proportional to the corresponding derivatives, whereas a_0 equals 1 in the flexible case and is positive but less than 1 in the rigidity case.

Non-tradable prices in the case of full price flexibility may be expressed as

$$PN_t = \eta^\eta (1-\eta)^{1-\eta} W_t^\eta \left[\rho^\rho (1-\rho)^{1-\rho} \left(PM_t^*\right)^\rho \left(\frac{\phi}{\phi-1} PX_t^* \right)^{1-\rho} S_t \right]^{1-\eta} \tag{83}$$

The log linear approximation gives

$$pn_t = s_t + \log\left(\eta^\eta (1-\eta)^{1-\eta}\right) + \eta\left(a_1 \log \theta_t - a_3 \lambda_t^e\right) +$$

$$\log\left(\rho^\rho (1-\rho)^{1-\rho}\right) + (1-\rho)\log\frac{\phi}{\phi-1} + \left(\rho(1-\eta) + \eta a_3\right) pm_t^* + \left((1-\rho)(1-\eta) + \eta a_2\right) px_t^* \tag{84}$$

The formula is straightforward: non-tradable prices are influenced by those real variables that enter the formula for nominal wages, ie productivity and aggregate demand.

With rigid home tradable prices

$$PN_t = \eta^\eta (1-\eta)^{1-\eta} W_t^n \left[\rho^\rho (1-\rho)^{1-\rho} PM_t^{*\rho} \left(\frac{\phi}{\phi-1} \frac{E_{t-1}\left(PX_t^* \Lambda_t^e\right)}{E_{t-1}\left(\dfrac{\Lambda_t^e}{S_t}\right)} \right)^{1-\rho} S_t^\rho \right]^{1-\eta} \tag{85}$$

The approximation can be written as

$$pn_t = (\eta + \rho - \eta\rho) s_t + \log\left(\eta^\eta (1-\eta)^{1-\eta}\right) + \eta\left(a_1 \log \theta_t \, a_2 px_t^* - a_3 \lambda_t^e\right) + \log\left(\rho^\rho (1-\rho)^{1-\rho}\right) + (1-\rho)\log\frac{\phi}{\phi-1} +$$

$$\rho(1-\eta) pm_t^* + (1-\rho)\left(E_{t-1}\left(px_t^* + s_t\right) + \frac{1}{2}\mathrm{var}_{t-1} px_t^* + \frac{1}{2}\mathrm{var}_{t-1} s_t + \mathrm{cov}_{t-1}\left(\lambda_t^e, px_t^*\right) - \mathrm{cov}_{t-1}\left(\lambda_t^e, s_t\right)\right) \tag{86}$$

Again, the exchange rate's elasticity is less than 1. Also, uncertainty affects prices by generating risk premium terms. One can find again that parallel policies result in higher prices. Or, in other words, increased parallelism leads to higher inflation. This means, incidentally, that if policy turns from antiparallelism to something like no parallelism, inflation in the non-tradable sector would rise.

From the formulas it can be seen that the aggregate demand variable has an effect on relative prices, irrespective of price rigidity, and that exchange rate policy affects contemporaneous relative prices.

4. Analysis

4.1 Long-run volatility of the price level

Our model has no exact aggregate price index. Aggregate CPI indices used in practice are Laspeyres type indices where individual price indices are averaged by applying past relative expenditures as weights. This would give an exact price index only if preferences belonged to the generalised Leontief type (see Pollak (1983)). If relative expenditures change, then the impact of any of our four price indices on the aggregate CPI also changes. We can create plausible conditions under which, as the economy grows, the expenditure weights on food and public services converge to 0. For the sake of a simple demonstration let us suppose now that $\vartheta_N = 1$; ie non-tradable consumption enters the utility function as a logarithm. Then

$$PN_t \, CN_t = \frac{S_t}{\Lambda_t^e}$$

and

$$PA_t \, CA_t = \frac{CA_t^{1-\vartheta_a} \, S_t}{\Lambda_t^e}$$

imply that

$$\frac{PA_t \, CA}{PN_t CN_t} = CA_t^{1-\vartheta_a}$$

This ratio approaches 0 if the growth rate of the exogenous supply of food is lower than $\vartheta_a - 1$.

For the public service

$$PP_t \, CP_t = \Lambda_t^{e-\frac{1}{\vartheta^P}} \, S_t^{\frac{1}{\vartheta P}} \, PP_t^{1-\frac{1}{\vartheta P}}$$

Under the assumptions made on price formation in the public service sector, and on the assumption that foreign prices are stationary, one can rewrite this equation as

$$PP_t \, CP_t = \Lambda_t^{e-\frac{1}{\vartheta^P}} \, S_t \, G_t$$

where G_t is stationary.

Thus

$$\frac{PP_t \, CP_t}{PN_t \, CN_t} = G_t \, \Lambda_t^{e-\frac{1}{\vartheta^P}}$$

Then assuming that Λ_t^e grows at a negative rate is sufficient to have a vanishing share for expenditure on public services.

If the above conditions are fulfilled, the CPI volatility stemming from public service and food prices decreases as income and consumption grow. Thus even if these prices are more volatile than durable and non-tradable prices, the volatility of the overall index tends to approach the volatility of the latter two as the economy becomes richer.

4.2 Stabilisation of the price level

In our model, irrespective of the price flexibility assumption, exchange rate policy can achieve the stabilisation of any individual price index, except for that of the public service price. A brief inspection of the price formulas shows that all other prices depend on the nominal exchange rate. Thus, if we allow monetary policy to have the power to respond to shocks simultaneously, any CPI aggregate can be stabilised by appropriately adjusting the exchange rate. However, flexible exchange rates may have real effects in the model. In the following we will study this issue through thought experiments. Let us suppose that monetary policy responds in a price level stabilising manner to each of the five shocks. What are the real consequences of, and the possible trade-offs consequent upon, these policies? First we must ask what a price stabilising response means.

Initially, let us suppose that aggregate demand policies of the government are given. Inspecting the formulas demonstrates that for the export and import price and for the productivity variable an increase would lead to a price level increase if the exchange rate were fixed. Thus a strengthening of the exchange rate would be stabilising in these cases. On the other hand, a positive food production shock would result in a reduction in the price level, making depreciation the appropriate response. The foreign interest rate does not figure in any of the formulas; thus changes in it should not draw a response from monetary policy. However, it is clear from the implementability condition that aggregate demand policies are affected by foreign interest rate changes. Thus foreign interest rates may have an indirect effect on prices and we have to ask what this indirect effect is like.

The implementation condition

$$\Lambda_t^e = \beta I_t^* E_t\left(\Lambda_{t+1}^e\right)$$

has one certain implication. Expected aggregate demand must depend on the current foreign interest rate. The aggregate demand expectation has a role in the determination of several prices. It plays a role in the rental price equation, irrespective of price rigidity, and, in the case of rigid prices, influences tradable and non-tradable prices as well. The log linear approximations show, however, that only in the case of the rental price does $E_t\left(\Lambda_{t+1}^e\right)$ have a direct effect on the current price. Otherwise only covariance terms involving surprises are involved in the formulas. In the case of the rental price, a decrease in $E_t\left(\Lambda_{t+1}^e\right)$ (ie an expected increase in future aggregate demand) decreases current demand via a negative effect on the rental price. (This is just the effect of increasing the nominal interest rate on the demand for a capital (durable) good.) However, what is important for us here is the response of fiscal policy to a shock to foreign interest rates. We think of aggregate demand policies as substituting for capital markets to stabilise debt in the economy in question. Since for an indebted country the worsening of borrowing terms would naturally imply a restriction in demand, it is plausible to assume that a current shock to foreign simultaneously rates results in a higher Λ_t^e. It is easy to check that this response entails a reduction in all components of the CPI aggregate, except for public service prices, on which it has no effect. One can conclude that, because of these indirect effects, the appropriate price stabilising response of monetary policy would be to depreciate the nominal exchange rate following an increase in the foreign interest rate.

Now it is time to discard the assumption of constant fiscal policy in the face of shocks. One must ask how fiscal policy responds to the other four shocks, if it is supposed to behave in the manner hypothesised. The answers are plausible enough. Food supply shocks should leave aggregate demand undisturbed. Import price increases could invoke tightening, whereas export price and productivity increases would require more relaxed demand conditions. Changes in the policy mix that stabilise prices via monetary policy and debt via fiscal policy are shown in Table 1 for positive shocks to productivity, export prices, import prices, food supply and foreign interest rates.

Table 1

Type of stock	Policy response	
	Debt stabilising fiscal	**Price stabilising monetary**
Productivity shock	Ease	Tighten
Export price shock	Ease	Tighten
Import price shock	Tighten	Tighten
Food supply shock	Neither	Ease
Foreign rates shock	Tighten	Ease

In the case of import price shocks, it may be that fiscal tightening would achieve price stability without the intervention of monetary policy, or even overshoot so that price stability would require monetary easing.[6] The conjunction of debt and price stabilisation does not in general lead to parallelism. Only in the case of the import price shock do the two policies move in parallel.

[6] It is worth noting that the interplay between responses to these shocks determines the risk premia that are present in three places in the model: the determination of the domestic interest rate, of rigid home tradable prices and of rental prices.

We have summarised how price stabilising monetary policies would work. Next we ask whether there are trade-offs; ie whether there exist negative side effects to such policies that may prevent their application. First, suppose that a negative food supply shock hits the economy and the exchange rate appreciates to restore price stability. Let us look for effects on tradable and import demand. Appreciation has a negative effect on the demand for public services, because of its predetermined nature. Via this it generates a decrease in the demand for tradables. With flexible prices no further effect exists, but with predetermined prices there is a reduction in the demand for non-tradables and durables alike. Thus price stabilisation would lead to an improvement in the current account, except for a change in the relative prices facing home producers. Because of price rigidity, relative prices are changed and imports become relatively cheaper than home tradables. The sign of the effect on the current account depends on the precise configuration of parameters. It is important to note that the effect on the demand for durable expenditures is variable, since it depends on the existing stock and thus on the history of shocks and responses. Whatever the net effect, it remains true that the current account would vary for no good reason at all.

Similar remarks are valid for the other cases as well. Take the example of a positive import price shock. From a debt stabilising point of view, an adjustment via import substitution would be needed. However, the strengthening of the exchange rate as a price stabilising response makes imports cheaper and further deteriorates the current account. Of course, the effects on total demand may make up for this, but this is a point where one could not make any judgements without knowing the parameters. The main point is that whereas changes in aggregate demand can unambiguously take the current account in the desired direction, monetary policy changes may not. In other words, monetary policy as a tool for managing the current account is just a second best solution. Hence, price stabilisation can have current account effects that may vary in time.

What happens if the exchange rate is fixed? In our model, all relative price changes would reflect real variation in exogenous conditions and in fiscal policy. Here, price rigidity coexists with nominal volatility. Hence, from a real allocation point of view, the fixed exchange rate solution seems to be superior. If price stability is also desirable, there is a genuine trade-off, the study of which would require the modelling of the costs of price level instability.

To summarise, we may state that to avoid fortuitous changes implied by using monetary policy to stabilise prices, one may resign oneself to accepting fluctuating prices. Striving for price stability would result in variation in domestic demand and in the current account in ways which depend on deep parameters, are time-varying, and may have no connection to the debt stabilisation objectives. Of course, one can make the course of fiscal policy subject to monetary policy's price stabilising intentions.

Still, fiscal policy may not be easily adjustable and, at any rate, it is limited by the implementability constraint. In sum, relative price variation may be a concern to policymakers and, in certain circumstances, could make them prefer some price level volatility.

4.3 Real interest rates

In the absence of a linear homogenous price aggregate, we have to define an own real interest rate for each good. The own interest rate of a good between *t* and *t+1* is the price of the good delivered in *t* in terms of the same good delivered in *t+1* minus 1. Then the own expected rate of interest of any good with price P_t can be written as

$$r_{t,t+1} = \frac{I_t P_t}{E_t\left(P_{t+1}\right)}$$

Assuming that a second-order approximation is valid, the effect of the real exchange rate on the slope of consumption can be written as

$$E_t\left(c_{t+1}-c_t\right) = \frac{1}{\vartheta}\left(i_t - \left(E_t\left(p_{t+1}\right)-p_t\right) + \log(\beta) + \frac{1}{2}\operatorname{var}_t\left(c_{t+1}\right) - \frac{1}{2}\operatorname{var}_t\left(p_{t+1}\right) + \operatorname{cov}_t\left(c_{t+1}, p_{t+1}\right)\right)$$

One can see that the slope depends on the parameter ϑ, with higher values implying a weaker effect on the expected change in consumption.

For any CPI aggregate we can have a corresponding real interest rate measure, the interpretation of which is, however, not clear at all. To become informed on this issue we first ask what the meaning of an interest rate change in our model is. Using the same approximation again we obtain

$$i_t = i_t^* - s_t + E_t s_{t+1} - \frac{1}{2}\operatorname{var}_t(s_{t+1}) + \operatorname{cov}_t\left(s_{t+1}, \lambda_{t+1}^e\right)$$

Assuming that the expectation terms are constant, there is a one-to-one relationship between the nominal exchange rate and the nominal interest rate. Ceteris paribus, an appreciation implies an immediate increase in the interest rate. Thus the real effects of changing the nominal interest rates are those of unexpected nominal exchange rate changes. We next ask whether these changes are associated with changes in the own real interest rates, and what the correlations between real interest rates, prices and demand are.

For foodstuffs, changes in the interest rate have no independent effect on consumption. Own rates are independent of the level of the nominal exchange rate and no effect via an interest rate demand price channel can exist. For instance, food prices can be stable while the exchange rate and the nominal interest rate fluctuate, resulting in real interest rate variations that have nothing to do with demand or price variation. For the other goods, price rigidity gives rise to real interest rate effects by altering demand. As public service prices are predetermined, a surprise appreciation gives rise to both an increase in the own real rate and a temporary decrease in demand. However, the demand change depends on the ϑ_P (intertemporal elasticity of substitution) parameter and may be rather small. Still, we have here a negative correlation between the real rate and demand. Suppose now that we have a monetary policy that strives to only partially undo any price shock. For concreteness' sake, let us assume that the price level is always set halfway between its no shock value and what the shock would imply if exchange rates were fixed. It is clear that this policy would imply a positive correlation between real interest rates and inflation.

For the non-tradable demand a negative relationship exists in the case of price rigidity, but its strength depends on the degree of implied price rigidity, and also on the preference parameter, ϑ^N. The situation is the most complicated for the rental price. Price rigidity causes a negative correlation between the real rate and demand, but the relationship depends on the amount of stocks; thus it is time-varying. What is also important here is that the relevant price for demand determination is the rental price and not the price of the tradable and durable good. Indeed, one can see from the relevant formulas that since price rigidity has two effects on the rental price, the change in the nominal exchange rate can be magnified. Again, an important conclusion is that the same real rate probably has time-varying effects, depending on the state of the economy.

Does a change in demand influence present or future prices? One way in which current monetary policy may affect future prices is via its effect on the future course of fiscal policy, the Λ_{t+1}^e variable. If we assume that fiscal policy is debt conscious, then a current exchange rate change that increases (decreases) foreign debt leads to an expected increase (decrease) in Λ_{t+1}^e and thereby to downward (upward) pressure on tomorrow's price level. However, this pressure depends on the net effect on imports of exchange rate policy, whose sign is, a priori, uncertain and time-varying.[7]

From the above analysis we have the following general observation about real rates in this economy. With exchange rate flexibility it is possible to obtain a fixed price level by changing nominal and, therefore, real interest rates. This is because prices and real interest rates are not correlated at all, even though real rates and demand are negatively correlated.

A few important conclusions emerge from the above discussion:

– If we want a useful indicator of the real interest rate, supply-determined prices should not be part of the corresponding price index.

[7] Maybe this uncertainty is the cause of a certain schizophrenia exhibited by central bankers. They sometimes wish for a weaker exchange rate and a higher interest rate simultaneously.

- As the demand effects of interest rates depend on intertemporal substitutability, any aggregate index ignoring this can be misleading.
- Because of the existence of durables, the effect of the interest rate on demand must be time-varying.
- A strong positive correlation between prices and real interest rates may signal only partial commitment to price stability.

4.4 Core inflation

Even the term core inflation reflects the desire of many to capture an inherent and presumably essential feature of reported inflation indices. By core inflation different authors refer to things that have similar, but not identical, properties (for a survey see Wynne (1999)). Supporters of one view claim that core inflation is a price index over which monetary policy exerts (direct) influence. On another view it is something which contains little temporary noise. The accurate definition of both criteria would require a model to determine if they are identical or what differences they contain. If an optimal core inflation measure is sought, one cannot ignore the question of what kind of information one intends to distil from it. Now we will consider the consequences of defining core inflation indices in our model. Roughly, our concern is to speculate on what sort of information a specific core index may provide or hide. Of the known domain of methodologies we will look at two general classes: core inflation obtained by excluding certain subgroups and outliers respectively.

4.4.1 Excluding certain subgroups

In order to define a core inflation index a frequently used expediency is to exclude food (or at least certain food) prices from the CPI. In our model, quite naturally, food prices contain information not only on supply shocks, but on demand and monetary policies as well. Thus excluding food prices may prevent one from judging whether monetary policy intends to stabilise the price level. However, our model also suggests that responding to supply shocks may have unwanted side effects, generating relative price and domestic demand variation. If this is thought to be a nuisance then monetary policy has a reason to neglect food supply shocks. This is a decision based on a judgement concerning the trade-off between the adverse effects of price level instability and real instability. The decision taken on this matter can tell us something about monetary policy.[8]

Another common expediency is to exclude public sector prices or changes in indirect taxes. There is a certain plausibility to the idea that these prices may provide useful information on future monetary policy and inflation as long as their pricing is motivated by price expectations (see Cecchetti and Groshen (2000)). However, in practice, the monthly variation of public service prices has been high in the transition economies, as noted above. Political considerations have caused another type of uncertainty. Though adjustments have usually been made once a year, this adjustment was not realised in every year. Thus in the catch-up period, the information provided by these prices may have been very noisy.

Excluding durable prices has probably never been considered. Still, this could be useful if, in certain circumstances, durable prices were a very noisy signal of true rental prices.[9] In principle, rental prices contain useful information on policy since they inform on expectations. Of course, an important empirical problem is whether the supply of durables is capable of adjusting promptly to shocks. In our model this is assumed, but on some real markets it may be far from the truth. In this case, rental prices may be similar to food prices.

Excluding non-tradable prices has not been considered either. In our model they are probably the most synthetic variable, containing information on many aspects of the economy. Therefore, this information may not be peculiar to monetary policy, and demand and tax policies may have substantial roles in determining non-tradable prices in the short run. On the other hand, technological shocks may

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[8] Of course, the size of shocks can also be an influential motive to neglect these shocks.

[9] If durable prices are included because they are related to transactions' demand for money, then it is not clear why house or share prices are not included in the price index to be watched or stabilised.

have permanent effects, making non-tradable prices less than perfect for signalling the stance of monetary policy.

In sum, one can have arguments for and against excluding the usual candidates from the CPI. One can even have reasons to exclude those subgroups that are normally considered to belong to the core. Concrete circumstances and purposes are decisive.

4.4.2 Excluding outliers

Trimming is hallowed as a method to filter out temporary noise, without the need to identify beforehand the possible origin of this noise. However, it has been argued that trimming may discard very good information if certain price-makers set prices according to expectations (see Bakshi and Yates (1998)). This may be a reason why infrequently changed public service prices should not be excluded at the time when they are changed, even if they seem to be outliers at that moment. An important aspect of our model is that a price stabilising monetary policy narrows the spread between predetermined public service prices and those that are at least partially responsive to exchange rate shocks immediately. In this sense, if policy is required to actively stabilise the price level, then large spreads of the distribution may signal that policy is not up to this task. On the other hand, the relative price of foodstuffs in terms of, say, non-tradables can be either larger or smaller, depending on the exact state of shocks. Thus we must know more about the nature of relative price changes before attributing them to noise. Indeed, it seems somewhat incredible to claim that central banks cannot do anything about food or energy prices (see, for instance, Blinder (1997)) that may become outliers more frequently than others. Still, as we have seen, central banks might have reasons to do little about these prices. This is, however, a signal of preferences and not of feasibility.

4.4.3 Discussion

We conclude that if one wants to justify adjustments to the price index or define an appropriate price index, one must be very specific about the structure of the economy and what is expected of monetary policy. We believe that core indices make sense as long as they have a useful function for policymakers or analysts, and not because they grasp some fundamental feature of never-changing reality. Thus the concept of core inflation cannot be seen as either a purely statistical phenomenon or a universal problem that is free of national characteristics. Let us look at a few practical examples.

1. Temporary changes in (non-processed) food supplies. A monetary policy response to such changes may cause large relative price fluctuations and unwarranted real volatility. Therefore, for a central bank caring about this, the right core inflation index should exclude these prices. At the same time, the operation of food markets may vary from country to country. While in some countries such supply shocks occur frequently and tend to cause significant changes in the CPI, in other countries they are supposed to be of no consequence. If the latter is the case, there is no reason to meddle with the price index.

2. Changes in taxation. The issue to resolve here is how persistent the effects on inflation of a specific tax change will be, given the reaction of markets. It also matters whether the real distortion caused by the tax change is of a type that will prompt monetary policymakers to take corrective action on the basis of their preferences and views on the operation of the economy. For example, an increase in labour costs is likely to speed up inflation, and not only in the very short run. An inflation-wary monetary policymaker will conclude from this that tightening may be in order. However, tightening may further aggravate the probable ensuing direct drop in profitability and take the economy towards recession. This is no trivial problem for a monetary policymaker seeking to achieve real economy objectives as well. Easing is another alternative, but the monetary policymaker may also decide not to make any moves. In the latter case, the effect of the tax change may be excluded from the core inflation index.

3. Fuel price changes. Experience has shown that changes in oil prices tend to be persistent, but lacking a permanent positive or negative trend. Central bankers may be faced with the genuine dilemma of whether to treat oil price changes the same way as changes in non-processed food prices or to take them seriously instead. The outcome of their pondering obviously depends on the exposure of a country's price level to fuel prices. Another consideration may be whether monetary policymakers wish to correct the changes in the terms of trade and in the real exchange rate that follow.

We would like to conclude by adding two further practical comments. First, in view of the fact that monetary policy objectives and the structure of the economy may change over time, a correct core inflation index, as well as the weights given to the individual components, may undergo a simultaneous change. Second, the relevance or irrelevance of a particular price shock to core inflation does not depend on whether the shock is temporary or not. The propagating mechanisms might make the most ephemeral shock persistent and relevant.

5. Conclusions

In this paper we investigated the consequences of introducing goods heterogeneity into a stochastic general equilibrium model for a small open economy. The behaviour of individual price series suggests that such an approach is required to answer certain questions. The main body of the study contains a model that serves to clarify ideas and enables us to derive the consequences of some hypotheses. For the sake of treatability we had to make several simplifying assumptions, the most heroic being that regarding fiscal policy. In essence, it is assumed that fiscal policy controls aggregate demand (under an implementability condition) via determining the euro marginal utility of households. What are the most likely shortcomings of the model and how do they influence the inferences we draw?

Excluding money and money demand from models used for the analysis of monetary policy has been in vogue for some time. This certainly makes an already complicated mathematical system more amenable to analysis. However, this may conceivably be misleading. One can give a justification for this neglect of money if one had money-in-the-utility function together with separability assumptions. We see little reason to include such a money demand formulation in the model. However, a plausible specification may bring important changes and new conclusions into the analysis and would be worth trying. This would also necessitate a numerical approach, towards which we want to move anyway.

Our modelling of fiscal policy may raise questions of consistency. A numerical solution of the model may also be useful in checking whether treating Λ_t^e as a (constrained) policy variable is consistent in the sense that one can establish a mapping between this variable and more traditional or fundamental fiscal policy variables.

The present model contains some features that depend on our modelling of price setting. Clearly, there are too few nominal and real rigidities in the model, and all inflation inertia must be attributed to (unexplained) policy inertia. Also, too many of the results may be driven by the assumption of foreign currency pricing of both exports and imports. However, this does not seem to be a totally implausible assumption for small developing economies.

The decomposition of the aggregate CPI as modelled here only partially answers the empirical description reported in Section 2. To make the model more useful for understanding the past and, possibly, for forecasting the future, it may be necessary to add new goods, like energy or commodities, as well as to relax the simplifying assumptions concerning the food sector. This step towards enhanced realism would also lead us to numerical simulations.

Having said that, we can summarise the most important lessons of this study, which may survive future refinements of the model.

First, it seems justified that the conjunction of non-homothetic preferences and permanent relative price changes raises the possibility that some of those notions we mentioned in the introduction should be modified. With respect to price stability, we found that at higher income levels, for any given monetary policy rule, CPI volatility probably declines, and that monetary policies striving for stabilising prices may involve fortuitous changes in real variables. (This result can be contrasted with the finding that stabilising prices is optimal in models with essentially homogenous goods, but differential costs to changing prices.) Concerning real interest rate indicators, we can conclude that they must be calculated with a careful view to differential intertemporal substitutability if they are to make any sense at all. Yet they may still not have the assumed correlation with inflation. Regarding the use of core inflation indices, goods heterogeneity may require other types of considerations than have been developed in the literature.

Second, we were able to derive some interesting hypotheses about price formation, such as those referring to risk premium terms, that may give rise to relative price changes distinct from those stipulated by Balassa-Samuelson type theories. And it turned out that the monetary and fiscal policy mix can modify durable prices; for instance parallelism (as defined above) may cause them to increase.

Third, we obtained assertions about policy. We found that parallelism is not consistent with price stability except when import price shocks are the overwhelming source of fluctuations. Also, trade-offs between price level stability and real stability may exist, and stabilising the price level may have uncertain effects on the current account. Furthermore, because of the existence of durables, or capital goods in general, the effect of monetary policy on demand must be time-varying. Finally, it appears that a strong positive correlation between prices and real interest rates may possibly signal only partial commitment to price stability.

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Monetary policy and the transmission mechanism in Mexico[1]

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Abstract

This paper describes the evolution of monetary policy implementation in Mexico from 1995 to the present. At the beginning of this period, monetary policy was set in terms of a quantitative target. This framework then gradually evolved into one in which discretionary actions of monetary policy, aimed at reaching an inflation target, took on greater relevance. Additionally, we analyse two issues that have recently generated doubts about the effectiveness of the implementation of monetary policy: the use of borrowed reserves as a policy instrument and the effectiveness of monetary policy in affecting inflation by a channel other than the exchange rate. The main results indicate that the behaviour of the real interest rate has been determined by the traditional variables that guide the discretionary actions of any central bank and that this rate has affected aggregate demand and credit in a statistically significant way.

1. Introduction

Since the adoption of the flexible exchange rate regime, as a result of the balance of payments crisis of 1994-95, monetary policy has become the nominal anchor of the economy. In 1995, there was little experience from countries with similar economic characteristics to Mexico that had a flexible exchange regime, which is why the current monetary policy framework is the result of an evolutionary process. This framework has been influenced by the experiences of small, developed economies with a floating regime and, more recently, by other Latin American economies that have adopted similar exchange rate regimes.

In Section 2 of this paper, we describe the evolution of the operation of monetary policy in Mexico from 1995 to the present. At the beginning of this period, monetary policy was set in terms of a quantitative target. This framework then evolved into one in which discretionary actions of monetary policy, aimed at reaching an inflation target, took on greater relevance. By analysing the evolution of the monetary base during the period that followed the crisis, we found that the relationship between the monetary base and prices has been very unstable. These dynamics severely limited the use of the former variable as an indicator of inflationary pressures.

In Sections 3 and 4, we focus on two issues that have recently generated doubts on the effectiveness of the implementation of monetary policy: the use of borrowed reserves as a policy instrument and the effectiveness of monetary policy in affecting inflation by a channel other than the exchange rate. We found, firstly, that in both cases the current monetary policy framework has been effective. This conclusion is sustained by the fact that the behaviour of real interest rates can be explained with the traditional variables that guide the discretionary actions of monetary policy of any central bank. Among these variables we could mention the gap between expected inflation and the inflation target and the output gap. Secondly, it is shown that besides its effect on the exchange rate, the real interest rate has

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affected inflation through the aggregate demand channel. Finally, in Section 5 the main conclusions of the paper are presented.

2. Evolution of the monetary policy framework in Mexico: 1995-2000

The exchange rate and financial crisis that took place at the end of 1994 and during 1995 forced the authorities to adopt a floating exchange rate regime. The use of the exchange rate as the nominal anchor of the economy was therefore abandoned. As a result of the peso devaluation and the rise in inflation, the credibility of the Bank of Mexico was severely damaged. Criticism centred on the lack of transparency regarding the conduct of monetary policy, the dissemination of information and the lack of determination to tighten monetary policy before, during and immediately after the crisis.

Due to this criticism, and to the need to establish a visible and strict nominal anchor, in 1995 a limit on the growth of the central bank's net domestic credit was adopted. This limit was derived from an estimate of the growth of demand for monetary base and a null anticipated accumulation of international reserves. We should clarify that at the time neither that limit nor base growth were considered as intermediate objectives that could be used as quasi-automatic rules, given that their limitations were known by the authority. Nevertheless, due to the credibility crisis experienced by the central bank, the adoption of a visible monetary target was judged advisable. The limitations of monetary aggregates and their advantages in the circumstances that the Mexican economy was going through were expressed in the following way in the monetary programme for 1995:[3]

Most central banks have stopped setting quantitative targets for the evolution of their own credit or of monetary aggregates, such as notes and coins in circulation, M1 and others. This has been in response to technological changes and adjustments in financial regulations that have come about in the last few decades, and which have negatively affected the more or less stable relationship that used to exist between some of these aggregates and nominal GDP in years past.

Nevertheless, the current crisis of confidence in the national currency calls for the adoption of an extremely strict primary credit policy. The Bank of Mexico can do this by imposing a limit to the growth of its own domestic credit for the year.

This procedure can efficiently encourage economic agents' inflationary expectations to meet price projections contained in the economic programme adopted by the Federal Government - projections that correspond to the provisions of the Agreement to overcome the economic emergency.

In addition, as a result of the great uncertainty with respect to the evolution of the Mexican economy, it was considered extremely risky to use a short-term interest rate as an instrument of monetary policy. Therefore, with the aim of implementing an operating framework in which both the exchange rate and the interest rate were determined freely, the Bank of Mexico established the level of borrowed reserves (BR) as its instrument of monetary policy.[4] By setting this target, the Bank of Mexico sends signals to financial markets, without determining specific levels for interest rates or exchange rates.

Under this framework, the Bank of Mexico intervenes every day in the money market through auctions, credits, deposits, or through transactions with government paper, either directly or through repos. To that end, the central bank sets the amount to auction such that the aggregate level of borrowed reserves in the banking system starts the following day at the level determined beforehand.

In order to send signals regarding its monetary policy intentions, the Bank of Mexico determines the target level of BR for the start of the following working day. Thus, a zero BR target would indicate the intention of the central bank to satisfy, at market interest rates, the money demand and, therefore, to provide the necessary resources so that no bank is forced to incur overdrafts or to accumulate undesired positive balances at the end of the holding period. This would be indicative of a neutral monetary policy.

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[3] *Exposition on the monetary policy, January 1 to December 31 1995*, pp 53-54.

[4] For a detailed explanation of this mechanism, see *Annual Report*, Bank of Mexico, 1997, Appendix 4.

A negative BR target, a *corto* (to leave the money market short), would indicate the central bank's intention not to provide the banking system with sufficient resources at market interest rates, thus forcing one or several credit institutions to obtain part of their required reserves through overdrafts on their current accounts. This, abstracting from other influences, would cause a rise in interest rates, since the institutions will try to avoid paying the higher overdraft rate by raising funds in the money market. This would send the signal to the market that the Bank of Mexico has adopted a restrictive monetary policy stance.

Therefore the Bank of Mexico always provides the credit needed to fully meet the demand for money, even when it adopts a negative accumulated balances target. In this last case, part of that credit is granted at a penalty rate, in the form of an overdraft on the current account of one or more banks.

In 1995, as in previous years, the Bank of Mexico defined an annual inflation target (December 1994-December 1995) which, after the modifications made to the economic programme during the first quarter of the year, was set at 42%.

In addition, in the same year the Bank of Mexico encouraged the development of the futures and options markets for the Mexican peso and established a new information policy, in order to ensure that economic agents could count on these financial instruments to cover themselves against the greater exchange volatility and that they had the necessary information to follow and monitor the actions of the monetary authority.

During 1996 and 1997, this monetary policy framework was maintained. In 1996, the limits on the growth rate of domestic credit, on the anticipated accumulation of international assets and the growth forecast for the monetary base were presented quarterly, while for 1997 the monetary programme announced the anticipated daily path of the monetary base during that year.

The well established, attested seasonal behaviour that monetary base demand exhibits generated the perception that at certain times of year monetary policy was very expansive. For this reason, it was decided that the monetary programmes and the annual reports of those years would include quarterly and daily forecasts.[5] By doing this, it was easier to show that these seasonal increases were consistent with the annual forecast and did not represent a relaxed monetary policy stance, avoiding the confusion associated with seasonal increases in the monetary base. Nevertheless, increasing the frequency of these commitments raises the possibility of failing to fulfil them due to transitory or fortuitous events, since the relationship between money and nominal income is even more unstable in the short term. The inflation targets determined by the Bank of Mexico for 1996 and 1997 were 20.5% and 15% respectively.

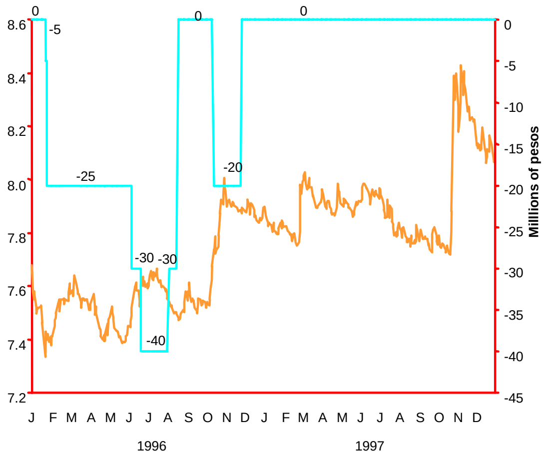
Regarding the discretionary actions of the Bank of Mexico during these years, the application of the corto was oriented towards restoring stable conditions in financial markets when these faced disturbances. Once order in these markets was restored, the target for BR returned to zero. In this sense, the annual inflation target played an important role at the beginning of the year, by guiding the expectations of economic agents, and the discretionary actions of monetary policy taken during the year were oriented towards reducing the impact of unanticipated financial disturbances on the inflation path.

During this period, inflation came down from 52% in 1995 to 15.7% in 1997. Nevertheless, as shown in Graph 1, due to the great inflationary uncertainty associated with the high level of inflation, the annual targets for 1995 and 1996 were not reached. However, in 1997 inflation was only 0.7 percentage points above the proposed target.

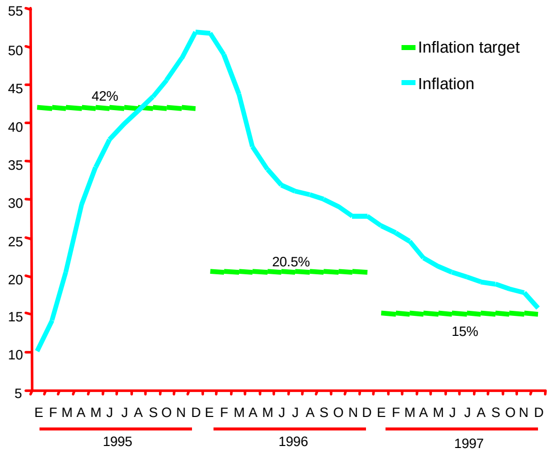
[5] 1997 monetary programme.

Graph 1

Exchange rate and the borrowed reserves target: 1996-97



Inflation and targeted inflation in Mexico: 1995-97



In 1998, the monetary policy framework began a gradual transition towards an explicit inflation targeting framework. In the process, the behaviour of the monetary base has become less relevant in the analysis of inflationary pressures, and the short- and medium-term inflation targets have increased their importance. Additionally, the focus of discretionary monetary policy has shifted towards the attainment of the short- and medium-term inflation targets.

Although the monetary programme for 1998 was similar to the previous one, some changes suggest the beginning of the transition mentioned in the previous paragraph. In particular, this document described what the reaction of the monetary authority would be if different external and internal disturbances were to occur. Another indication of this transition was the increase in the corto, during November of that year when, as a result of the Russian crisis and the fall in the oil price, inflation expectations for the next year were way above the target. The intention of this monetary policy action was:

To try, through the conduct of monetary policy, to bring about a rapid adjustment in the recent trend of annual inflation. For that reason, the Board of the Central Bank has decided that, from now on, policy actions will be taken to ensure that we can reach the inflation target of 13% for December 1999. Thus, in order to offset the process of revision of inflationary expectations for 1999, to avoid disorderly price reactions and to be able to reach the inflation target of 13% for next year, the Board of the Bank of Mexico has decided to increase the monetary restriction, raising the amount of the “corto” from 100 million to 130 million pesos.[6]

This was the first occasion on which the corto was increased as a preventive measure in order to bring about the appropriate monetary conditions for achieving the inflation target for the following year.

The monetary programme for 1999 set a target inflation ceiling of 13%. This programme also envisaged a gradual convergence, over the next five years, towards the rate of inflation of Mexico’s main trading partners. Recently, this long-term objective has become more explicit and currently the long-term goal of monetary policy is to reach an inflation target of 3% in 2003. The implementation of monetary policy continues to move towards anticipatory management in which the lags that affect the evolution of prices are recognised and, therefore, the monetary authority needs to act in a preventive way to induce behaviour consistent with the proposed targets. For 2000 an inflation target of less than 10% was set. In October 1999, in addition to the inflation targets for 2001 (6.5%) and 2003 (3%), an indication with respect to the target that would be adopted for 2002 (4.5%) was announced.

[6] Bank of Mexico *Press Bulletin*, no 139, 30 November 1998.

During the period 1998-2000, the trend reduction in the importance of the targets for the growth of the monetary aggregates has continued, in response to the unstable relationship experienced between the monetary base and prices during the period. Although money demand estimations indicate the existence of a long-run stable function, the instability in the short term has prevented its use as an intermediate target. Recent studies (Garcés (2000)) have identified a long-term stable demand for monetary base for the period 1982-2000. In addition, the estimated long-term elasticities are consistent with a Baumol-Tobin demand for money. Nevertheless, the deviations present in the short term with respect to this long-term demand for monetary base are high (nearly 7.9%) and are eliminated over an extended period of time (50% in four quarters and 95% in sixteen quarters). Therefore, although over a long horizon this relationship holds, over an annual period it shows considerable deviations. The negative relationship between the growth of the monetary base and inflation present in the 1995-99 period is shown in the graph below.

Graph 2

Annual growth of monetary base and inflation: 1995-99

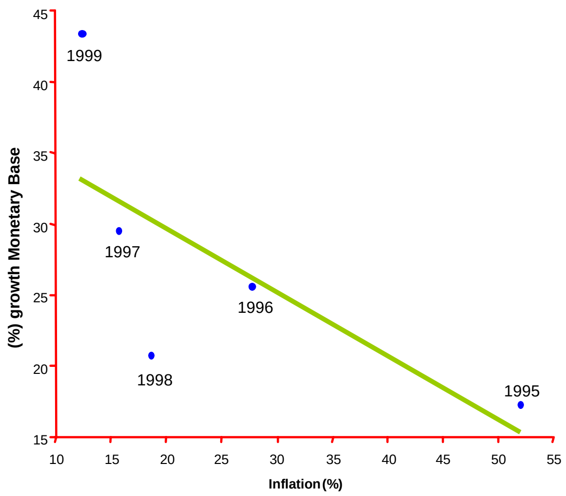


Table 1 shows that in those years in which the inflation target was reached, the monetary base growth projection was significantly different from the observed outcome, whereas in those years in which inflation exceeded the target, the growth of the monetary base was similar to that forecast. In this table, it can also be seen in forming future inflationary expectations, economic agents consider the previous fulfilment of the inflation targets and not if the monetary base targets were reached.

Table 1

Monetary base and inflation

(percentage)

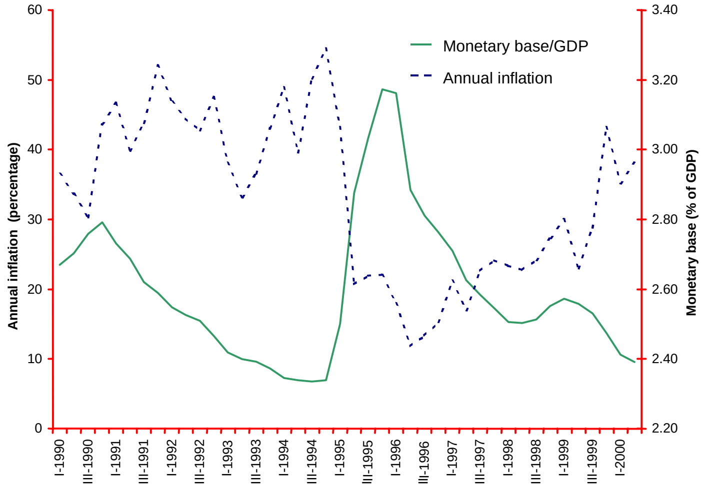
	Inflation objective	Observed inflation	Targeted monetary base growth	Observed monetary base growth	Inflation expectations at the start of the year
1995	42.0	52.0	29.1	17.3	29.9
1996	20.5	27.7	28.6	25.7	28.6
1997	15.0	15.7	24.5	29.6	18.2
1998	12.0	18.5	22.5	20.8	13.2
1999	13.0	12.3	18.1	43.5	16.5
2000	10.0		20.6		10.6

Due to the large deviation between the observed and the anticipated growth of the monetary base in 1999, the monetary programme for 2000 explained why the importance of these elements in the monetary policy framework was reduced.

Going deeper into this last point, it is important to highlight that during 1999 the sharp increase in the money base had two causes. First, the process initiated in 1997 continued once the rate of inflation had re-established a clear downward trend. As shown in Graph 3, the proportion of money to GDP registered in 1998 and 1999 was less than that observed in 1991 and 1992, when similar levels of inflation were experienced. It can also be seen, by looking at the relationship between the annual inflation rate and the money/GDP ratio, that the increase in the latter only begins once the reduction in the inflation rate has been consolidated. Second, it becomes clear from the graph that the reduction of this ratio happens significantly faster than its increases. Therefore, as the disinflation process continues, it is reasonable to expect that this ratio will keep growing.

Graph 3

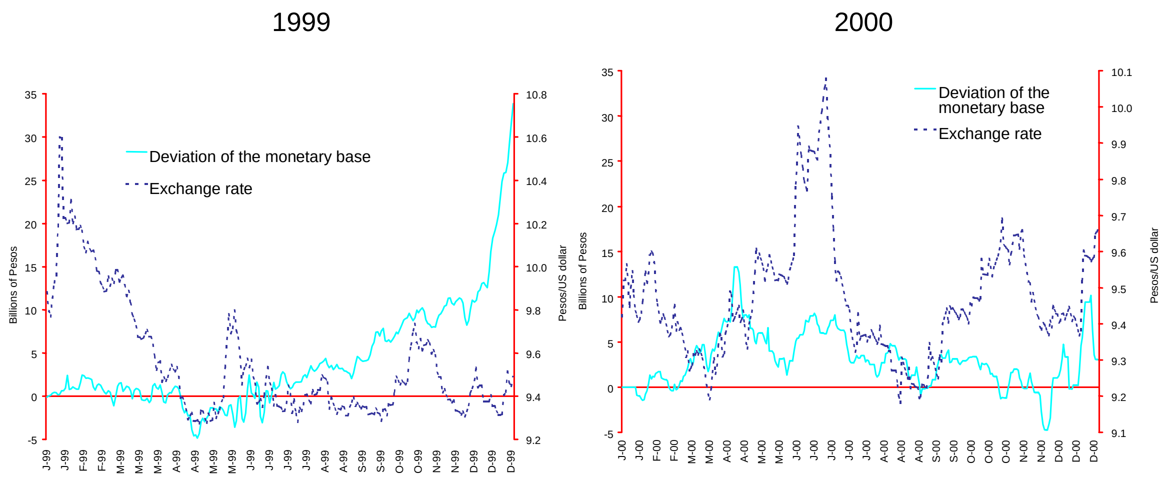
Monetary base/GDP ratio and annual inflation



If an excess of monetary base supply were to be deliberately generated, this would be reflected in the behaviour of financial markets. In particular, the economic agents would want to get rid of the excess money by acquiring assets denominated in foreign currency, thereby causing an exchange rate depreciation. As shown in Graph 4, the gap between the observed and the programmed evolution of the monetary base that was experienced in 1999 and in some months of 2000 can hardly be associated with exchange rate depreciations.

Graph 4

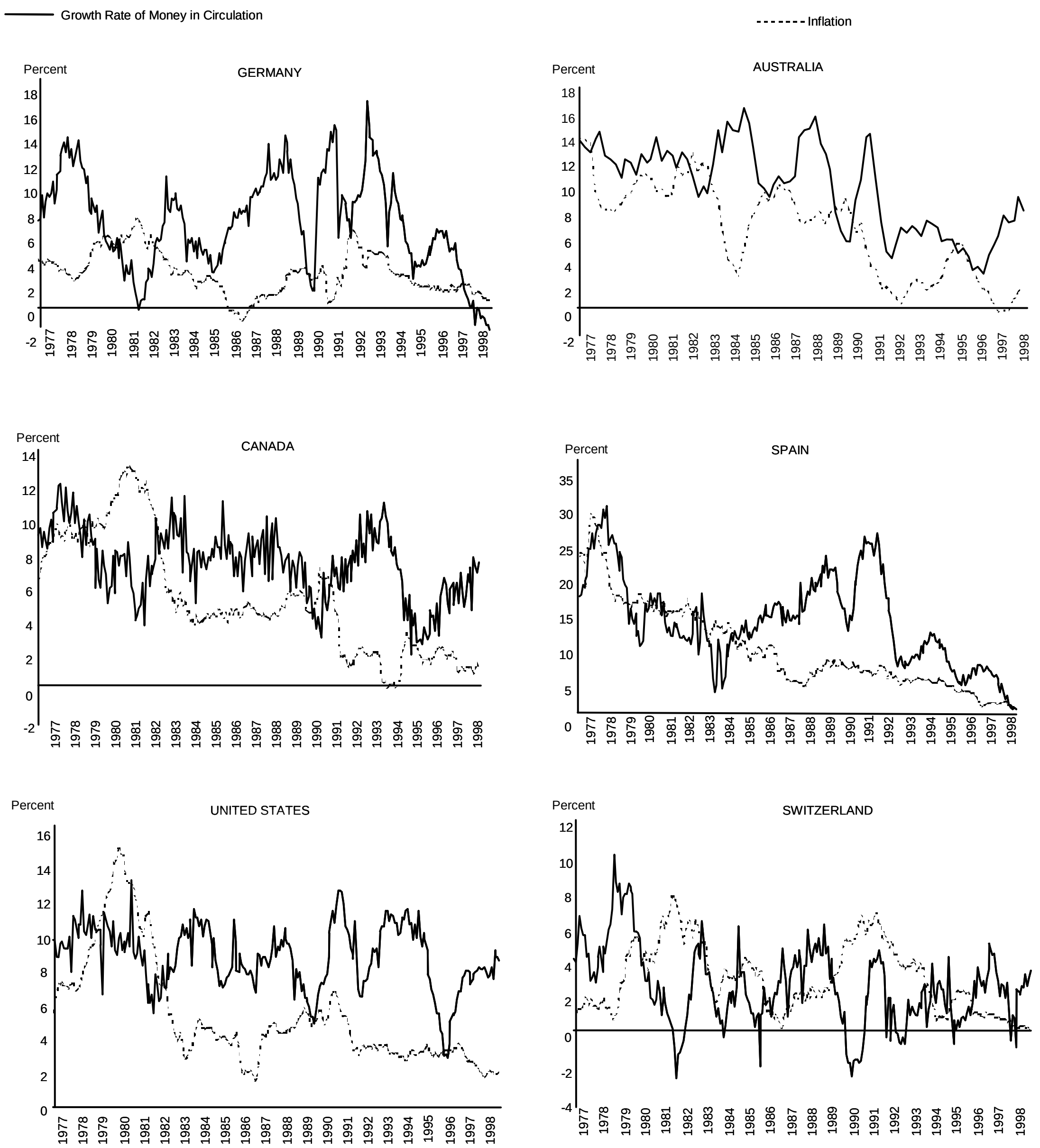
Deviations of monetary base and exchange rate



The absence of a stable relationship between these aggregates and the inflation rate has motivated the great majority of central banks to reduce the importance granted to the evolution of these variables in the analysis and evaluation of inflationary pressures. Therefore, this has discredited the mechanical use of these variables for the conduct of monetary policy. Several authors, for example Mishkin (2000), have described in detail the international experience with the use of monetary aggregates as intermediate targets. The empirical evidence supporting the decision by several central banks to reduce the importance of monetary aggregates in the analysis of inflationary pressures is shown in Graph 5, where the growth rates of the monetary base and the general price index for several developed countries are presented. The graph shows how the relationship has not been stable - mainly in the short term - and it can be seen that, on several occasions in those periods in which inflation diminishes, the growth rate of the monetary base increases considerably.

Graph 5

Growth rate of base money and inflation: international experience



Thus, both international and national experience indicate that the inflationary phenomenon is so complex that it cannot be anticipated exactly from the behaviour of only a few variables.

Consequently, at the moment the Bank of Mexico adjusts its monetary policy stance when the need arises to modify the monetary conditions so that it will be able to achieve the inflation target. In particular, the Bank will use the corto, adopting a more restrictive monetary policy, mainly in the following circumstances:

1. When it detects future inflationary pressures inconsistent with the achievement of the adopted inflation targets and if, in turn, inflationary expectations have deviated considerably from the inflation target;
2. When inflationary shocks appear. In particular, monetary policy will try in every circumstance to neutralise the indirect effect of exogenous shocks on prices, and will sometimes take preventive action to partially offset the direct inflationary effects of the movements of key prices in the economy. The ultimate aim is that the necessary adjustments of relative prices affect the CPI only moderately, increasing its level but avoiding a deterioration in inflationary expectations;
3. When it is necessary to restore orderly conditions in the exchange and money markets.

In the absence of a clear short-term relationship between monetary base growth and inflationary pressures, up to 1999 economic agents had little information on which to base an evaluation of the conduct of monetary policy. Therefore, in 2000 the Bank of Mexico considered it appropriate to extend its instruments of communication with the public by publishing a quarterly inflation report. In this report, the evolution of inflation and the application of monetary policy are described and analysed, and a balance of risks in terms of the future path of the growth of prices is discussed.

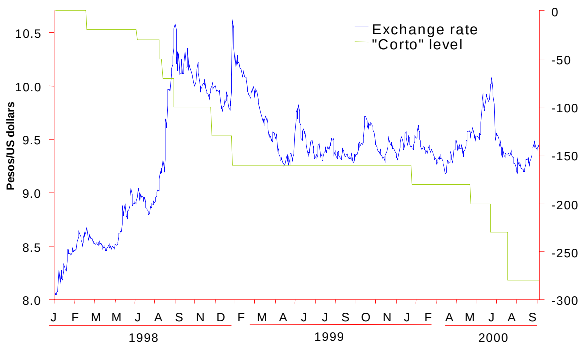
The introduction of a medium-term inflation target, the extension of the mechanisms of communication with the public, the reduced use of monetary aggregates and the reduction of the rate of inflation have brought about an important change in the implementation of monetary policy in Mexico.

At present, monetary policy actions are aimed at influencing monetary conditions and expected inflation in order to achieve convergence between these and the proposed targets. Thus, during most of the period 1998-2000, when public inflation expectations were greater than the proposed targets, the authority had to intensify the restrictive stance of monetary policy. Therefore, during this period, the monetary policy moves (increases in the corto) towards greater tightening have been longer-lasting (Graph 6). This contrasts with the experience in 1996-97, when in the face of a gap between expectations and targets, the corto was only used to calm the markets, and thus had a transitory character.

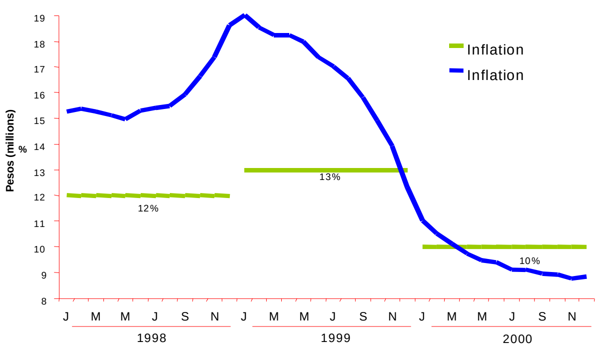
Although in 1998, due to the external disturbances that the Mexican economy was experiencing and to the programmed increases of public goods prices, inflation was way above target, in 1999 and 2000 it ended below the targets originally established (Graph 6).

Graph 6

Exchange rate and borrowed reserves objective: 1998-2000



Inflation and inflation targets: 1998-2000

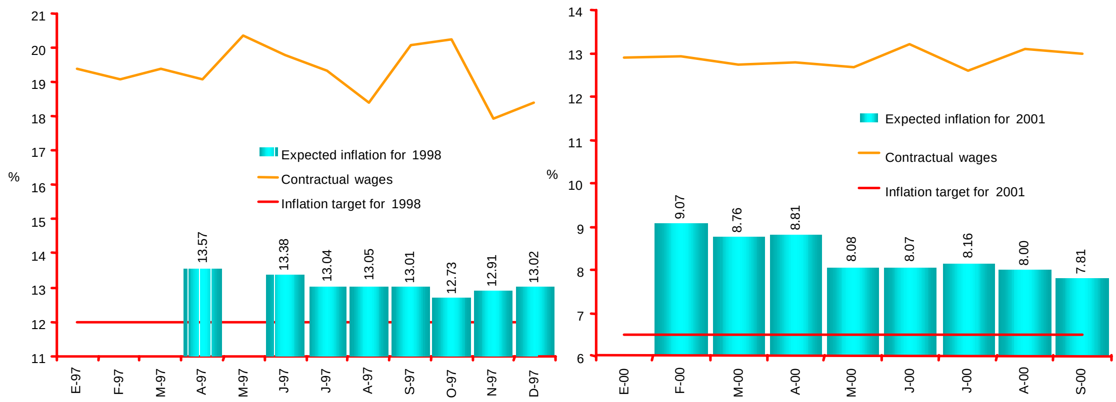


The change in the reaction function of the monetary authority can be illustrated by comparing monetary policy actions and the evolution of interest rates in 1997 and 2000. In these two years, the Mexican economy experienced a favourable external environment, the inflation rate was similar to the targets proposed and economic growth surpassed the original forecasts (observed growth was 7% in both years).

In addition, in the second half of these two years, the evolution of expected inflation for the following year and contractual wage settlements were inconsistent with the proposed targets for the following year, as illustrated in Graph 7.

Graph 7

Inflation expectations, contractual wages and inflation target for the next year



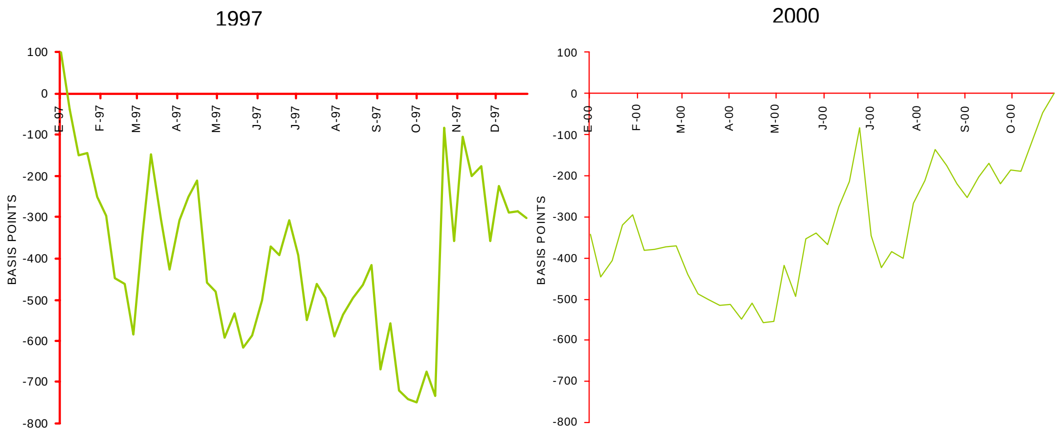
Under this scenario, the monetary authority did not respond during 1997 and the gap between real interest rates denominated in national currency and foreign currency diminished over the year, later registering a substantial increase in reaction to the intensification of the Asian crisis in November of that year. In contrast, during 2000, when inflationary pressures appeared to be endangering the future reduction of inflation, the monetary authority progressively increased the corto and induced a significant and constant increase in the gap between domestic and foreign real interest rates from April of that year. This can be clearly observed in the evolution of the spread between the real interest rate in pesos for one-month government bonds (Cetes) and the gross yield of the UMS26 bond. As observed in Graph 8, this spread was greater on average during 2000 than during 1997. In addition, it increased in the second half of the year in response to the restrictive actions of monetary policy. In contrast, in 1997 this differential[7] was falling for much of the year, only increasing in response to the Asian crisis when the currencies of Hong Kong and Korea were attacked. As can be seen in this graph, once this pressure diminished, the interest rate resumed its declining trend. This change in the reaction function of the monetary authority will be demonstrated more formally in the following sections of the document.

In this transition towards explicit inflation targets, the effectiveness of monetary policy in Mexico has frequently been questioned. In particular, some doubts have emerged about the optimality of the instrument used and about the operation of the transmission mechanisms. These subjects are analysed in the following sections.

[7] Due to the great influence of external rates on domestic ones, this spread measures the movement of rates denominated in national currency once the effect of external rates has been removed.

Graph 8

Real rate on Cetes (one month) - gross yield UMS 26



3. Monetary policy implementation in Mexico

Currently, most central banks recognise as their main policy objective the achievement and maintenance of price stability. Throughout history, these institutions have used different variables to accomplish this objective:

1. the interest rate charged to commercial banks;
2. the reserve requirements that determine the proportion of liabilities that commercial banks have to maintain as deposits in the central bank;
3. the terms on which the central bank grants more liquidity to the market.

The management of monetary policy consists in defining the level of the instrument that, given the transmission mechanism of monetary policy, is consistent with the achievement of the target. It is not hard to recognise that through any of the instruments listed above the central bank is able to influence, directly or indirectly, the determination of the short-term market interest rate.

The tools of monetary policy that modern central banks use can be divided into two groups:

1. interventions in the money market to fix the overnight rate or to limit its fluctuation within a band;
2. management of money market conditions through quantitative restrictions.

For example, the US Federal Reserve (Fed) and the Bank of England work with mechanisms geared towards maintaining a target rate around a given level. Other central banks, such as the European Central Bank and the Bank of Canada, hold the official rate within a band. This rate is defined in terms of a penalty rate, which is used in the overnight market, and of a floor defined by the rate which is paid on the deposits that commercial banks hold at the central bank.

As can be seen from Table 2, nowadays in most countries monetary policy is implemented through the definition of a target for the short-term interest rate. In the past, however, several central banks have operated through adjustments in the amount of resources they provide to the system. This was the case with the "non-borrowed reserves" target regime implemented by the Fed at the beginning of the 1980s, and the regime of "settlement balances" used in New Zealand up to March 1999.

Table 2

Interest rates used for monetary policy actions

Country	Interest rate used	Term
United States	Overnight federal fund rate	1 day
Canada	Bank rate	1 day
Australia	Cash rate	1 day
New Zealand	Official cash rate	1 day
England	Repo rate	2 weeks (average)
Sweden	Repo rate	7 days
Japan	Official discount rate	1 day
Korea	Overnight fund rate	1 day
Israel	Nominal effective interest rate	1 day
Poland	Discount credit rate	1 day
Brazil	Base rate	1 day
Colombia	Intervention rate	7 days
Chile	Monetary policy rate	1 day
European Monetary Union	Refi rate	2 weeks

Under the non-borrowed reserves target system, the Fed auctioned a given amount of non-borrowed reserves daily, while the rest of the funds that the system required in the short term were provided at some penalty rate through the discount window. In this way, each time the central bank reduced the amount of non-borrowed reserves, more funds were available at the discount rate, forcing an increase in the short-term interest rate. After 1982, the Fed returned to the implementation of monetary policy based on an objective for the federal funds rate.[8]

Under the system of settlement balances in New Zealand, the commercial banks could hold positive balances in their account at the central bank that paid a lower return than the market's (300 basis points in 1998) and zero for every balance higher than a certain limit. No overdrafts were allowed. The only source for additional immediate liquidity were reserve bonds, since the central bank was willing to buy all bonds with an effective maturity of less than 28 days at discount. By taking the bonds at discount, the central bank imposed a penalty rate (equal to 90 basis points in 1998) which was charged at the expiration of the discounted paper.[9] Thus, financing through this mechanism was more expensive than through the use of their balances in the account held at the central bank. These balances constituted the demand for settlement balances. The central bank performed its open market operations in such way that the financial system closed with a positive balance equal to the pre-established objective, which constituted the target for settlement balances. By reducing this target, the central bank generated greater competition for funds, imposing upward pressure on the short-term interest rate. In March 1999, the implementation of monetary policy in New Zealand was changed from this system, in which the central bank indirectly manipulated market conditions through the mechanism described, to a system in which the central bank fixes an objective for the interest rate.

Under the regimes of non-borrowed reserves and settlement balances, as well as under the BR framework implemented in Mexico, the central bank fixes an objective for the amount of funds it provides at market interest rates and/or at a penalty rate, affecting the interest rate only indirectly. In Mexico, under the BR targeting, explained in Section 2, the central bank manipulates the amount of funds provides to the market so that a certain amount (corto) will be granted at the penalty rate and the rest of the funds at the market rate. The situation was similar in the case of the settlement balances system, where, by reducing the objective, the central bank pushed the commercial banks to satisfy their extra liquidity needs through rediscount operations. Finally, under the non-borrowed reserves regime, the Fed fixed an objective for funds provided at the market rate, and the rest of the funds were provided at the penalty rate.

[8] For a detailed description of the instruments used in the United States, see Walsh (1998).

[9] The penalty for taking a bond with an effective maturity of three days was 270 basis points in 1998. Given the need of commercial banks to finance operations within one day, this alternative could become very expensive.

3.1 Advantages and disadvantages of a quantitative instrument vs an interest rate instrument

When defining the instrument of monetary policy, a central bank takes into account internal and external factors. On the one hand, the instrument determines the transparency of the monetary policy signal, as well as its effectiveness in affecting the short-term interest rate, the rest of the yield curve, the prices of other assets, the exchange rate and future expected inflation. This determines its impact on the components of aggregate demand and on the setting of prices in the economy. On the other hand, in an open economy with a flexible exchange rate, the definition of the instrument determines how external volatility translates into changes in the interest rate or the exchange rate.

Among the advantages of an instrument that affects money market conditions through a quantitative restriction is the inclusion of all the information available to market participants and the central bank on the determination of interest rates. This happens because the instrument only works as a signal that interacts with the action taken by market agents. Under volatile conditions, the preceding argument implies that the short-term interest rate changes automatically, making it very flexible and allowing the distribution of external shocks between changes in it and in the exchange rate.

On the other hand, the quantitative instrument is compatible with different levels of the interest rate as it simply defines the amount of funds that the central bank offers to the commercial banks at the penalty rate, and this last rate is defined as a function of the market interest rate. That is why, by being compatible with different levels of interest rates, its effect on them is more uncertain, because it depends on the conditions that prevail in the financial markets.

The implementation of monetary policy based on an objective for the short-term interest rate represents a much more direct signal. In practice, the use of this instrument has taken the form of gradual action by central banks. This can happen because, in situations with uncertainty, mistakes in the calculation of the target rate can have consequences for the central bank's ability to control inflation. Besides, frequent variations in the target interest rate imply constant changes of direction in the monetary policy stance, and this could generate confusion in the market.[10]

Next, we analyse the behaviour of the target interest rate in countries in which the central bank uses this as a policy instrument. Even though in Mexico the monetary policy instrument has not been the fixing of a target rate, we present a measure of what could have been the "target" rate with the intention of comparing it with the implementation of monetary policy observed in other countries.

To estimate the "target" rate in Mexico, we assume that it would have been equal to the weekly average of the overnight rate. We also consider that the "target" rate would have stayed constant if the weekly change, in absolute value, of the overnight rate were less than 150 basis points. Finally, when this change is greater than 150 basis points, the new "target" rate becomes equal to last week's average overnight rate. Graph 9 shows the behaviour of the observed overnight rate and the estimated "target" rate based on this methodology. As can be seen, the behaviour of the estimated "target" rate for Mexico would have been characterised not only by frequent movements, but also by constant changes in the direction of the monetary policy stance.

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[10] Some authors have analysed the gradualism of United States monetary policy. Among them, Cukierman (1991) argues that one of the reasons why the Fed has an element of smoothing of movements in the interest rate in its reaction function to protect the banking sector from financial crises. On the other hand, Sack (1998) finds that this element of gradualism in the Fed's reaction function can be explained by introducing uncertainty in the parameters of a structural model for the economy.

Graph 9

Overnight interest rates and "hypothetical objective"

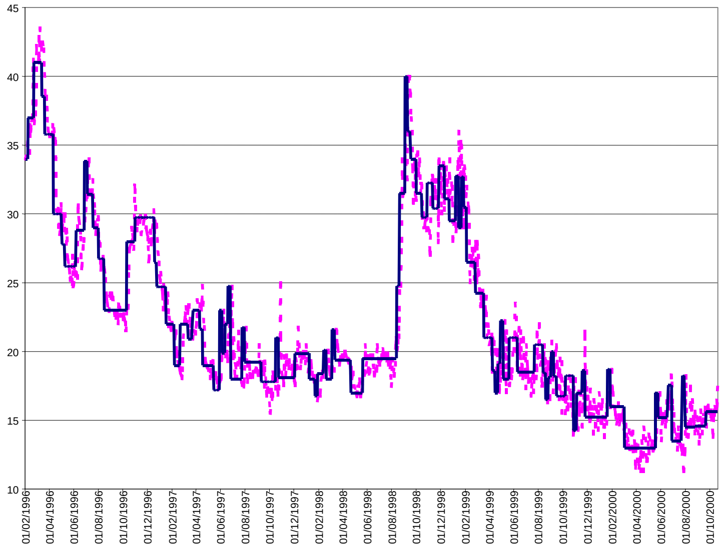


Table 3 shows changes observed in the target rate of a group of countries, and the estimates for Mexico based on the methodology described above. From these results it is possible to see that the monetary policy of central banks that use a target rate as their instrument is characterised not only by gradual movements in the rates, but also by limited changes in direction. When we compare this behaviour with that of the estimated "target" rate for Mexico, we see that to approximate the observed fluctuations in the overnight rate, the Bank of Mexico would have had to make a large number of modifications to the "target" rate.

The last row of Table 3 shows the frequency of the changes in the direction of the target rate. As we can see, in most countries the direction of monetary policy has changed with a probability of between 9% and 30%. Whereas, based on the estimation for Mexico, this number would have been 57%. This means that more than half of the changes in the estimated "target" rate would have caused a change in the direction of the monetary policy stance.[11]

It should, however, be noted that if the observed modifications in the overnight rate had not been made, that probably would have been reflected in more abrupt changes in the exchange rate. This, and the high pass-through of exchange rate movements to prices, would have affected the path of inflation.

Therefore, the observed frequency of changes in the conditions of the money market in Mexico has been necessary to keep the inflation rate on a path consistent with the central bank target, fundamentally because of two factors:

(a) volatility in the yield of Mexican bonds denominated in foreign currency in the international capital markets (foreign bonds), and

(b) the effect of exchange rate changes on the behaviour of prices.

[11] When the exercise is carried out using the behaviour of the 28 day Cetes, the number of changes in the "target" rate during the year is more similar to the average observed in other countries. Even so, the probability of a change in direction is 52%, which is still greater than that observed in other countries.

Table 3
Changes in target rate

	Australia		Germany[1]		Israel		Canada		United Kingdom		United States		Mexico	
	Changes		Changes		Changes		Changes		Changes		Changes		Changes	
	Total	Direction	Total	Direction	Total	Direction	Total	Direction	Total	Direction	Total	Direction	Total	Direction
1996	3	(+)0 (-)3	1	(+)0 (-)1	9	(+)4 (-)5	16	(+)4 (-)12	4	(+)1 (-)3	1	(+)0 (-)1	17	(+)6 (-)11
1997	2	(+)0 (-)2	0	(+)0 (-)0	4	(+)1 (-)3	4	(+)4 (-)0	5	(+)5 (-)0	1	(+)1 (-)0	19	(+)8 (-)11
1998	1	(+)0 (-)1	0	(+)0 (-)0	10	(+)2 (-)8	5	(+)2 (-)3	4	(+)1 (-)3	3	(+)0 (-)3	21	(+)9 (-)12
1999	1	(+)1 (-)0	2	(+)1 (-)1	6	(+)0 (-)6	3	(+)1 (-)2	6	(+)2 (-)4	3	(+)3 (-)0	26	(+)11 (-)15
2000	4	(+)4 (-)0	6	(+)6 (-)0	8	(+)0 (-)8	3	(+)3 (-)0	2	(+)2 (-)0	3	(+)3 (-)0	11	(+)6 (-)5
Probability of change in the target rate	9		11		14		26		14		27		57	

[1] For 1999 and 2000 the source is the European Central Bank.

The instrument of monetary policy imposes conditions so that the adjustment to internal as well as external shocks will be distributed between fluctuations in interest rates and exchange rates. Thus, in the presence of high pass-through, the necessary condition for keeping inflation online with the central bank's target is the distribution of the reaction to the shocks between the interest rate and the exchange rate. In the following two sections, we analyse how the implementation of monetary policy in Mexico has been conditioned by the two factors mentioned above.

3.2 The volatility of the external rate

To analyse the effect of the volatility of the yield of foreign bonds on domestic money market conditions, it must be considered as being transmitted through movements in the exchange rate or in the interest rate depending on the instrument of monetary policy. This can be seen in a simple way from the equation of the interest rate parity condition. Under the assumption of perfect capital mobility we have:

$$i_t = i^*_t + (s_{t+1} - s_t)$$

where i is the national interest rate, i^* is the yield of a Mexican government bond denominated in dollars, and $s_{t+1} - s_t$ is the expected exchange rate depreciation (or appreciation). Solving for i^* and calculating the variances on both sides of the equation, we find that the sum of the variance of the interest rate and the exchange rate depreciation is equal to the variance of the yield of the bond in dollars.[12]

$$\mathrm{var}(i) + \mathrm{var}(\Delta s) \pm \mathrm{cov}(i, \Delta s) = \mathrm{var}(i^*)$$

The equation above implies that when the central bank fixes the short-term interest rate, the external volatility will be transmitted mainly to the exchange rate market. On the other hand, when the central bank allows fluctuations in the short-term interest rate the external disturbances are distributed between adjustments in both variables. Table 4 shows the standard deviation of the yields of foreign bonds. As can be seen, this measure of the yield's volatility has been much greater for the Mexican bonds than for the securities of other countries with freely floating exchange regimes.

[12] The yield of the bonds the government places in other countries includes the external interest rate and the country risk.

Table 4

Standard deviation of the yield of government bonds denominated in foreign currency

(basis points)

	Mexico	Canada	Australia	New Zealand
97 I	20	9	10	…
97 II	15	7	8	7
97 III	11	8	8	8
97 IV	28	7	7	7
98 I	10	8	10	8
98 II	11	5	5	7
98 III	54	7	7	6
98 IV	30	13	15	11
99 I	31	10	11	10
99 II	21	11	10	9
99 III	14	11	9	9
99 IV	13	9	10	9
00 I	21	8	8	8
00 II	23	14	14	13
00 III	12	6	9	6

In order to analyse the effect of this high variability of the external rate on the behaviour of the exchange rate and the interest rate, Tables 5 and 6 compare the volatility of these variables with those observed in other countries. As we can see from both tables, exchange rate volatility in Mexico has not been significantly different from that in other countries. Nevertheless, the volatility of the overnight rate has been considerably greater than that in other countries (Table 6).

Table 5

Volatility of exchange rate depreciation

(percentages)[1]

	Germany[2]	United Kingdom	Canada	Australia	New Zealand	Mexico
96 I	6.4	5.8	3.7	6.2	5.4	6.4
96 II	6.6	5.4	3.1	6.3	5.8	5.1
97 I	9.8	8.5	4.8	7.4	6.0	4.7
97 II	9.8	8.0	4.2	10.3	8.6	10.7
98 I	8.1	7.1	4.3	11.9	12.5	6.7
98 II	9.2	7.3	7.0	15.0	15.1	11.1
99 I	8.9	6.9	5.7	9.9	9.5	9.9
99 II	10.0	7.3	5.2	8.6	10.1	7.1
2000 Q1	12.2	7.3	5.0	10.7	11.2	5.9
2000 Q2	12.5	8.1	5.1	11.4	13.5	7.2
2000 Q3	11.0	8.1	4.5	10.7	11.4	9.1

[1] Variation coefficients for the exchange rate of each country vis-à-vis the US dollar. [2] For 1999-2000, the source is the European Central Bank.

Table 6

Volatility of short-term interest rates

(percentages)[1]

	Germany[2]	United Kingdom	Canada	Australia	New Zealand	Mexico
97 I	4.2	0.7	0.2	0.6	3.5	20.6
97 II	5.0	1.0	0.6	0.7	5.0	7.1
98 I	3.1	0.5	0.7	0.1	3.2	5.1
98 II	2.0	2.2	1.3	0.2	14.4	57.9
99 I	5.8	3.7	0.2	0.1	5.7	20.6
99 II	0.5	1.9	0.2	0.1	0.3	5.3
2000 Q1	0.2	5.7	0.4	0.7	1.0	6.2
2000 Q2	0.9	3.0	0.6	0.4	0.9	9.1
2000 Q3	0.5	3.5	0.0	0.1	0.1	11.5

[1] Variation coefficients. [2] For 1999-2000, the source is the European Central Bank.

If Mexico had fixed the interest rate, given the international experience and assuming that the central bank had not sent ambiguous signals to the markets, the variability of the overnight rate would probably have been smaller. Nevertheless, in the light of the arguments presented above, this would have caused an increase in exchange rate volatility, which, due to the high pass-through, could have resulted in higher inflation.

The previous point can be illustrated with the experience of New Zealand, a country for which, as we saw in the first section, the monetary policy instrument until February 1999 was similar to that used in Mexico. As we can see from Table 6, the adoption of an interest rate instrument in March 1999 caused a fall in the variability of rates while, as observed in Table 5, the exchange rate volatility during 1999 and 2000 was considerably greater than that observed in 1996 and 1997. In this comparison, the period from the second half of 1997 to the end of 1998 was excluded due to the high volatility generated by the Asian and Russian crises.

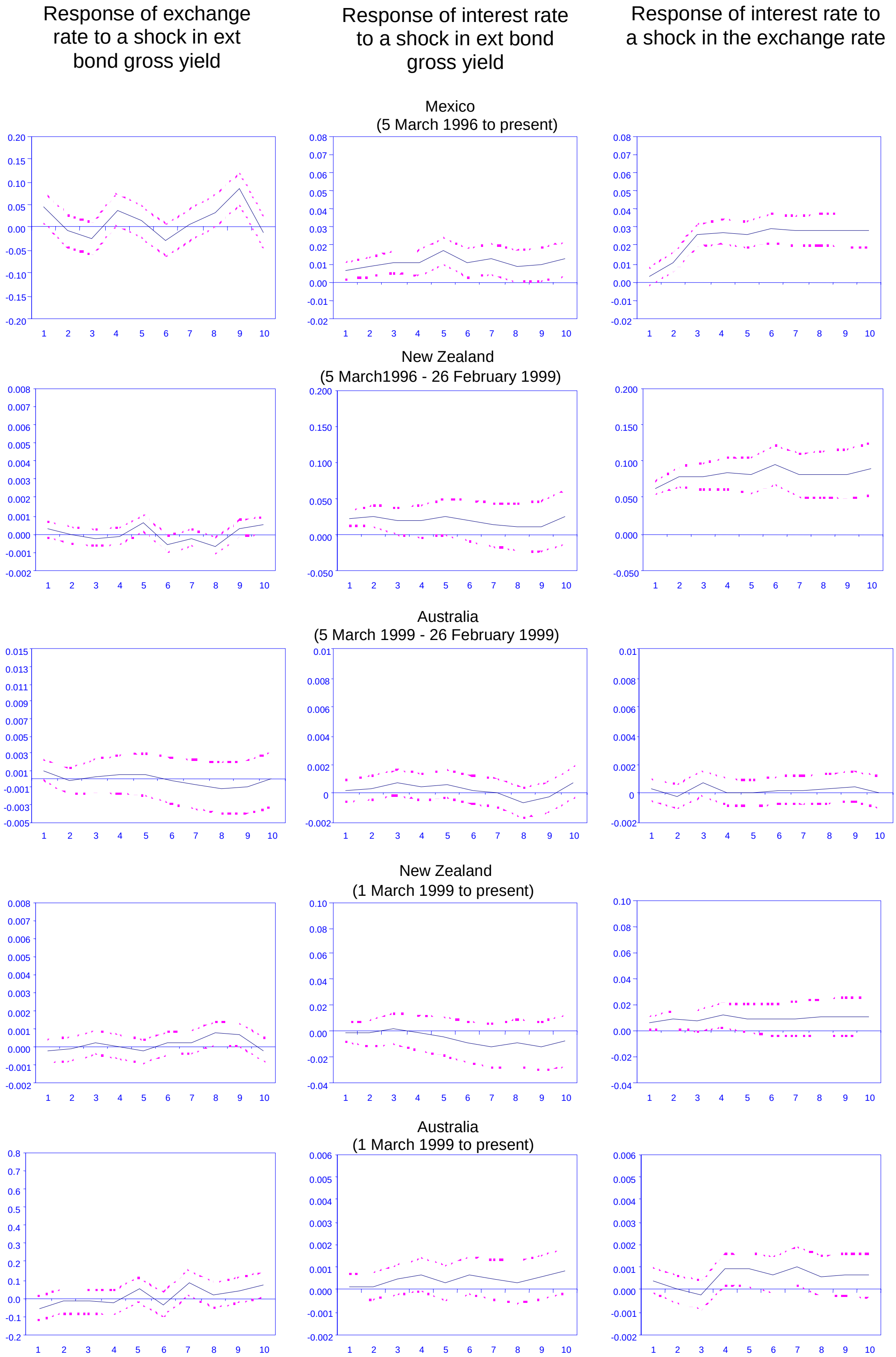
The fall in the variability of the interest rate in New Zealand could also have resulted from a fall in the volatility of the external rate, country risk or the terms of trade. In order to control for these effects of the external environment, we took the observed variability of the interest rate and the exchange rate of Australia, an economy with very similar characteristics. Referring back to Table 6, we can see that since the adoption of the interest rate instrument in New Zealand in March 1999, the difference between the volatility of the interest rate in both countries has fallen significantly. On the other hand, in Table 5, we see that the volatility of the exchange rate in New Zealand was greater than that in Australia during the second half of 1999 and in 2000, while during most of 1996 and 1997, that of Australia was greater.

In order to study the distribution of the effect caused by fluctuations in the yield of foreign bonds, in the interest rate and in the exchange rate, we analyse the joint behaviour of these three variables for the case of Mexico in the context of the floating exchange rate regime and the BR framework. In this exercise, we estimate a VAR that includes the yield of the external bonds, the logarithmic change in the exchange rate, and the overnight rate during the period from 5 March 1996 to the end of 2000.[13] In the first row of Graph 10, it is possible to see how in Mexico a shock of one standard deviation to the yield of the external bond causes a statistically significant increase in the interest rate as well as in the exchange rate. In addition, we see evidence of a positive and significant effect of exchange rate depreciation on the interest rate.

[13] The observations are daily, the exogeneity order of the variables adopted is: external yield, exchange rate depreciation, interest rate. The number of lags does not change the result.

Graph 10

Impulse response functions



These effects can be caused by two factors. First, when the exchange rate depreciates, an increase in expected inflation is observed, causing an increase in nominal interest rate. Second, in the context of an instrument of monetary policy that affects market conditions through quantitative restrictions, the effects can be interpreted as the reaction of the central bank to a depreciation. Under these circumstances, the authority anticipates the inflationary effect by restricting monetary policy.

To analyse the distribution of a shock to the external yield between the interest rate and the exchange rate, we performed a similar exercise for New Zealand during the settlement balances regime in place from 5 March 1996 to 26 February 1999. The second row of Graph 10 shows the same type of reactions. A shock of one standard deviation in the external yield of the New Zealand bond causes a marginally significant and lagged increase in the exchange rate depreciation and a positive and significant transitory effect on the short-term interest rate. Moreover, the increase in the exchange rate depreciation seems to generate significant increases in the interest rate. When the exercise is performed for Australia during the same period (third row of Graph 10), we see that none of these effects is significant.

Next, we analyse the behaviour of the same variables for the period 1 March 1999 to 26 July 2000 (period after the adoption of the interest rate regime in New Zealand). The fourth row of the graph shows that after the change of regime, the interest rate no longer responds to the external shock, and barely responds to the exchange rate depreciation. Finally, in the last row it can be seen that in Australia during this period, only the response of the interest rate to the exchange rate depreciation is marginally significant after some lags.

In this section, we have shown how the implementation of monetary policy imposes conditions on the effect of the external rate on the interest rate and the exchange rate. In the next section, we will address the importance of limiting fluctuations in the exchange rate when these fluctuations have lasting effects on the growth of prices, either directly or through changes in inflation expectations.

3.3 The effect of exchange rate movements on prices

The high pass-through that exists in Mexico can be illustrated in a simple way by comparing the speed of response of prices to changes in the exchange rate for Mexico and for other countries. Graph 11 shows that the long-run effect of an exchange rate depreciation of 10% on prices is greater in Mexico than in Australia.[14] It can also be seen that in Mexico 50% of the effect happens after two quarters, and 82% during the first year. This contrasts with the estimated response in Australia, where in two quarters we see only 7% of the effect, and during the first year the total effect is barely 14%.

The fluctuations in the exchange rate affect the price index directly through their effect on the prices of tradable goods, or indirectly through changes in inflation expectations, which determine wage adjustments as well as the changes of other prices in the economy. As mentioned above, the importance of the first channel is determined by the degree of openness of the economy, as well as the market structure of the tradables sector.[15] The second channel is affected by the response of inflation expectations to exchange rate changes.

There are several reasons why the effect of exchange rate changes on prices has been greater in Mexico than in other economies. The first is the integration of the economy through trade, which increases the sensitivity of prices, production processes and aggregate demand to fluctuations in the exchange rate. In Mexico, the proportion of total trade to GDP has increased from 15% in 1990 to 58% in 1999, while in Australia this number increased from 26% to 31% during the same period. In addition, the history of high inflation and balance of payments crises followed by surprise devaluations

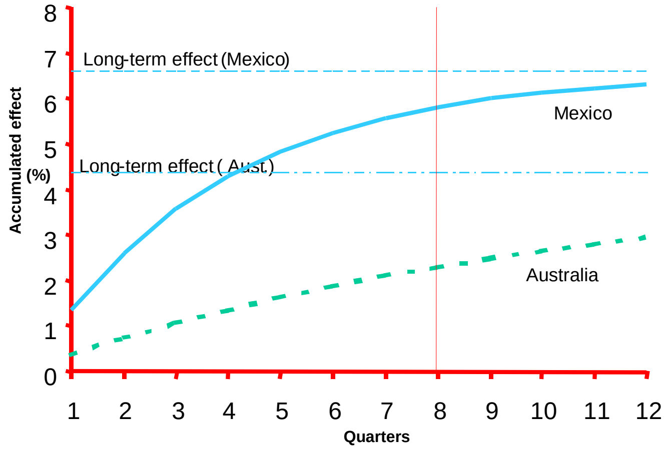
[14] The estimation for Australia is taken from De Brower and Ericsson (1998). Garcés (1999) performs this same analysis for Mexico. In addition, he finds that in the Mexican case the response of the price index depends on the amount of the depreciation. In other words, when the depreciation is greater than some limit the reaction of prices is 1 to 1 in the long term, ie the pass-through is complete, and in the case of smaller depreciations the estimated coefficient is less than one.

[15] The response of tradable goods prices to changes in the exchange rate is determined by the market structure of these goods. This structure affects the willingness of participants to use the change in relative prices caused by the exchange rate depreciation to maintain or increase their market share by cutting their profit margins. The importance of these factors for the Mexican economy is studied by Conesa (1998).

contributed to exacerbate the association of inflation expectations with movements in the exchange rate. Graph 12 shows how the exchange rate depreciation precedes the inflation rate, and that there is a very high correlation between the two variables.

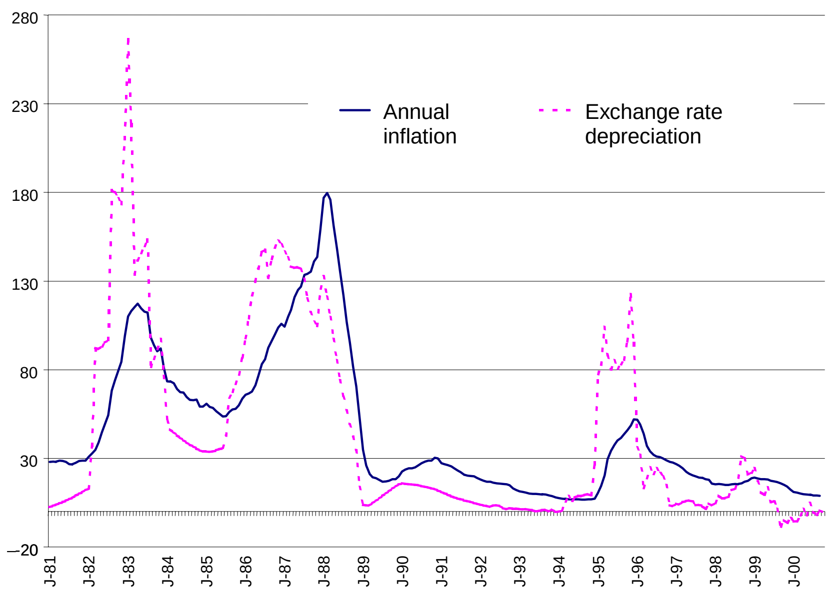
Graph 11

Pass-through to an exchange rate depreciation of 10%



Graph 12

Exchange rate depreciation and inflation rate in Mexico



In order to evaluate the effect of exchange rate fluctuations on expected inflation, and to test if it has decreased recently, we estimate a linear regression for expected inflation for the next 12 months as a function of the observed weekly depreciation, the change in the BR objective and inflationary surprises (the gap between observed and expected inflation). The results of this equation are shown in Table 7, where all the coefficients are significant and have the right sign. Next, we perform recursive estimations for the period December 1997 to October 2000. Graph 13 shows the results of this recursive regression for the coefficient associated with the exchange rate depreciation.

Table 7

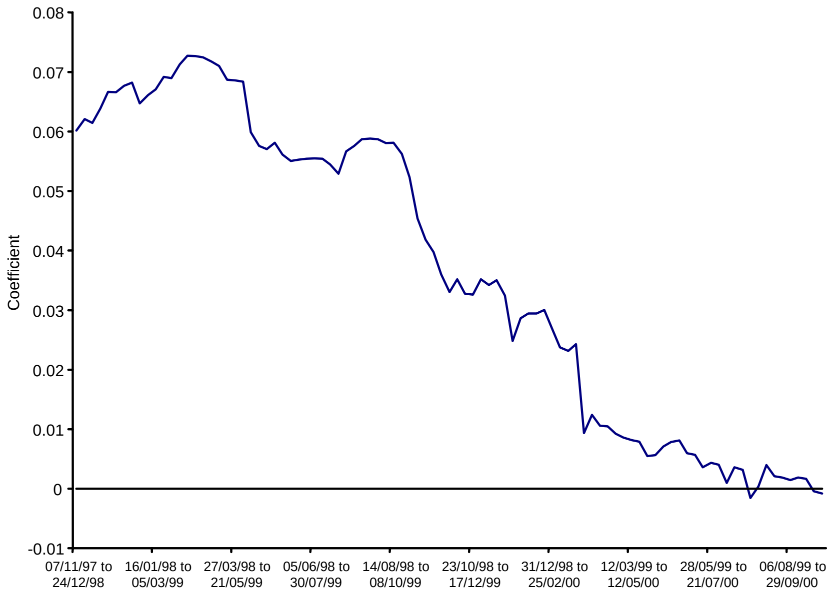
Determinants of changes in inflation expectations for the next 12 months

	Coefficient	t-statistic
Changes in corto	0.0076 (0.0039)	1.9295
Exchange rate depreciation (– 1)	0.0530 0.0145	3.6618
Inflation surprises	1.0359 (0.2735)	3.7880
Prices of public goods	0.0053 (0.0031)	1.7354
R-squared	0.3259	
F	7.4123	

As can be seen from Graph 13, since 1999 the effect of a 1% depreciation on the changes in inflation expectations for the next 12 months has fallen from around 6 basis points to less than 1 basis point. This could indicate that the pass-through has been reduced. Nevertheless, it is important to note that if a non-linear relationship exists between the exchange rate depreciation and the inflation rate, our results would be biased. So the recent fall in the pass-through[16] would be at least partially explained by the fact that lately there have been no abrupt movements in the exchange rate.

Graph 13

Behavior of exchange rate depreciation coefficient of the previous week



[16] Garcés (2000) finds evidence of a non-linear relationship between the fluctuations in the exchange rate and the inflation rate for Mexico.

3.4 Results of the implementation of monetary policy in Mexico

In the context of the conduct of monetary policy in Mexico, the achievement of the inflation target is the fundamental goal of the monetary authority. In this respect, the central bank acts whenever it considers that the monetary conditions determined by the market are inconsistent with this goal. As we saw previously, in an environment of constant internal and external shocks the current implementation of monetary policy in Mexico has been effective in distributing the effect of these shocks between the exchange rate and the interest rate. Nevertheless, under this scheme, the behaviour of the interest rate is also influenced by the actions of other market participants. This implies that monetary policy actions could in principle be offset, reducing their effectiveness in meeting the inflation target.

One way to evaluate the effectiveness of the framework of borrowed reserves and the actions of monetary policy is by estimating the effect on the real interest rate of the typical variables that should enter into the authorities' reaction function. Having done that, we could evaluate if monetary policy has reacted effectively to them. Several authors have studied the policy rule that must be followed in the context of emerging market economies, generalising the analysis of the reaction function of a central bank that determines the interest rate in a closed economy and that has the stabilisation of the price level as its main objective. For example, Svensson (1998) and Ball (1999) develop models of an open economy under rational expectations, and find that the reaction function of the central bank must include the external interest rate and the real exchange rate, in addition to the traditional elements, ie the output gap and the actual or observed inflation rate. At the same time, Corbo (1999) studies the factors that contribute to explaining the conduct of monetary policy in Latin America.

In order to evaluate whether the borrowed reserves scheme used in Mexico has resulted in a behaviour of the real interest rate consistent with the objective of reducing inflation, following the estimations made by Ortiz (2000) we run a function for the behaviour of the ex ante real interest rate, that is, a Taylor rule for the Mexican economy for the period from May 1997 to August 2000. The determinants of the ex ante real interest rate that are included in the analysis are: the deviation of private sector inflation expectations from the central bank's target, the measure of the output gap, the depreciation of the exchange rate in the previous period, and the gross yield of public sector debt denominated in foreign currency.

The results under different specifications are shown in Table 8. In the first three columns, the real rate was calculated based on expected inflation for the next 12 months. For the last three columns, expected inflation for the month was taken; it is clear that in this case we will have important seasonal fluctuations and the estimated real rate was therefore adjusted to eliminate that variability.

Column (1) shows the results obtained for the period mentioned. All the coefficients have the expected signs, even though the output gap is not statistically significant. The results in column (4) also correspond to the full sample using the second estimation described for the interest rate. In this case the signs are also as expected, but only the external rate is significant.

During the period from May 1997 to November 1998, international financial markets suffered shocks caused by the Asian and Russian crises. These events were a source of high volatility for emerging market economies, and translated into increases on the yield of bonds placed in the external markets and in considerable exchange depreciations. In addition, as explained in Section 2, in 1998 Mexico started its transition to a new framework of explicit inflation targets. In order to capture a possible change in the determinants of the ex ante real interest rate during this period, caused by external factors as well as by changes in the reaction function of the monetary authority, the sample was divided in two. The results for the first subperiod are shown in columns (2) and (5). As can be seen from these columns, the only significant determinants of the real ex ante interest rate for the period from May 1997 to November 1998 turn out to be the yield of the bonds placed in the external markets and the exchange rate depreciation of the previous period.

On the other hand, for the period from December 1998 to August 2000, when a greater stability in international financial markets was observed, the relative importance of the determinants of movements in the real interest rate is reversed. As can be seen from the results shown in colums (3) and (6) of Table 8, the coefficient of the deviation of expected inflation from target inflation increases and becomes statistically significant, as does the coefficient of the output gap. The coefficients of the yield of bonds placed in the external market and of the exchange rate depreciation, on the other hand, become non-significant.

From these results we can conclude that during the period of greater stability in the international markets and transition towards an inflation targeting regime, the behaviour of real interest rates was consistent with the necessity to eliminate the inflationary pressures coming from the internal market.

Table 8

Monetary policy rule of the Bank of Mexico

	Real interest rate (12-month inflation expectations)			Real interest rate (one-month inflation expectations)		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Constant	-10.92 (-8.28)	-16.12 (-15.06)	-6.92 (-7.65)	-16.94[1] (-9.34)	-30.52[2] (-13.16)	-4.24 (-6.22)
Expected inflation - inf target	1.65[3] (-0.49)	0.72 (-0.89)	2.80[3] (-0.78)	0.45 (-0.47)	-0.59 (-0.76)	1.21[2] (-0.52)
Output gap	0.09 (-0.18)	-0.22 (-0.31)	0.42[2] (-0.17)	0.04 (-0.23)	-0.48 (-1.24)	0.34[1] (-0.17)
Lagged depreciation rate	0.39[3] (-0.16)	0.61[3] (-0.21)	0.08 (-0.20)	0.17 (-0.15)	0.36[1] (-0.19)	-0.22 (-0.25)
Yield of the government bonds placed outside	1.51[2] (-0.87)	2.13 (-1.60)	0.97 (-0.83)	2.14[2] (-0.99)	3.62[2] (-1.43)	0.79 (-0.67)
N	41	19	22	41	19	22
$\bar{R}^2$	0.63	0.68	0.68	0.44	0.64	0.36

Note: Standard errors are in parentheses.
[1] Significant at 10%. [2] Significant at 5%. [3] Significant at 1%.

The analysis presented in this section indicates that the implementation of monetary policy in Mexico based on the use of a borrowed reserves target and the application of the corto has implied a behaviour of real interest rates consistent with the stabilisation of the price level. In a context of high external volatility and high pass-through, the implementation of monetary policy has contributed to absorbing shocks without causing constant reversions in the instrument of monetary policy, which would have sent ambiguous signals to market participants. On the other hand, in the recent period of greater stability, the monetary framework has resulted in an interest rate behaviour focused on offsetting shocks to aggregate demand and to the spread between inflation expectations and the inflation target. In the following section, we continue the analysis of the effectiveness of monetary policy through the study of monetary policy transmission channels.

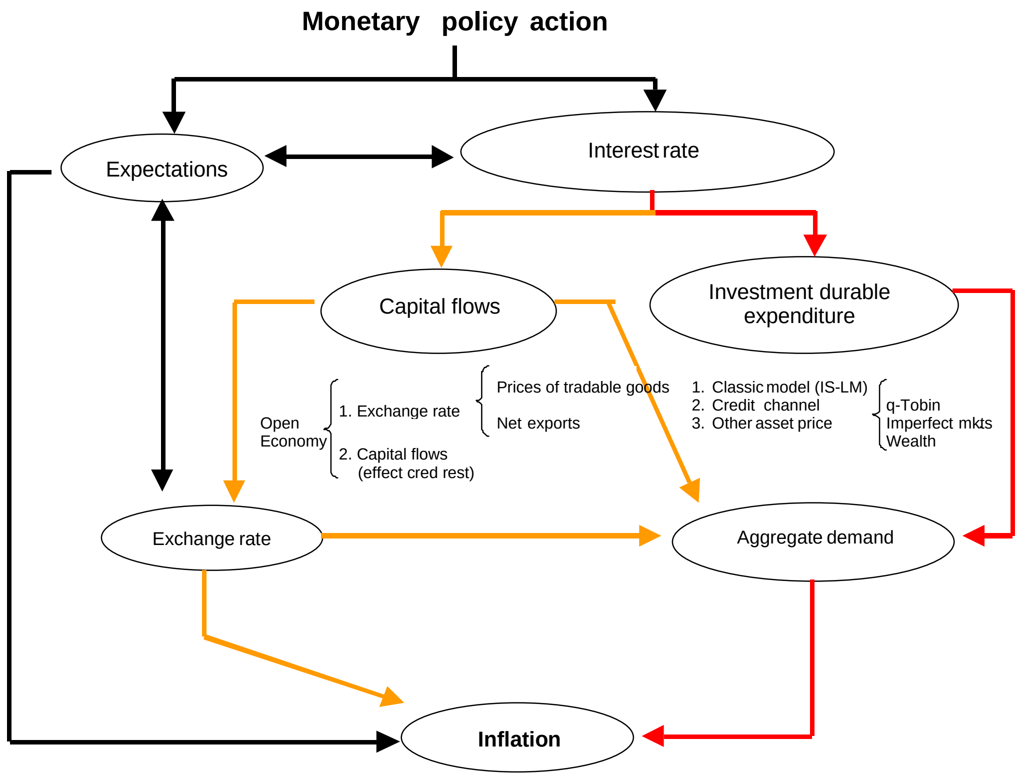
4. The transmission channels of monetary policy in Mexico: 1997-2000

4.1 Description of the transmission mechanism

The economic literature has widely reviewed the process by which the monetary authority can influence the inflation rate, both from a theoretical perspective and from an empirical one. Diagram 1 illustrates the mechanisms, developed in this literature and summarised by Mishkin (1995), through which the monetary authority affects the evolution of the inflation rate. The authority, through its monetary policy actions, has the power to influence short-term interest rates and future expected inflation. The central bank can affect the interest rate directly, as most central banks do at present, or indirectly through quantitative restrictions such as the one used by the Bank of Mexico. The differences, advantages and disadvantages of the instruments used by some monetary authorities were presented in Section 3.1.

As can be seen from the diagram, the interest rate affects the evolution of expected inflation, which can also influence actual inflation, reinforcing the effect of the actions taken by the central bank. Below, we explain how these variables affect aggregate demand and other economic variables that influence the determination of prices. For simplicity, we describe the transmission of a restrictive monetary policy. The mechanism operates the other way around with an expansionary policy.

Diagram 1



When the announcements of the authority have perfect credibility, the central bank can control inflation without needing to significantly affect economic activity. This happens because if all the economic agents believe in the target and make their pricing decisions based on this, the growth of prices will be equal to the inflation target. In this scenario, there will never be disparities between expected and targeted inflation, and therefore action by the authority to induce a price behaviour consistent with the targets will not be needed. In these circumstances, a reduction or direct control of the inflation rate can be achieved at minimum cost. This phenomenon depends to a great extent on the reputation that the authority enjoys. However, in general, an economy with high inflation that requires a stabilisation process finds it hard to achieve the necessary credibility.[17] In these cases, in the absence of a restrictive policy expected inflation will remain above the authority's inflation target. Therefore, to reach the target it will be necessary to induce a deceleration of the economy through an increase in the interest rate.

The increase in the real interest rate affects inflation in two ways. The first effect arises through the impact on the financing cost, which can be divided into three channels. The first of these is the aggregate demand channel. This channel is the one illustrated in the traditional IS-LM model and indicates that an increase in the short-term interest rate is transmitted to the whole yield curve, increasing the price of financing and thereby inducing a reduction in investment and an increase in savings. This reduction in aggregate demand reduces the pressure on prices and eventually on inflation. The second channel is the so-called credit channel, first highlighted by Bernanke (1983). This channel arises as a result of imperfections in the credit market. Through its effect, an interest rate increase will be translated into a reduction in the supply of credit. In the literature, different reasons for

[17] Except for the model presented by Sargent (1986), most of the stabilisation models require a cost in terms of output and employment to succeed.

how this effect is produced have been presented.[18] Moreover, it has been separated into the banking credit channel and that of the broader definition of financial sector, which has been called the financial accelerator mechanism. The banking credit channel can be explained in the following way. An increase in the lending rate attracts riskier projects, increasing banks' monitoring cost and causing an increase in the intermediation cost, which is reflected in the spread between the lending and deposit rates. This has consequences, in the last instance for the supply of credit, affecting investment negatively. Because of this, to verify the existence of that channel several authors have empirically studied whether monetary policy affects this spread. Other studies have analysed the effect of this spread on investment after controlling for the interest rate. A similar effect, the accelerator, is triggered as a result of a recession. When the wealth of the agents drops, agency problems increase and credit supply should fall and the interest rate spread increase (Bernanke and Gertler (1989)).

The third channel related to the financing cost arises as a result of a reduction in asset prices motivated by the increase in the interest rate. According to Tobin's *q* theory of investment, when the value of a company, approximated by its market value, is less than the cost of capital there should be a decrease in its assets or negative investment. The presence of asymmetric information in financial markets reinforces this effect, because in these circumstances a company access to financing depends to a great extent on the collateral it can offer. This is determined by the value of the company, which for public companies is given by its market value. For that reason, when interest rates are increased, stock prices fall and with it the companies capacity to find financing; resulting in smaller investment. In addition, the fall in the stock market implies a reduction in the wealth of the individuals that invest in this market, who will reduce their consumption as a result of this shock.

The second way in which the real interest rate affects inflation, denominated the *exchange rate channel*, only applies in an economy open both to trade and to capital flows. When there is an increase in interest rates, investment in peso-denominated bonds becomes more attractive, and an increase in the flow of capital towards the country is generated. Under a flexible exchange rate regime, this flow results in an appreciation of the exchange rate. In a country like Mexico, with little influence in the international markets, the appreciation should be translated into a reduction in the national currency price of tradable goods. This fall in the price of tradable goods makes the production of non-tradable goods more attractive, and a reallocation of resources from the tradable sectors towards the non-tradable ones occurs. From the demand side, when non-tradable goods become relatively more expensive, the quantity demanded will fall. Both effects, demand and supply, lead to an eventual reduction in the prices of non-tradable goods. It should be mentioned that the use of imported inputs can reinforce this effect.

In addition, the impact of capital flows can affect aggregate demand, due to the existence of liquidity constraints for both consumers and companies. This effect works in the opposite direction to the ones described in the previous paragraph. An increase in capital inflows causes the exchange rate to appreciate but also increases aggregate demand. The pressure on prices that results will only be reflected in the non-tradable sector due to the restriction that international competition imposes on the prices of the tradable sectors.

In the following section, we will analyse the importance of the different transmission channels of monetary policy for the Mexican economy. The identification of the relative importance of these is crucial for the evaluation of the effectiveness of monetary policy.

4.2 Estimation of the transmission channels for the Mexican economy

In this section, we empirically analyse the mechanisms by which the transmission of monetary policy to the inflation rate has occurred in the Mexican economy from 1997 to 2000 using VARs.

We present a simple model that incorporates the elements described in the previous section that are relevant for an open economy and that we will be using to determine the limitations of the identification assumptions imposed when estimating the VAR. The first equation is given by an accelerating Phillips curve which relates the change in the observed rate of inflation to the output gap and the devaluation

[18] The first formalisation of this channel was performed by Bernanke and Blinder (1988), in which required banking reserves had a crucial role.

of the real exchange rate (this is the nominal depreciation minus the inflation rate). In order to maintain a limited number of variables in the system, without excluding fundamental variables of the transmission mechanism of monetary policy, we use the core inflation rate. In this way, we avoid the problem of trying to control for variations in inflation associated with additional shocks, such as those that affect the determination of prices of public goods, of agricultural products and of commodities that are determined in international markets. It is clear that even so, the fluctuations in the prices of goods and services not included in the calculation of core inflation can have an effect indirectly and with a certain lag.

$$\Delta\pi_t = \alpha_0 + \alpha_1(y - y_p)_t + \alpha_2 \Delta RER_t + \varepsilon_t^{\pi} \tag{1}$$

Equation (2) shows the determinants of the output gap. This gap depends, in the first instance, on the real interest rate and on the real exchange rate. The effect of these variables appears with at least one lag, although in general it has been found in the literature that this lag is longer than six months. The error in this equation could be interpreted as shocks to fiscal policy, or to the marginal propensity to consume due to variations in the expectations of future economic growth.

$$(y - y_p)_t = \beta_0 + \beta_1 r_{t-i} + \beta_2 RER_{t-i} + \varepsilon_t^{y} \tag{2}$$

Although monetary policy in Mexico has not been implemented through the direct setting of interest rates, we can say that independently of the instrument used by the central bank, any change in the real interest rate affects the evolution of the determinants of inflation and, eventually, in the behaviour of inflation. Equation (3) describes the real interest rate determination process, which can be interpreted as the reaction function of the market and the central bank, and which is similar to the one presented in Section 3. To avoid making unnecessary assumptions, the output gap is incorporated contemporaneously, which assumes that the monetary authority counts on reliable forward-looking indicators. By adopting this specification, it is possible to determine if this reaction occurs contemporaneously or with a certain lag.

$$r_t = \gamma_0 + \gamma_1(y - y_p)_t + \gamma_2(E(\pi) - \pi_{obj}) + \gamma_3(\Delta RER_t) + \varepsilon_t^{r} \tag{3}$$

It is important to note that the relevant interest rate in equations (2) and (3) is the ex ante real rate, since the monetary authority as well as investors and consumers make their decisions based on this rate. This happens because the actual rate of inflation is only observed with a certain lag. To complete the model, we only require an equation for the exchange rate, which we can model on the basis of the interest parity condition expressed in real terms. So the real devaluation, in the context of a floating exchange rate, is determined by the disparity of real rates, adjusted by country risk.

An approximation of this model can be estimated with a VAR, adopting a triangular decomposition following the order: RER_t, $(y-y_p)$, π and r. In this specification, we are not considering the effect of the gap between expected inflation and the target. This assumption implies that the error identified as ε_t^{r} will incorporate any exogenous change of the interest rate that is motivated by a change in this difference. Another important assumption is that the interest rate is restricted to affect the RER only with a one-month lag. Finally, the yield of the Mexican bonds denominated in foreign currency is included as an exogenous variable to control for external shocks.[19]

The variables used in the analysis are:[20]

$LRER = le + lp^* - lp$	Logarithm of the real exchange rate
$(y - y_p)$	Industrial production index minus its trend[21]
π	Annual monthly core inflation rate (%)

[19] If the output growth of the United States is included as an additional exogenous variable, the results are not affected.

[20] Because the RER, inflation and the real interest rate are I(1), we tested for cointegration, finding that according to the Johansen test the hypothesis of non-cointegration at 5% is rejected. In addition, the hypothesis that only one cointegration vector exists is not rejected.

[21] The trend was calculated with the Hodrick-Prescott filter.

$r = cetes28 - E(\pi)$	Annual real ex ante interest rate (%)
i^*	Gross yield of the UMS26 bond (%)

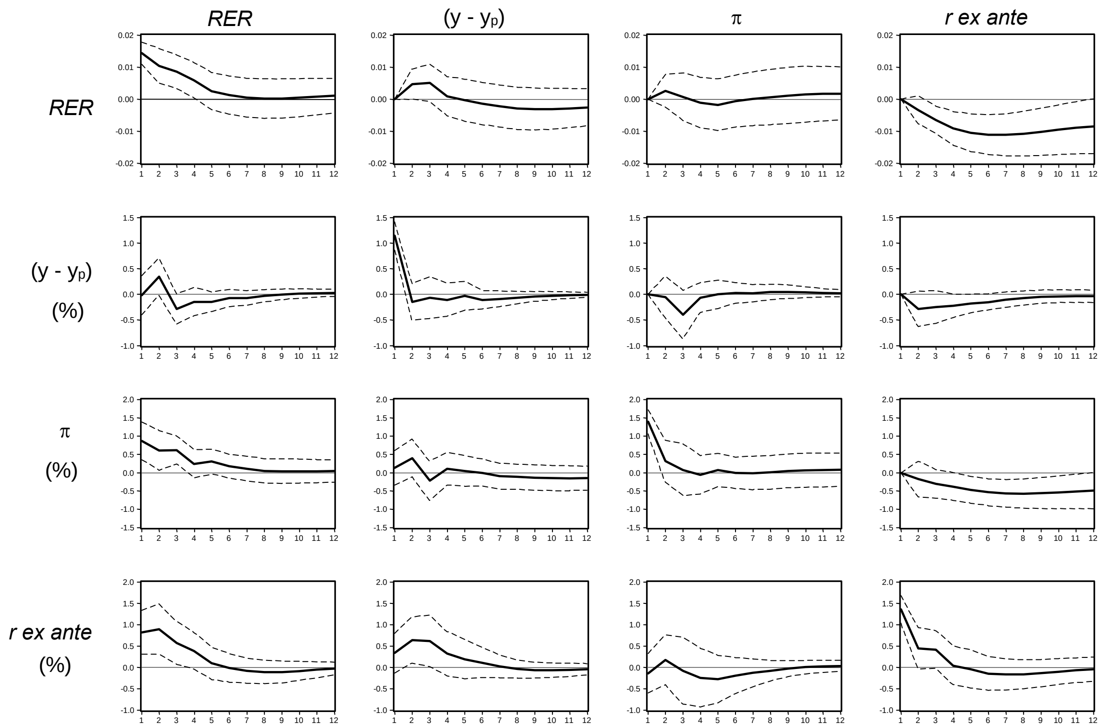
The availability of expected inflation data limits in an important way the period for which the estimation can be carried out, in this case May 1997 to May 2000. Nevertheless, the advantage gained in the explanatory power of the system justifies using this variable for the calculation of the real rate. This happens because during the last few years there have been periods in which expected inflation has shown a high error of prediction and, most importantly, this error has followed an erratic pattern, leading to a significant difference between the results obtained with the real ex post rate and the ones obtained when including an ex ante rate.

The specification adopted and the use of the real ex ante interest rate allow us to identify the shocks to the interest rate independent of other factors that affect the external supply of funds. This is because if we opt for a specification in which the interest rate precedes the exchange rate, even after controlling for the external interest rate, the change in interest rates and exchange rates occurs in the same direction. This reaction represents the response to a shock in the supply of capital flows and not to a change in the interest rate when this supply remains constant.[22]

Graph 14 shows the impulse response functions that result from the estimation of the VAR and the assumptions mentioned above. The rows show the reaction of each of the endogenous variables to each of the structural shocks presented in the columns.

Graph 14

Impulse response functions



The first column of Graph 14 illustrates the dynamics of the variables as a result of a one standard deviation disturbance to the real exchange rate, equivalent to a real devaluation of 1.4%. This shock can be due to any internal or external factor other than the yield of the bond denominated in dollars, which was incorporated in the estimation as an exogenous variable. The reaction of all the variables is consistent with the expected behaviour. The output gap increases with a one-month lag and after

22 Schwartz and Torres (2000) find similar effects when considering innovations to the corto.

three months the effect disappears. The rate of inflation and the interest rate increase instantaneously. Finally, the real interest rate increases by 0.82 percentage points in response to the real depreciation of 1.4%.

In terms of the speed and magnitude of the adjustment of prices to changes in the exchange rate, we found that this adjustment is slower and of smaller magnitude than that obtained in Section 3.3 and to that obtained by other authors (for example Garcés (1999)). This difference is due mainly to the period considered and, as Garcés mentions, there is some evidence that the pass-through from exchange rate movements to prices has decreased in recent years.

The second column corresponds to a shock in the output gap, which could be associated, for example, with an expansionary fiscal policy. In response to an increase in this gap, the RER, inflation and the real interest rate increase. The increase in the real interest rate can be due on the one hand, to the increase in the demand for credit and, on the other hand, to a greater tightening of monetary policy oriented towards reducing the inflationary effect of the expansion.

In the third column we can see the effects of a shock to the rate of inflation, by which the rest of the variables are not affected significantly. In the following section, when discussing the monetary rule we will go deeper into the possible interpretations of the absence of adjustment of the interest rate.

The fourth column presents the reaction to an increase in the real interest rate not explained by a change in some other variable. Since the central purpose of this section is to analyse the transmission mechanism of monetary policy, we pay special attention to the analysis of the results illustrated in this column.

An increase of 1.4 percentage points in the ex ante real rate entails a real appreciation that reaches a maximum of 1% after seven months and then disappears slowly. The output gap also experiences a fall after a month, in this case of 0.3%. This effect is significant between the fourth and sixth month after the shock takes place. The rate of annual inflation also drops, due to the effect of the appreciation as well as the fall in output. This reduction is largest during the eighth month and is equivalent to 0.57 percentage points. It is significant after four months and remains so until the 10th month.

The last row of the graph gives us information about the reaction of real interest rates to different disturbances. These results indicate that the monetary authority and/or the market induce an interest rate increase when inflationary pressures appear as a result of a devaluation (first column) or of an increase in the output gap caused by an increase in the marginal propensity to consume or a loosening of fiscal policy or other demand factor (second column). Nevertheless, in the third column, it is not possible to detect a significant effect on the interest rate of an inflation shock originating from another source of uncertainty. The joint path of these variables could indicate that the market and the authority identify these shocks as transitory or probably seasonal, which is why it turns out to be optimal to keep the real interest rate constant.

Table 9 presents the long-term variance decomposition, ie the variation attributed to each of the shocks as a percentage of the total variance explained by the model. It is important to clarify that because the yield of the bond denominated in dollars was included as an exogenous variable, the explained variance is net of the effect of this variable. The shaded area is of greater interest in the sense that it reflects the relative impact of the independent movements in real interest rates on the evolution of the other variables of the system.

Among the domestic sources of variations in the rate of inflation, the real exchange rate and the output gap, the movements in the real interest rate stand out in terms of importance: they explain 14% of the variation of the output gap and 50% of that of the rate of inflation.

Table 9

Variance decomposition

percentage variance attributable to shocks to:

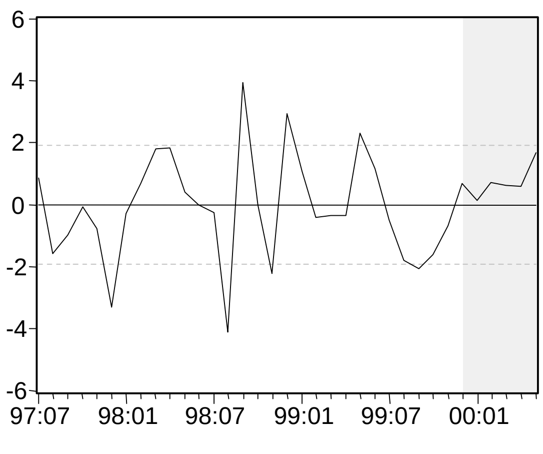
	LRER	**(y-y_p)**	**Infl**	***r***
LRER	21	6	2	71
(y-y_p)	12	66	8	14
Infl	20	6	24	50
r	35	19	5	41

Using the estimated coefficients, we can determine how interest rates have deviated from the estimated rule by analysing the path followed by the error identified as a shock to the interest rate (Graph 15). By construction, the average of the error is equal to zero, but it should be noted that during the last year, unlike the rest of the period, this error has been consistently positive. The behaviour of this error indicates that during this period the real interest rate has been on average 1 percentage point above the value determined by the estimated rule. This result reflects the strengthening of monetary policy to continue with greater reductions in the inflation rate. It is important to emphasise that this behaviour could possibly be incorporated in the monetary policy rule, making it more general by including the gap between the expected inflation and the inflation target, so that this bias towards a more restrictive position responds to an increase in this gap. In Section 3.4, structural estimations of the reaction function of the Bank of Mexico were carried out, and indeed we find that this gap is important for the monetary rule and that it has grown in importance in the last year. In this case, the behaviour of the error indicates that for the period mentioned, the interest rate has been only 0.6 percentage points above the value predicted by the rule.

Graph 15

Deviation of the ex ante real interest rate from the estimated monetary policy rule

(percentages)



4.3 Decomposition of the impact of a disturbance in the real interest rate

The estimation performed indicates that an increase in the real interest rate causes a real exchange rate appreciation, induces a fall in the output gap and generates a reduction in inflation. Nevertheless, this estimation does not allow us to determine if the fall in inflation is due exclusively to the appreciation of the real exchange rate or if the reduction in the output gap helps to explain this phenomenon. With this objective, a second estimation was carried out, separating tradable goods and non-tradables. By means of this separation, we want to determine if the fall in inflation as a result of an increase in the interest rate is due purely to the effect of the appreciation on tradable goods prices.

In addition, when describing the channels by which monetary policy affects the economy, we mentioned that the increase of capital flows caused by an increase in interest rates could relax certain liquidity constraints, creating a positive effect on aggregate demand. With the estimation using aggregate economic activity performed in the previous section, we can not determine if this effect exists. However, we find that, where it is present, it is offset by the recessionary impact of the interest rate. If we now analyse the inflation in non-tradable goods separately, we can determine if the increase in the demand for this kind of good caused by this effect is superior to the recessionary effect. In this way, we can see whether a restrictive policy causes a reduction in prices, not only through its impact on the nominal exchange rate but also through its negative impact on aggregate demand.

In this exercise, for tradable goods inflation we used the inflation from the core price index for merchandise, and for non-tradable goods we took the core price index for services. Unfortunately, for the non-tradable sector there are no reliable monthly indicators for the output gap. Due to this limitation, the sectoral output gap was not included in the estimations. In order to be able to compare the results, this variable was also excluded for tradable goods.

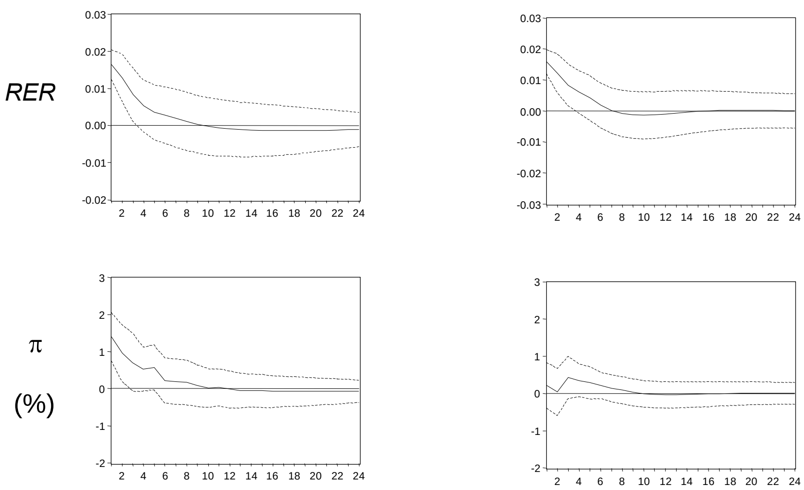
A VAR for each sector was estimated, similar to the one presented in the previous section, including the following variables: *LTCR*, π_i *and r,* in that order and with *i=trad or nontrad*, according to the case. Because the identification methodology is the same as the one described above, the interpretation of the shocks is also similar.

Graph 16 shows the impulse response functions for the rate of inflation in both sectors to an exchange rate shock.[23] As expected, the effect of the exchange rate on the inflation in tradable goods is immediate. A depreciation of 1% causes an increase in annual inflation of 0.83 percentage points. In the case of non-tradable goods, the effect is very small and non-significant.

Graph 16

Impulse response functions to a shock in *RER*

Tradable goods (merchandises) Non-tradable goods (services)



[23] The graph of the impulse on the interest rate is not included to save space and because this is very similar to the one presented in the estimation for the aggregate economy.

Graph 17 shows the impulse response functions of a shock to the real interest rate. In both sectors a fall in the inflation rate occurs, although the effect occurs more quickly and is of greater magnitude in the tradables sector. These results indicate that the increase in demand in response to greater financing is relatively less important compared with the effect of the appreciation and the contraction caused by the direct effect of the interest rate. In addition, according to the functions shown in Graph 16, the exchange rate depreciation has a small and non-significant effect on the inflation in non-tradable goods. The fall in inflation in these goods associated with the increase in the real interest rate is explained by the effect of the contraction of the output gap and not by the exchange rate appreciation.

The variance decomposition for inflation (Table 10) shows that even in the non-tradable goods sector shocks to the real interest rate are very important in the determination of inflation, explaining 44% of the variance for this variable. For tradable goods the importance is lower because in this case the exchange rate plays a fundamental role. Nevertheless, 41% of the variance is generated by the interest rate shock. Moreover, shocks to the real exchange rate explain an almost insignificant percentage of the variance for the inflation in non-tradable goods. These results suggest that the traditional transmission channel of monetary policy has operated in the Mexican economy for the last four years.

Graph 17

Impulse response functions to a shock in *r*

Tradable goods (merchandise) Non-tradable goods (services)

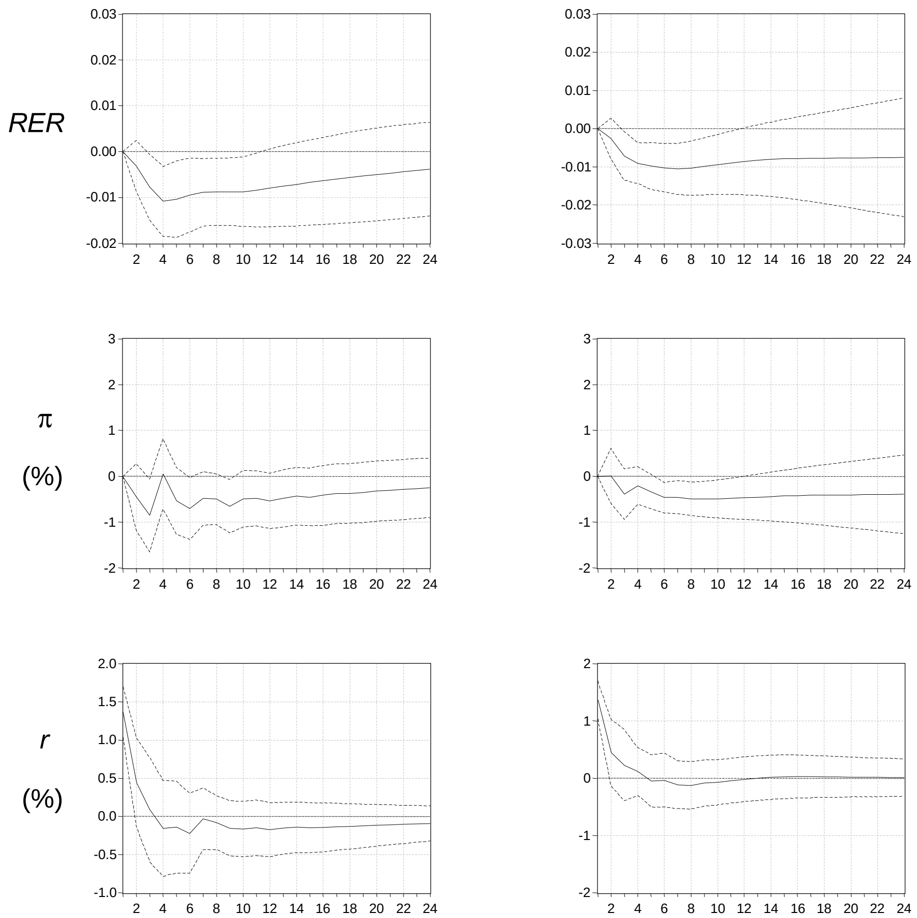


Table 10

Variance decomposition

Percentage variance attributable to shocks to:

	RER	**Infl**	***r***
Tradables infl	34	24	41
Non-tradables infl	6	51	44

4.4 Importance of the credit channel

As described in Section 4.1, imperfections in financial markets tend to amplify the effect of monetary policy. That is, the characteristics of banking credit, unlike commercial paper for example, imply that an increase in interest rates generates a fall in the supply of this type of credit. This contraction in the supply will be reflected not only in a credit contraction but also in an increase in the spread between the lending and deposit rates.[24]

There are some studies that estimate the importance of this channel for the Mexican economy (Copelman and Werner (1995) and Hernández (1999)). Nevertheless, we do not have evidence for the period after the crisis of 1995. This analysis is particularly relevant because since 1995 banking credit has been extremely scarce, which is why a priori it is difficult to think that this channel has been important. On the other hand, it has been found that financing has not occurred through the bond market but through the external market and other non-banking sources, such as supplier credit or trade credit. These alternative credit mechanisms, like banking credit, are subject to serious problems of information, which can give rise to mechanisms similar to the traditional credit channel.

In this section, we empirically analyse this hypothesis, adopting two alternative strategies. The first consists in determining if the interest rate, in reaffirming the monetary policy stance, has had a significant effect on the lending-deposit rate spread and if this has affected economic activity. The second consists in using data on trade loans by companies to estimate the effect that interest rates have had on them.

Monetary policy, interest rates spreads and economic activity

As a first step, an OLS regression was estimated to explain the relationship between interest rates and the spread[25] on interest rates, including as explanatory variables the lag of the spread, the nominal devaluation, the interest rate on Mexican bonds denominated in dollars and the ex ante real interest rate in pesos. The effect of this spread on economic activity was then estimated. This second step is essential due to the limited role that banking credit has played as a financing alternative. This could mean that, even though interest rates have a major effect on spreads, this does not have significant repercussions for the economy. The first column of Table 11 presents the results of the equations for this first step and the last two columns show those for the second step.

When estimating the determinants of the spread (first column), we found that the real rate is positively and extremely significant. In addition, the magnitude of the effect is quite high.

[24] Kashyap et al (1993) develop a theoretical model with which they derive this result.

[25] The interest rate spread is equal to the lending rate, based on information provided by the firms obtaining credit in Mexico, minus the average funding cost.

Table 11

Effect of the real interest rate on interest rate spreads and on the income gap

	$\left(i^a - i^p\right)$	$(y - y_p)$	$(y - y_p)$
$\left(i^a - i^p\right)$	0.26 (0.19)		
$\left(i^a - i^p\right)_{-4}$			-0.47^{1} (0.23)
r	0.36^{2} (0.11)		
r_{-4}		-0.27^{2} (0.08)	0.01 (0.15)
$\Delta\%e_{-4}$	0.13 (0.09)	0.06 (0.10)	0.11 (0.10)
UMS26	0.58 (0.40)		
$\overline{R}^2$	0.84	0.26	0.33
N	37	33	33

Note: Standard errors are in parentheses

[1] Significant at 10%. [2] Significant at 5%. [3] Significant at 1%.

The estimations imply that an increase in the real rate of 1 percentage point is associated with a contemporaneous increase in the spread of 0.36 percentage points and a long-term effect of 0.49 percentage points The second column of the table shows that the real rate is an important determinant of the output gap when we do not control for the spread. This effect is negative and significant, even when controlling for nominal depreciation, and implies that an increase of 1 percentage point in this rate leads to a fall in activity below its potential level, after four months, of 0.27%. Once the spread is included (third column), this variable appears significant and the real interest rate loses its significance. The results indicate that an increase in the spread of 1 percentage point causes, after four months, a fall in the output gap of 0.47%. These results hold even when controlling for different lags of the external interest rate.

Supplier credit and interest rate

For this analysis, we used quarterly data from the non-financial companies quoted on the Mexican stock exchange, for the period 1996 to 1999. The total number of companies considered was 231. The following concepts were used as proxies for financing via suppliers: clients and receivables, which reflect the credit that these companies grant; and supplier credit, which reflects the debts owed to them. Because both concepts reflect a stock, first differences and growth rates were alternatively taken as endogenous variables.[26] In order to control for the economic situation, we included as explanatory variables different transformations of net sales.[27] In addition, the contemporaneous and lagged real interest rates were included as interest variables. The estimations were carried out using a fixed effect model and they appear in the first two columns of Table 12.

The first column of the table shows the results for receivables, where we find a contemporaneous positive effect of the interest rate, and a negative effect when using a one-quarter lag. The initial positive effect, common in this kind of estimation, is due to an increase in the credit default rate. Thus, at the beginning the former effect dominates the fall in new credits, and only after three months does

[26] For reasons of space and because the results are not significantly modified, Table 12 includes only the results obtained with the growth rates of the endogenous variables.

[27] GDP growth was also used, but because the results were very similar they were not included in Table 12.

the latter effect become more important. The net effect of an increase of 1 percentage point in the rate is a reduction of 0.6 percentage points in the growth rate of the receivables.

Table 12
Effects of interest rates on trade credit

	Receivables	Suppliers	Receivables	Suppliers
	1996-99		1989-94	
r	0.01[1]	0.03[2]	-0.14	0.35
	(0.006)	(0.007)	(0.356)	(0.442)
r_{-1}	-0.02[1]	-0.04[2]	0.11	0.12
	(0.006)	(0.007)	(0.331)	(1.796)
Sales	-0.00	-0.00	0.000	0.0004[2]
	(0.000)	(0.000)	(0.000)	(0.000)
N	2,095	2,064	4,445	4,430
$\bar{R}^2$	0.58	0.04	0.30	-0.03

Note: The dependent variables are growth rates. Standard errors are in parentheses
[1] Significant at 10%, significant at 5%. [2] Significant at 1%.

The second column shows the same specification using supplier credit as the endogenous variable. The results also confirm the hypothesis that supplier credit is not immune to changes in the stance of monetary policy. In this case, the net effect of this change in the interest rate is a 1 percentage point in the growth of debts with suppliers.

In the last two columns of the table, we present similar estimations for the pre-crisis period from 1989 to 1994, with the aim of analysing whether supplier credit followed the same pattern even though banking credit experienced strong dynamism. This comparison is important because in the sparse literature that analyses the effect of interest rates, and in particular changes in monetary policy, on supplier credit it is found that supplier credit behaviour is the opposite of banking credit behaviour, which implies that the former is an imperfect substitute for the latter. When finding that this result does not hold for Mexico during the period from 1996 to 1999, the dilemma arises owing to the fact that in general supplier credit is a complement of banking credit or due to the absence of this type of credit during the period analysed. According to the table, the result is very different for the period before the crisis (1989-94). In this case, a significant effect of the interest rate on credit is not found. This reflects the fact that before the crisis supplier credit responded to factors other than the aggregate conditions of the economy, such as cash flow or net sales, that now become significant for the second specification.

Although the evidence confirms that the interest rate has negatively affected the amount of credit in the economy, the conclusion that this effect is completely attributable to the credit channel is questionable. A more detailed analysis, which is beyond the scope of this work, could contribute in an important way to resolving this question. Nevertheless, both strategies indicate that an increase in the interest rate implies a fall in credit even if it occurs directly or as result of a fall in aggregate demand. What matters for our purposes is that ultimately the interest rate channel works independently of the exchange rate in the Mexican economy in spite of the low levels of banking credit.

5. Conclusions

In this paper, we addressed the implementation of monetary policy in Mexico. We first described the evolution of the monetary policy framework in Mexico since 1995, and then the operating mechanism and the response of the central bank to shocks affecting the exchange rate and its effects on economic activity and, ultimately, the rate of inflation.

The exchange rate and financial crisis that took place at the end of 1994 and during 1995 forced the authorities to adopt a freely floating exchange rate regime. The use of the exchange rate as the nominal anchor of the economy was therefore abandoned. Due to criticisms about the lack of transparency and dissemination of information, and given the need to establish a visible and strict nominal anchor, in 1995 a target for the annual growth of net internal credit was adopted. In addition, as a consequence of the great uncertainty with respect to the evolution of the Mexican economy, it was considered extremely risky to use a short-term interest rate as the instrument of monetary policy. Therefore, with the aim of implementing an operating framework in which the exchange rate as well as interest rates were freely determined, the Bank of Mexico adopted a borrowed reserves target as its instrument.

Since 1998, monetary policy has undergone a gradual shift towards an explicit inflation targeting framework. In the process, the monetary base has become less important as an intermediate target and the short- and medium-term inflation targets have increased in importance. The implementation of discretionary monetary policy actions has contributed to the attainment of these targets.

The relevance of this study lies in clearing up some doubts about monetary policy in Mexico:

1. the advisability of using a quantitative restriction as an instrument in an environment in which most countries have adopted interest rates objectives.

2. the effectiveness of monetary policy, in general terms, in an open economy in which domestic banking credit has been very limited.

With respect to the first point, we found that although the corto entails greater uncertainty over its effect on interest rates, compared with an interest rate objective, it has been very effective in distributing the impact of external shocks between the exchange rate and the interest rate. This advantage is extremely important for the Mexican economy, which is exposed to great volatility and a high pass-through of changes in the exchange rate to prices. The second point above is supported by the finding that this mechanism has contributed in a significant way to the stabilisation process, especially since 1998, when the ex ante real interest rate has reacted significantly to deviations of expected inflation from the target.

With regard to the effectiveness of monetary policy, our results indicate that in addition to the exchange rate channel, monetary policy has affected inflation via the financing cost in the Mexican economy since 1997.

By estimating a VAR, we reached the conclusion that this effect has been particularly important. In the first instance, we found that an exogenous increase in the ex ante real interest rate negatively affects the output gap. An increase of 1 percentage point in this rate leads, after a month, to a fall in GDP of 0.2% with respect to its potential level. This effect is significant between the fourth and sixth months after the initial disturbance.

When analysing the tradable and non-tradable sectors separately, we observed that the exchange rate by itself has not had a significant effect on the price of non-tradable goods, while exogenous increases in interest rates have caused a negative and significant effect in that variable. Both results indicate that the interest rate channel, in addition to its effect through the exchange rate, has negatively affected aggregate demand and, ultimately, the price level.

An additional channel through which monetary policy has operated is credit conditions. Increases in real interest rates have been reflected in higher intermediation costs, measured as the spread between the lending and deposit rates, and these have resulted, in turn in a reduction of the output gap. An increase of 1 percentage point in the ex ante real interest rate causes an average increase in this spread of 0.36 percentage points immediately and 0.49 percentage points in the long term, leading to a fall in the output gap of 0.23% after four months. In addition, we found that an increase in the ex ante real interest rate has negatively affected supplier credit. On average, an increase of 1 percentage point in this rate initially causes an increase but after three months a fall is observed, the net effect being a reduction of 0.6 percentage points in the growth rate of suppliers' credit.

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Transmission mechanisms of monetary policy in an economy with partial dollarisation: the case of Peru[1]

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1. Introduction

Implementing monetary policy requires a good understanding and modelling of the monetary transmission mechanism. In the particular case of developing economies like Peru, this transmission mechanism would need to consider the degree of financial market development, price rigidities, the partial dollarisation of the economy, some possible non-linearity and the operating procedures of the central bank. It is also vital to be able to identify if shocks are transitory or permanent, nominal or real. These characteristics, together with the central bank's aversion/tendency to frequent policy changes and the structure of its loss function, will exert some influence on the monetary policymaker's reaction function.

In Peru, studies on monetary policy have shown that monetary transmission channels are not very clear. Moreover, the macroeconomic predictors and lag structures are less stable than in the case of developed economies, while economic variable series present some structural differences and are quite short-sampled and unstable.

Another important issue for monetary policy is the ability to forecast inflation in order to activate the operational procedures required to reach its main monetary stability target. However, both forecasts of inflation and the magnitude and time horizon of the central bank's reaction function depend on adequate identification of the transmission mechanisms of monetary policy. In general, understanding monetary transmission mechanisms is essential to adequate design and implementation of monetary policy. This aspect is even more important when the monetary authority announces the medium-term path of the inflation target, as in the case of the Central Reserve Bank of Peru.

Four important elements should be noted with regard to these transmission mechanisms:

- the relative importance of supply and demand shocks in explaining inflation;
- the best indicator of monetary policy stance;
- the time horizon of monetary policy's impact on inflation; and
- the magnitude of monetary policy's impact on inflation.

We are interested in identifying the transmission mechanisms of the monetary policy action in reaching its main goal: the reduction of the inflation rate. First, we intend to identify the sources of variation of the inflation rate, modelling, in a structural VAR, supply, demand and monetary shocks. The empirical evaluation of this model will give us some insights as to the policy instrument that best fits the monetary policy goals, whether influencing the aggregate demand or the supply side through the cost structure of firms. The empirical results show that the inflation process in Peru is mostly driven by demand shocks, with monetary shocks accounting for 30-40% of inflation rate variance.

The second step, identifying the best indicator of the monetary policy stance, found that different studies for Peru on this topic have shown that money aggregates are the best indicators of the monetary policy stance.

A third step in identifying the monetary transmission mechanisms is to model the operating procedures of the central bank, principally its interactions with the banking system through the money market, considering the partial dollarisation of the economy. The empirical results of these structural VAR

[1] This paper represents the views and analysis of the author and not those of the Central Reserve Bank of Peru.

procedures give some indication of the time horizon and the magnitude of the impact of monetary policy on its final target: the inflation rate. In this case, the estimations conclude that the time horizon of monetary policy transmission is between eight and 16 months. This result is consistent with a small open economy with partial dollarisation such as Peru. Another finding is that every 10 additional percentage points of variation in base money generate an additional 3.8% of inflation. A 10% depreciation of the exchange rate generates 1.2% of additional inflation.

A fourth interesting topic on monetary transmission mechanisms is the identification of the different transmission channels. We concentrate our attention on the money and credit channels considering the coexistence of currency denominations of banking sector credit to the private sector. The empirical results show that the money channel seems to be effective in Peru. There is no clear evidence of the effectiveness of the credit channel.

2. What drives the inflation rate: supply or demand shocks?

A first step in designing monetary policy is to diagnose the sources of inflation. In this section, we address the question of whether supply or demand shocks explain most of the inflation in Peru and the explanatory importance of money in demand shocks. We use the procedures developed by Machado et al back in 1994 to explain the postwar US inflation process, based on the VAR models used by Davis and Haltiwanger (1994) and the decomposition of shocks used in Blanchard and Quah (1989). The appendix describes the model identification and procedures of Machado et al (op cit).

With a classical GDP-prices-money structural VAR,[2] and considering that positive supply shocks increase output and reduce the price level while positive demand shocks increase both output and prices, we carried out some estimations using alternately base money and household cash holdings as monetary indicators. With monthly data from 1979-2000 we found that monetary shocks explain a significant part (between 22 and 30%) of the variance of inflation (see Graph 1). Demand shocks account for more than 60% over short (four-month) and long (16-month) horizons. Supply shocks seem to be of no relevance here. If we consider household cash holdings as the indicator of monetary policy, money shocks account for a more important portion of inflation (between 30 and 35%). This is consistent with the transactional role of household cash holdings which, consistent with many theoretical views, are the best indicator of aggregate demand in the economy (Graph 2). In sum, demand shocks explain more than 50% of the variance of inflation for short and long horizons, and money shocks explain inflation in a range of 30-40%. The evaluation of a smaller and more recent sample (considering important changes in monetary policy due to the stabilisation process and the structural reforms implemented since August 1990), from 1992-2000, produced no significant change in the results.

There was no clear conclusion about the relative importance of each shock in explaining GDP growth. We may argue that there are no important demand impacts on GDP growth, such that monetary policy is more effective when dealing with inflation.

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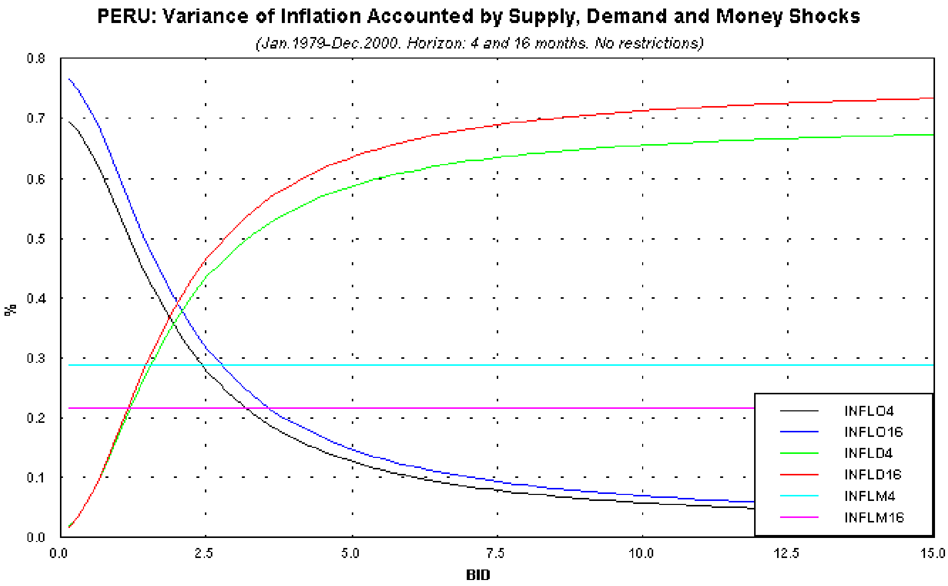
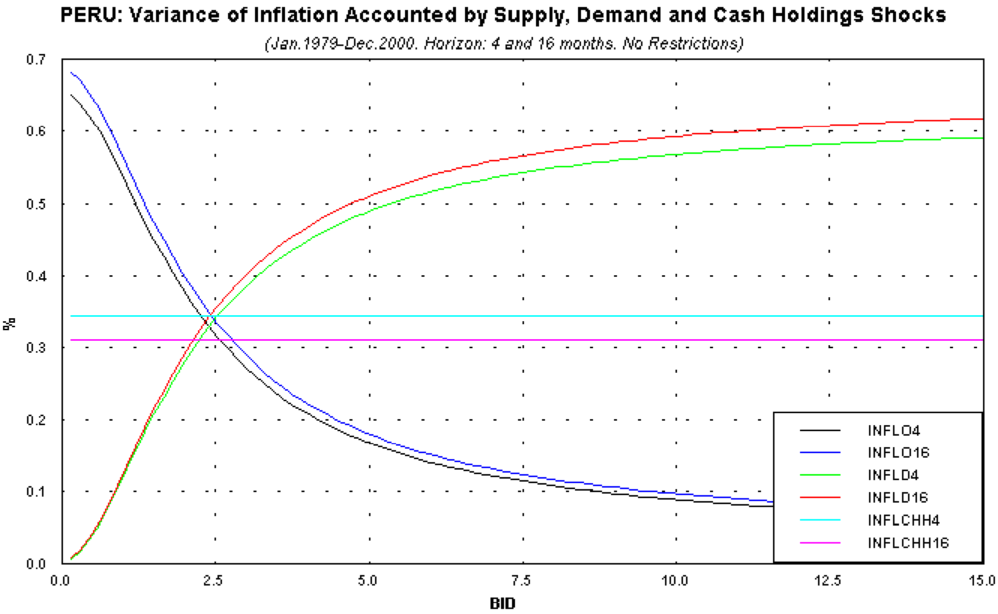
[2] For the optimum lag structure of the variables and the Unit Root tests, we used the same procedures as Quispe (2000). The Akaike and Schwarz criteria result in a three-month optimal lag, and the augmented Dickey-Fuller and Phillips-Perron tests show stationarity of the economic variables in first differences.

Graph 1

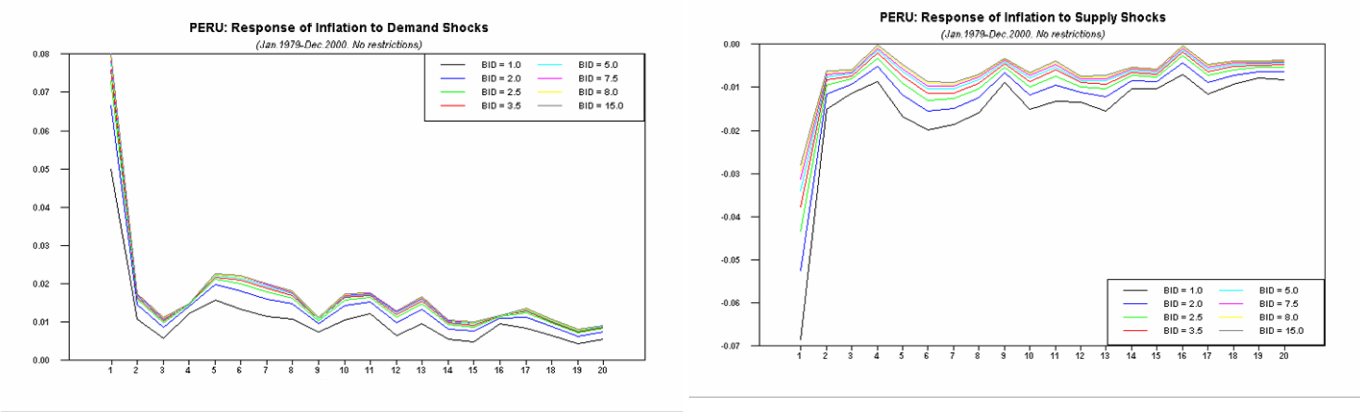


Graph 2



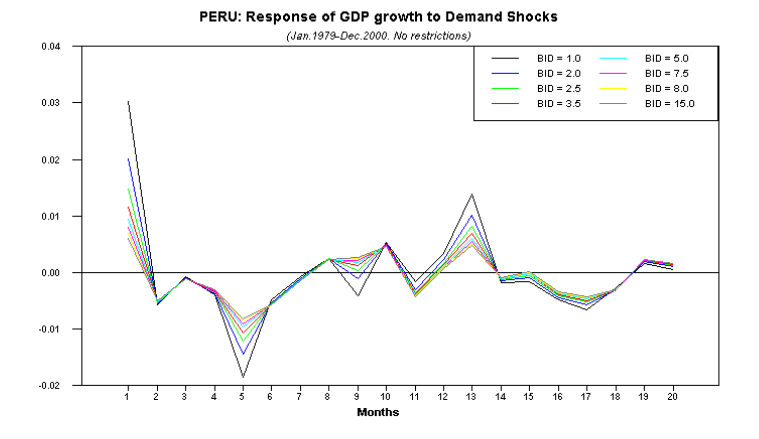
The impulse responses show a clear impact of demand shocks on inflation even with the identification uncertainty stated by the Machado et al model (Graph 3). The supply shocks explain inflation with the right negative sign but with less power than demand shocks.

Graph 3

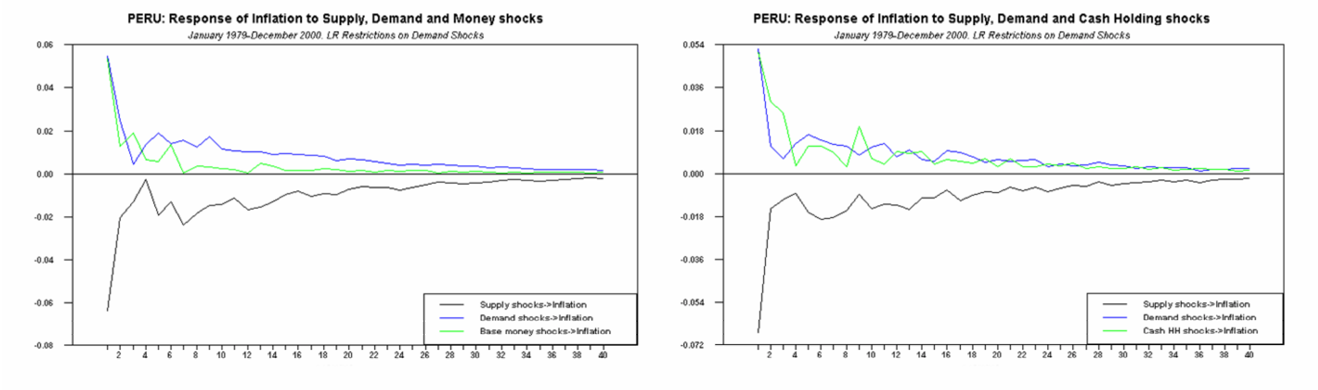


There is no clear conclusion about the relative importance of each shock in explaining GDP growth (Graph 4). This confirms our earlier finding that monetary policy is more effective in dealing with inflation. It also implies that there is no long-run effect of demand shocks on output growth.

Graph 4



Graph 5



The exactly identified model with the imposition of the long-run restriction gives no changes in the main results (Graph 5). Supply, demand and money shocks (base money or cash holdings) explain inflation with the expected sign as it is in the IS-LM framework.

3. Indicators of monetary policy stance

The previous section shows evidence that the inflation process in Peru has been driven by demand shocks, with monetary shocks accounting for a range of 30-40% inflation rate variance. Moreover, in identifying the best indicator of monetary policy stance, different studies have shown that money aggregates are the best such indicators in Peru.

Berg and Borenzstein (2000), using a sample of 82 quarters (from 1975 Q3 to 1995 Q4), found that narrow aggregates (base money and currency in circulation) best explain the inflation rate in Peru. However, given the structural breaks in price equations with all monetary aggregates in 1990, when Peru stabilised inflation and changed its exchange rate regime, they also made estimations with a smaller sample of 20 quarters (from 1991 Q1 to 1995 Q4) and found some evidence that broad money (including domestic and foreign currency deposits) could be the best predictor of inflation. In this last result, there is the possibility of a small sample bias due to low degrees of freedom.

Using a larger and monthly data sample (from 1991 M1 to 2000 M6), and considering end of period and monthly average data, Quispe (2000) found that narrow monetary aggregates are still the best predictors of inflation in Peru. These results are consistent with the asset substitution characteristic of the dollarisation process in Peru.

As seen in the previous section, money still has a significant impact on inflation. In addition, since 1995, different studies on monetary policy in Peru have shown that monetary aggregates seem to be the best indicators of monetary policy stance. The following table gives an overview of these studies.

Studies on monetary policy in Peru

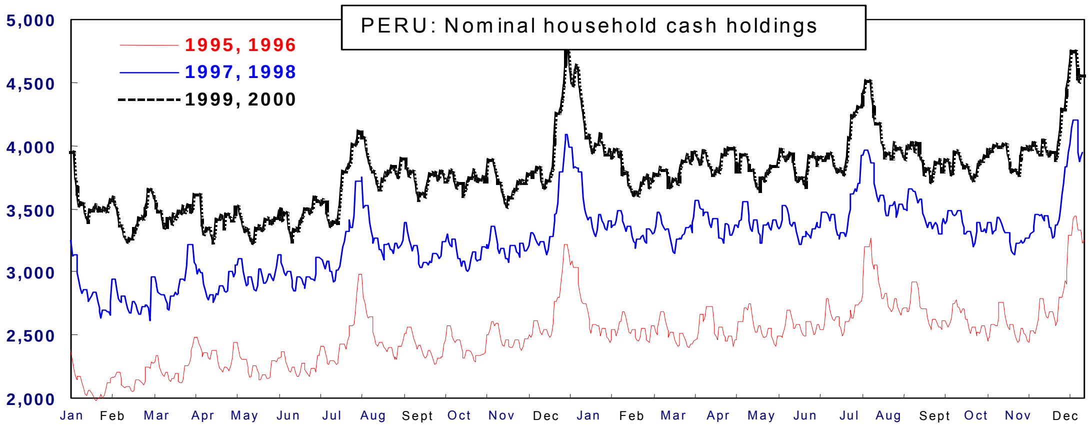
Researcher	Indicator of money	Time	Shocks impact - CD rates
Luque and Perea (1995)	Base money		
Ishisaka and Quispe (1995)	Reserves, current account balances in CB, CB CD interest rate	6-14 months	1.5%
Bringas and Tuesta (1997)	Excess reserves	3-12 months	
León (1999)	Cash holdings of households	4-14 months	
Barrera (2000)	CB CDs interest rate	8-12 months	2.0%
Grippa and Ferreyros (2000)	Cash holdings of households	9-12 months	
Quispe (2000)	Base money and cash holdings	8-16 months	

One explanation for the results of these studies is that the demand side of base money is mainly composed of household cash holdings (80%), which have a close relationship with current transactions in the economy. For current transactions, Peruvian households mainly use domestic currency.

Another aspect of these findings is connected to the time horizon of the transmission mechanism. This horizon has been expanding so that there is a more lagged impact of monetary policy on inflation, as the economy evolves over time and works in a more stable macroeconomic scenario. Is this a sign of higher credibility of monetary policy and of the commitment of the central bank to its inflation target? This evidence may suggest so.

As evidence of the transactional role of household cash holdings, the daily figures of this monetary variable follow a predictable pattern, reflecting the fact that the households are telling us: “I hold the money that I currently need for transactions” (Graph 6).

Graph 6



4. Monetary transmissions and the operating procedures of the central bank

With regard to the main channels in the monetary transmission mechanism in Peru, we summarise below important facts described by De la Rocha (1998).

The money channel seems to be effective in Peru because dollarisation is not of the currency substitution type. Central Reserve Bank of Peru estimates have shown that an increase in central bank CD interest rates tends to feed through to the banking overnight interest rate. This can then change longer-term market interest rates and so affect aggregate demand and inflation.

It is less clear whether the credit channel is important in a dollarised economy such as Peru. On the one hand, corporations tend to rely on the banking sector for credit, and bank credit is replacing informal funds for investment finance. (It is also worth noting that many non-bank financial institutions have liabilities outside the domestic financial sector.) On the other hand, the access of domestic firms to foreign credit and equity financing (on domestic and foreign markets) is becoming more important.

The exchange rate would seem a priori to be an important channel of monetary transmission in Peru. If domestic and foreign assets are highly substitutable, interest rate changes can lead to large foreign exchange swings and then feed into domestic prices. The ability of the central bank to intervene systematically to control inflation through the exchange rate is weak due to the asset substitution. These facts constrain the intervention of the central bank in the exchange market to only supporting its monetary targets and smoothing out large fluctuations in the exchange rate.

In Section 5, we try to identify the credit channel of monetary transmission considering that in the Peruvian case there is a banking credit dependence of small and medium-sized firms, and a very limited participation of large corporations in the incipient Peruvian capital markets. In theory, in this context the credit (lending) channel of monetary policy would be fully active. However, the central bank's ability to reduce the credit supply of the commercial banks through the reduction of domestic currency financial funds of the banking system is limited due to the existence of alternative external sources of funding, neutralising the possible impacts of monetary policy on domestic credit to the private sector.

Just by looking at the credit series it is not possible to identify which part of the credit variations represents changes in the supply of funds (associated with the credit or lending channel) and which part is accounted for by changes in the demand for credit (mainly associated with the money channel).

However, through a structural VAR procedure it is possible to model the fact that with demand shocks, we can expect positive variations in both domestic currency credit and foreign currency credit in the domestic market. If there is a negative supply shock in the credit market, we can expect a negative reaction of domestic currency credit and a positive reaction of foreign currency credit considering the substitution of flow-of-funds capacity of the banking system. With these identifying assumptions, we decompose the variance of the change in domestic currency and foreign currency credit.

In this way, we can identify what percentage of variation in domestic credit is due to supply and demand shocks respectively. With monthly data from 1979-2000, the variance in domestic currency credit due to supply shocks is 20%, while the variance in foreign currency credit due to supply shocks is more than 90%. The variance in domestic credit explained by demand shocks represents around 80%, while the variance in foreign currency credit explained by demand shocks is almost zero. It is clear that 80% of the variation in domestic currency credit resulted from monetary transmission through the money channel.

In conclusion, it seems clear that the ability of the banking system to use substitute funding neutralises the credit channel of monetary transmission in Peru.

4.1 Transmission mechanisms of monetary policy

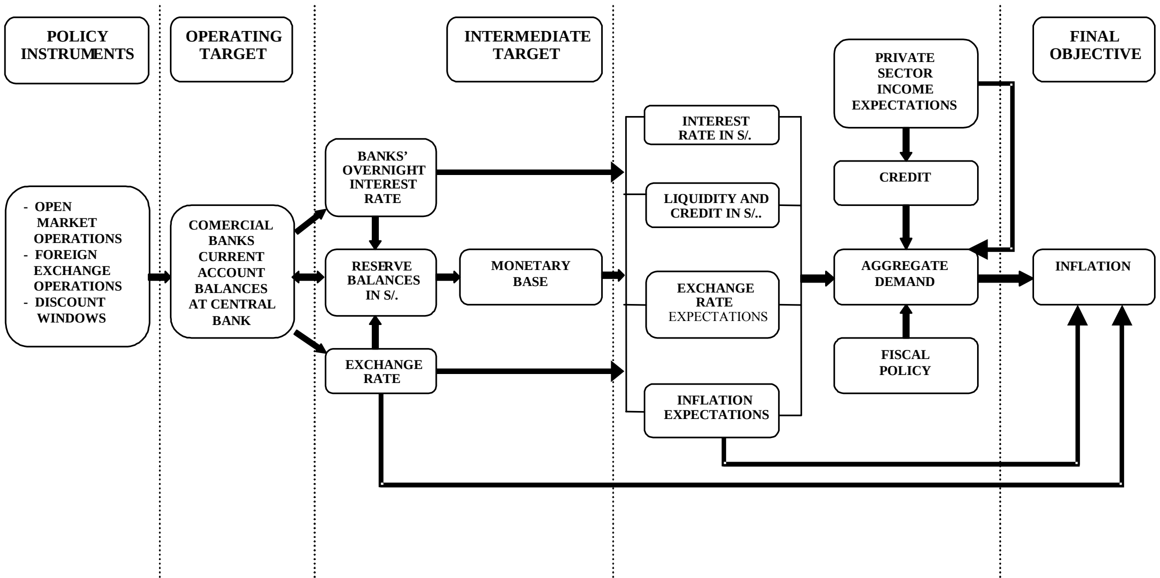
In attaining its main goal, the central bank announces the medium-term pattern of its inflation target and manages its policy instruments (open market operations, exchange market operations and discount window credits) in order to control the commercial bank current account balances maintained at the central bank (operational target).

The daily control of the commercial banks' average balances at the central bank, through management of the policy instruments and interaction with the financial system, induces the desired pattern of base money growth (intermediate target).

The strategy of the central bank rests on the close and stable relationship of base money growth with the inflation target. The evolution of base money growth gives an early warning about the stance of monetary policy and, through its impact on market interest rates, broad money aggregates, banking system credits to the private sector and expectations, influences aggregate demand and inflation.

The time horizon of these monetary transmission mechanisms is between eight and 16 months.

Transmission mechanisms of monetary policy



In the diagram it is clear that through the management of its policy instruments the central bank affects the liquidity position of banks and, subsequently, their current account balances maintained at the central bank. The change in the availability of funds in the money market causes changes in the overnight interest rate and the market exchange rate which, in turn, determine the banking system demand for reserves.

These central bank operating procedures lead to the desired target of base money growth. In turn, the base money, the overnight rate and the exchange rate affect longer-term lending interest rates and other variables such as inflation and depreciation expectations, the broad money aggregate in domestic currency, and private sector credit. This group of variables influences the spending decisions of the public, affecting aggregate demand. In particular, these variables influence the spending on consumer goods that comprise the CPI basket of goods and services. The variation of this index is the inflation definition used to specify the final targets. Finally, aggregate demand affects inflation.

4.2 Modelling the operating procedures of the central bank

As presented in Quispe (2000) and following Bernanke and Mihov (1998), the underlying structure of the economy can be written as:

$$P_t = \sum_{i=0}^{k} D_i Y_{t-i} + \sum_{i=0}^{k} G_i P_{t-i} + A^P v_t^P \tag{1}$$

$$Y_t = \sum_{i=0}^{k} B_i Y_{t-i} + \sum_{i=0}^{k} C_i P_{t-i} + A^Y v_t^Y \tag{2}$$

where vector P represents monetary policy variables. The vector Y contains non-policy macroeconomic variables. Equation (1) shows the policymakers' reaction functions, whereas equation (2) represents the structural relationships that describe the rest of the transmission mechanism. The variables v_t^P and v_t^Y can be naturally interpreted as unobservable structural shocks to the policy variables and the rest of the economic structure respectively. The system (1)-(2) needs identifying assumptions before the estimation of the parameters and structural shocks.

1. We can assume that v_t^P and v_t^Y are mutually uncorrelated structural error terms. This need only mean that v_t^P is defined as the vector of disturbances to the policy variables that are unrelated to the rest of the economic environment. We can go further and assume that all interaction between these errors occurs through the dynamics of the system: that A^Y and A^P are both identity matrices. In what follows, we make this assumption.

However, additional, more controversial assumptions are necessary.

2. For example, equation (1) can be identified if we assume that there is only one policy variable and that the shocks to this variable do not affect the given macroeconomic variables within the current period (Christiano et al (1996)).

The latter assumption $(C_0 = 0)$ is more plausible with high-frequency data. We use monthly data on macroeconomic and financial variables (including the Central Reserve Bank of Peru's GDP estimates) that have been reliably available since mid-1991. Despite that, with dollarisation some of the banking sector series that we could include in the VAR, such as domestic currency deposits foreign currency deposits, and residents' deposits abroad, can respond within a month to changes in policy.

In the Peruvian case, we cannot make the alternative assumption that the policymaker does not respond to contemporaneous information: we cannot assume that $D_0 = 0$. Information from macroeconomic variables can quickly lead to monetary policy changes. For example, foreign exchange market intervention is used to smooth out exchange rate shocks on a regular basis.

Another problem with these assumptions is that interest rates, cash in circulation, foreign exchange intervention and total reserves can all be used as policy variables in Peru. If each of these variables affects the other macroeconomic variables through different channels, including only a single policy variable in the VAR may be difficult to justify.

Bernanke and Mihov (1998) propose that to identify the optimal monetary policy indicator it is worthwhile to study the operating procedure of the central bank. In Peru, with a banking system that intermediates dollar assets, the central bank uses foreign exchange market interventions as an important instrument to provide domestic currency liquidity and issues certificates of deposit, auctioned in open market operations, announcing the amount of the auction and letting the market determine the interest rate. These instruments regulate base money creation through control of the reserves market.

In terms of equations (1) and (2), the problem now becomes to identify the impulse responses and structural shocks when there are many policy variables in vector P and when the contemporaneous reaction matrices A_0, B_0, C_0, and D_0 cannot be restricted.

The observable residuals in the VAR equation with policy variables, equation (1), include the component: $u_t = (1 - G_0)^{-1} A^P v_t^P$. Bernanke and Mihov suggest that plausible restrictions can be imposed on the matrix: $(1 - G_0)^{-1} A^P$, which tells us about how the unobservable policy shocks v_t^P feed into the policy variables.

In order to show how this can be implemented in Peru, an example can be provided with four policy variables: exchange rate interventions *e*, the money base *M0* and its two components separately: total reserves *TR* and cash holdings of households *CASH*. We can write down the plausible set of restrictions between the observable residuals to these variables' VAR equations (the u_t) and the unobservable shocks (the v_t^P):

$$u_{TR} = -\alpha u_{CDR} + \beta u_e + v^D \tag{1}$$

$$u_{CASH} = -\gamma u_{CDR} - \delta u_e + v^B \tag{2}$$

$$u_{M0} = \varphi^D v^D + \varphi^B v^B + \varphi^e v^e + v^S \tag{3}$$

$$u_e = \theta^D v^D + \theta^B v^B + v^e + \theta^S v^S \tag{4}$$

Equation (1), the banking system total reserves demand, depends negatively on its price and the interest rate of central bank CDs,[3] and positively on deviations of exchange rate devaluation. The positive relationship with the exchange rate comes from the interventions of the central bank in the foreign exchange market.

Equation (2), household demand for cash holdings, is negatively related to the market interest rate (using as proxy the CD rate) and inversely related to the exchange rate. This relationship comes from the free holdings of currencies in the country.

Equation (3), shows the reaction function of the central bank to shocks in total reserves demand, to shocks in household cash holdings demand, and to its own "monetary policy" shocks.

Equation (4) relates to the exchange rate devaluations that are carried out or allowed by the central bank. As the exchange rate becomes a policy variable, the restrictions are analogous to equation (3).

4.3 Further identification assumptions

The system has 14 unknown parameters (including the four structural shocks) that have to be estimated from 10 variances and covariances. Just-identification of the system requires four more restrictions. First, we assume that $\alpha = \beta$, which means that the banking system interprets the difference between the nominal interest rate and the rate of devaluation as the cost of total reserves in domestic currency (this assumption is reliable for dollarised economies). The second assumption is that, for monetary policy to be effective in a dollarised economy, there is no currency substitution; a proxy to this assumption is to make $\delta = 0$. Consistent with this approach is to assume that the central bank does not react through exchange market interventions to shocks to household demand for cash holdings, that is $\theta^B = 0$. A fourth assumption comes from the separation of the reaction function of the central bank through exchange market interventions from the reaction function through base money creation, that is $\varphi^e = 0$. This is a necessary assumption, since supply side base money creation should include (as a source) the exchange market interventions of the central bank.

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3 The cost of total reserves for the banking system should be the federal funds rate. However, the Peruvian banking system has reported this rate to the central bank only since the last quarter of 1995. Instead, we use the interest rate of central bank CDs. The use of the CD rate is valid because it is a market rate: the central bank auctions announced amounts of CDs and the bidders set the price. We have carried out estimations for a small sample that uses the federal funds rate to test the adequacy of this assumption.

With these four assumptions, we can obtain a just-identified system the estimation of which provides us with an indicator of monetary policy that is the weighted average of traditional indicators such as the CD interest rate.

The solution for the just-identified model will then be:

$$\begin{bmatrix} u_{CD} \\ u_{TR} \\ u_{CASH} \\ u_E \end{bmatrix} = \begin{bmatrix} \dfrac{1-\theta^D+\alpha\theta^D}{\alpha+\gamma} & \dfrac{(1-\varphi^B)}{\alpha+\gamma} & \dfrac{\alpha}{\alpha+\gamma} & \dfrac{-(1-\theta^S)}{\alpha+\gamma} \\ -\dfrac{\alpha[1-\gamma\theta^D-\varphi^D]}{\alpha+\gamma} & -\dfrac{\alpha(1-\varphi^B)}{\alpha+\gamma} & \dfrac{\alpha\gamma}{\alpha+\gamma} & \alpha\theta^S+\dfrac{\alpha(1-\theta^S)}{\alpha+\gamma} \\ -\dfrac{\gamma[1+\alpha\theta^D-\varphi^D]}{\alpha+\gamma} & -\dfrac{\gamma[1-\varphi^B]}{\alpha+\gamma} & \dfrac{-\alpha\gamma}{\alpha+\gamma} & \dfrac{\gamma(1-\theta^S)}{\alpha+\gamma} \\ \theta^D & 0 & 1 & \theta^S \end{bmatrix} \begin{bmatrix} v^D \\ v^B \\ v^E \\ v^S \end{bmatrix}$$

4.4 Empirical results on operating procedures of the central bank

In order to evaluate the model, we need to write the equations in the form of variations and separate the total reserves demand of the banking system into its components.

One of the characteristics of monetary policy with the use of monetary aggregates as operative or intermediate targets is the close relationship between the operative procedures of the central bank and the money market of the banking system. The following is an extension of the model presented by Quispe (2000) regarding the operating procedure of the central bank.

The demand for base money includes the household demand for cash holdings and the banking system demand for reserves, which in turn includes the demand for vault cash holdings of the banking system and the demand for commercial bank current account balances at the central bank. The central bank uses this commercial bank current account balance as its operational target. Writing in differences we have:

$$\Delta m_t^D = -a_1\Delta i_t - a_2\Delta e_t + a_3\Delta real\_gdp_t + v_t^c \tag{5}$$

$$\Delta chh_t^D = -\beta_1\Delta i_t + \beta_3\Delta real\_gdp_t + v_t^c \tag{6}$$

$$\Delta vch\_bs_t^D = \delta_1\Delta m_t + v_t^J \tag{7}$$

$$\Delta m_t^D = \Delta cabs\_bcr_t + \Delta chh_t^D + \Delta vch\_bs_t^D \tag{8}$$

$$\Delta cabs\_bcr_t = \varphi^D v_t^D + \varphi^C v_t^C + \varphi^J v_t^J + v_t^S \tag{9}$$

Equation (5) is the change in demand for base money, which depends negatively on changes in the interest rate, negatively on changes in the depreciation rate and positively on changes in real GDP.

Equation (6) describes the change in the household demand for cash holdings, which is negatively related to changes in interest rates and positively related to changes in real GDP (indicator of current transactions). We skip the relationship with changes in the depreciation rate because, as stated in earlier sections of the paper, there is asset substitution rather than money substitution in the economy, and because of the current transactional role of the cash holdings.

Equation (7) represents the variation of demand for vault cash holdings of the banking system, which is related to changes in base money demand. Commercial banks hold operative cash to meet public cash requirements. These domestic currency operative cash holdings are proportional to the deposits of the private sector (5% on average during the last three years). It is known that this money aggregate results from the product of base money and the money multiplier, δ_1 = 0.05 times the money multiplier. This characteristic enters the model as a condition:

$$\delta_1 = 0.05mult \tag{10}$$

Equation (8) is an identity referring to the demand side components of the variation in base money, which is the sum of: variation in household cash holdings, variation in vault cash holdings of the banks, and the current account balances held by commercial banks at the central bank.

Equation (9) reflects the reaction function of the central bank through changes on the current account balances of the banking system in response to base money shocks, shocks to household cash holdings demand, shocks to the vault cash holdings of banks and to its own "monetary policy" shocks.

Other conditions are related to the reserve requirement policy of the central bank (6% of the domestic currency liabilities of banks) and the requirement to maintain one percentage point of the reserve requirement as current account balances of commercial banks held at the central bank:

$$0.06(mult)(\Delta m_t) = \Delta vch\_bs_t + \Delta cabs\_bcr_t \tag{11}$$

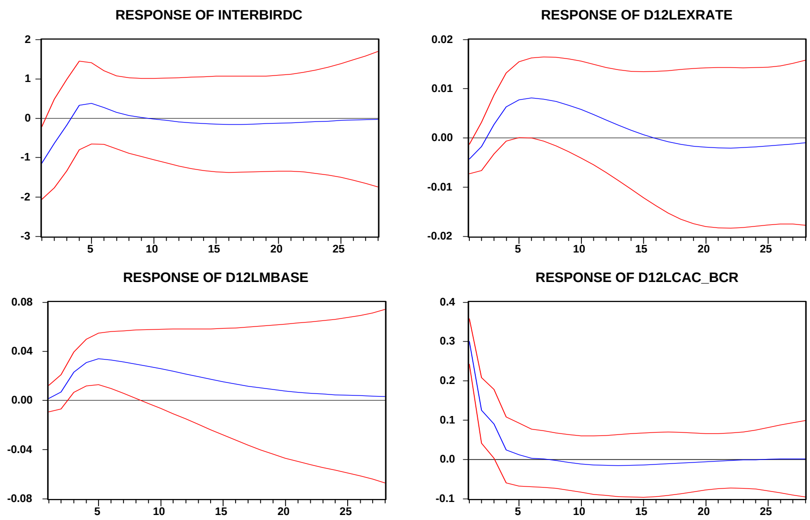
$$0.01(mult)(\Delta m_t) = \Delta cabs\_bcr_t \tag{12}$$

Solving this system allows us to determine the reaction function of the central bank through its operational target, which, in turn, is translated into the intermediate target reflected in the changes in base money.

The preliminary results with a semi-structural VAR show that positive shocks to current account balances of the banking system cause an immediate negative reaction in the short-term banking rate (Graph 7). It returns to its former level after five months. Similarly, the domestic currency depreciates, reaching its highest reaction after six months and returning to its former pattern after 15 months. Finally, base money growth increases, reaching its highest reaction after three to four months, with asymptotic return to its former pattern after 24 months.

Graph 7

PERU: SHOCKS TO BANKING BALANCES AT CENTRAL BANK



4.4.1 *A non-recursive approach to identifying policy*

To estimate the final effects on inflation we need to specify the whole system identification procedure. We use the approach presented by Leeper et al (1996), trying to find enough restrictions on the contemporaneous reactions of variables to each other in Peru without necessarily invoking a recursive ordering.

Commercial banks' current account as operational target for monetary policy

The following table is the adaptation for Peru of this non-recursive VAR identification merging the macroeconomic variables together with the operating procedures of the central bank, considering the case of using the commercial banks' current account at the central bank as operational target for monetary policy.

Non-recursive identification assumptions: commercial banks current account at the central bank as operational target for monetary policy

	CPI	GDP	BM0	CHH	VHB	VBN	NER	RBN	CAC
CPI	C_{11}								
GDP	C_{21}	C_{22}							
BM0	C_{31}	C_{32}	C_{33}				C_{37}	C_{38}	
CHH		C_{42}	C_{43}	C_{44}			?	C_{48}	
VHB			C_{53}	C_{54}	C_{55}				
VBN		C_{62}		C_{64}	C_{65}	C_{66}		C_{68}	C_{69}
NER		C_{72}	C_{73}	C_{74}		C_{76}	C_{77}		C_{79}
RBN		C_{82}			C_{85}	C_{86}	C_{87}	C_{88}	C_{89}
CAC	C_{91}	C_{92}	C_{93}	C_{94}	C_{95}	C_{96}	C_{97}	C_{98}	C_{99}

We classify the variables in the non-recursive VAR in the following categories:

Information variables are used as indicators by monetary policy; therefore current shocks to these variables feed through immediately to the policy variable, but because these indicators are assumed to be more costly to adjust than policy variables, they react to policy shocks only after a lag of at least one month. In Peru we can assume that output (GDP), consumer prices (CPI) and, very contentiously, the exchange rate (NER) are examples of information variables.

Policy variables immediately reflect the monetary policy stance but only respond to current shocks in information variables. Short-term money market interest rates (RBN), cash (CHH), base money (BM0) and commercial banks' current account at the central bank (CAC) are all likely contenders for this designation in Peru.

1. Output (GDP) and prices (CPI) adjust slowly to the other variables, with output unresponsive to current price movements (Graph 8). However, the exchange rate (NER) is now allowed to react within a quarter to shocks to any of the other variables in the system, with the exception of CPI, vault cash holdings of the banking system (VHB) and the overnight interest rate (RBN). One reason why this happens is that the Central Reserve Bank of Peru intervenes to reduce "abrupt and transitory changes in the exchange rate" (De la Rocha 1998, p 186).

2. The assumptions about the response of base money (BM0) reflect the fact that it is targeted by the Central Reserve Bank of Peru. The quarter-on-quarter changes to base money will therefore depend on either temporary deviations from the target or revision of the target itself. Money targets can be set and revised during the year to incorporate information about future inflationary pressure taken from GDP, prices and the exchange rate[4] (De la Rocha, (1998, p 186), Choy Chong (1999, p 196), and so these variables affect base money in the same period. Interest rate changes (RBN), understood to represent permanent changes in velocity, and exchange rates (NER) are incorporated in the base money target.

3. Short-term interest rates (represented by the overnight banking system rate, RBN) react within a quarter to CPI, GDP, vault cash holdings of the commercial banks (VHB), and vault cash holdings of Banco de la Nación (state-owned bank in charge of the management of treasury funds). Additionally, they react contemporaneously to nominal devaluations, their own shocks, and shocks to the current account of the commercial banks.

4. Money components used for transaction purposes (cash holdings of households, CHH) may react immediately to current shocks to GDP. However, whether cash holdings will be affected by contemporaneous exchange rate disturbances could depend on how important

[4] Net purchases of dollars by the Central Reserve Bank of Peru in foreign exchange intervention are sterilised so as not to affect base money.

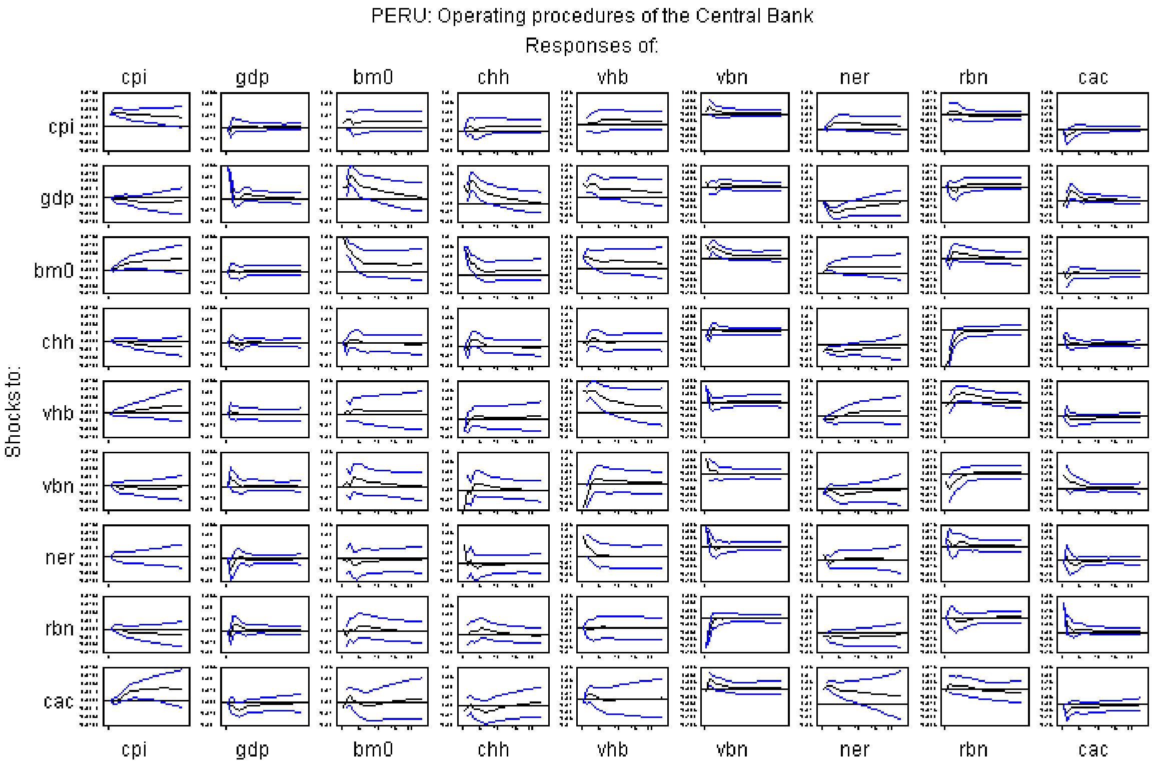
currency substitution is. A question mark in the table indicates the coefficient over which this decision has to be made. (We assume that in Peru there is no currency substitution given the empirical evidence previously stated by Quispe (2000). Of course, it depends on its own shocks and on interest rate shocks.

5. Some banking sector variables, specifically domestic currency vault cash holdings of commercial banks (VHB) and of Banco de la Nación (VBN), are held primarily for current financial transactions of the financial system. VHB is therefore assumed to be unaffected by current shocks to GDP. However, shocks to GDP have a contemporaneous impact on VBN considering that public sector current revenues are contemporaneous with GDP.

6. The operational target (CAC) reacts to all the variables. This corresponds to the approach that considers the contemporaneous relationship between the operational policy instrument and the other policy instruments, macroeconomic variables and the main target of monetary policy.

With this identification procedure, the non-recursive VAR estimates of impulse response functions for Peru (see the following graph) reflect clearly the fact that the current account performs adequately as a predictor of the inflation rate. A positive shock to the commercial banks' current account at the central bank leads to an increase in base money and in the inflation rate within a time horizon of eight to 16 months.

Graph 8



Testing the overnight interest rate as operational target for monetary policy in Peru

There is an important issue related to the relevance of monetary base targeting in a low-inflation environment. The lack of relationship between base money growth and the inflation rate, the instability of money demand, the increasing relevance of transparent monetary policy, and the increasing necessity of simple and clear communication with the population raise the importance of the interest rate as the operational target of monetary policy. Moreover, those facts are closely connected with the relevance of the interest rate as a clear signal of the stance of monetary policy related to its main objective of price stability with a stable long-run growth of output.

In that sense, we test through the non-recursive VAR estimation the performance of the overnight interest rate as if it were the operational target during the sample period. To do that we need to change some identification assumptions.

The overnight interest rate, acting in this case as the operational target for monetary policy, now reacts to all the variables, as can be seen in the following table.

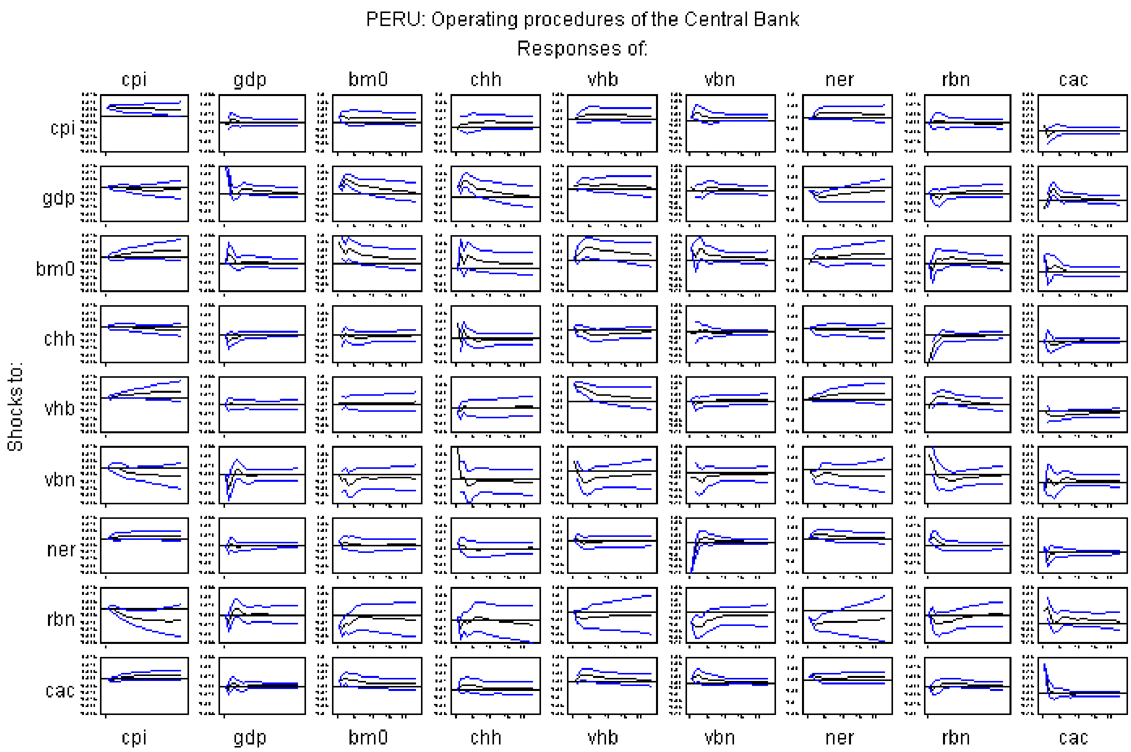
In contrast, the commercial banks' current account at the central bank, now acts mostly as an informative variable. It does not react to contemporaneous shocks on inflation, base money and cash holdings of households, maintaining its contemporaneous relationship with the other variables of the operative procedures of the central bank.

Non-recursive identification assumptions: overnight interest rates as operational target

	CPI	GDP	BM0	CHH	VHB	VBN	NER	RBN	CAC
CPI	C_{11}								
GDP	C_{21}	C_{22}							
BM0	C_{31}	C_{32}	C_{33}				C_{37}	C_{38}	
CHH		C_{42}	C_{43}	C_{44}			?	C_{48}	
VHB			C_{53}	C_{54}	C_{55}				
VBN		C_{62}		C_{64}	C_{65}	C_{66}		C_{68}	C_{69}
NER		C_{72}	C_{73}	C_{74}		C_{76}	C_{77}		C_{79}
RBN	C_{81}	C_{82}	C_{83}	C_{84}	C_{85}	C_{86}	C_{87}	C_{88}	C_{89}
CAC		C_{92}			C_{95}	C_{96}	C_{97}	C_{98}	C_{99}

We can see the estimation result of this new identification procedure in Graph 9. Here, a positive shock to the overnight interest rate of the banking system clearly generates a reduction in the inflation rate. There are theoretical arguments supporting these results: in the interbank money market the overnight interest rate is the price whose quantitative counterpart is the commercial banks' current account held at the central bank. Thus, in terms of monetary policy in Peru these findings give some support to the feasibility of using the overnight interest rate as operational target.

Graph 9

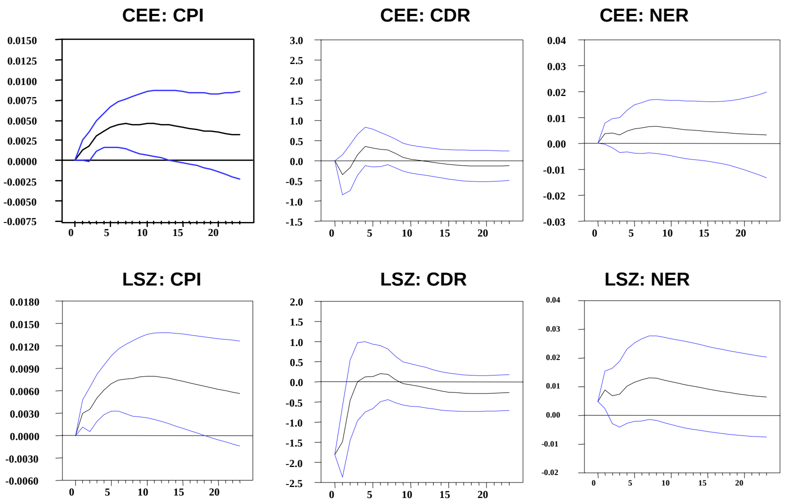


In summary, these identification procedures give a clear role to the monetary base as an instrument for reducing inflation in Peru. However, there is an important issue related to its relevance as an instrument for preserving long-run price stability in a context of low inflation.

As shown in Graph 10, using alternatively the recursive approach of Christiano, Eichenbaun and Evans (1996) - CEE, and the non-recursive approach of Leeper, Sims and Zha (1996) - LSZ; and considering the Central Bank Certificate of Deposits rate - CDR as the relevant interest rate for the operating procedures of the Central Bank, the finding that a positive shock to base money significantly affects inflation after eight months, a year or a year and a half is shown to be robust. Many of the other impulse responses are similar. Also, to confront the criticism that can be levelled at this VAR in terms of the correct identification of the role of policy, we have disaggregated M0 into its components - cash holdings of households, and total reserves (which in turn is composed of vault cash holdings of the commercial banks and the public sector bank, the current account maintained at the central bank) - and also allow for a separate role for the overnight interest rate.

Graph 10

PERU: Shocks to base money

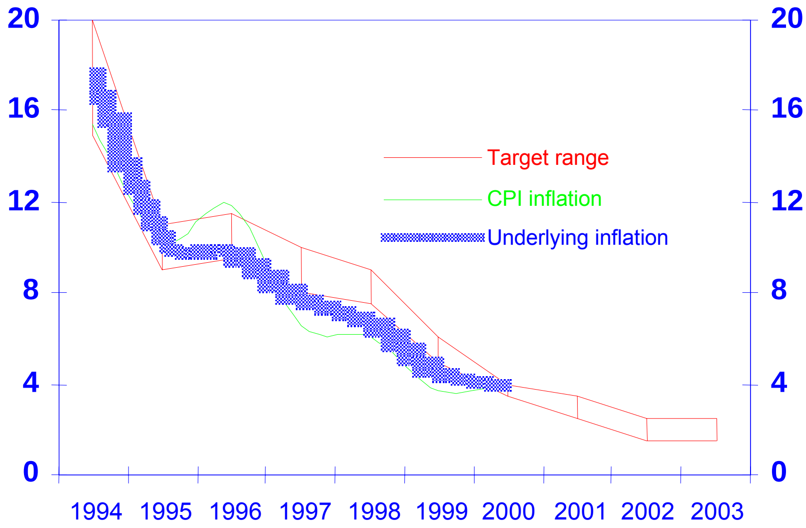


Our results have at least established the robust result that M0 shocks (or possibly just shocks to its cash holdings component) are responsible for about 30% of long-run inflationary movements.

The empirical results of these structural VAR procedures gave us some indication of the time horizon and magnitude of the impact of monetary policy on its final target: the inflation rate. In this case, the estimations conclude that the time horizon of monetary policy transmission is between eight and 16 months. This result is consistent with a small open economy with partial dollarisation such as Peru. Another finding is that every 10 additional percentage points of variation in base money generate an additional 3.8% of inflation. A 10% depreciation of the exchange rate generates 1.2% of additional inflation.

It is important to recall that, to avoid misunderstandings about the variation of base money, the central bank (in coordination with the central government) has been announcing a target range for the inflation rate since 1994. Graph 11 shows low levels of inflation, with only some small deviations from target. Underlying inflation exhibits better performance, although it is used only as an indicator.

Graph 11



In the light of this, a possible interpretation of the VAR results is that money base control has been successful in keeping the evolution of the inflation rate around its target range since 1994.

5. Identifying the money and credit channels of transmission

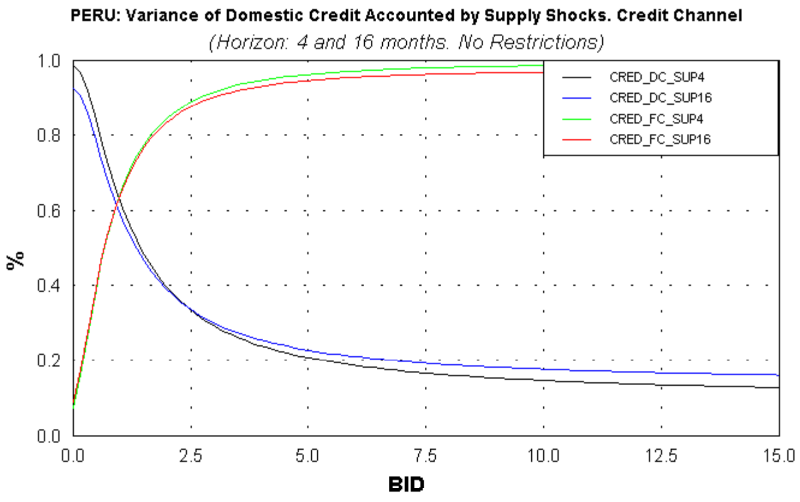
In the Peruvian case there is a banking credit dependence of the small and medium-sized firms, and even some of the big corporations still have only limited participation in the capital markets. This characteristic invites the conclusion that the credit (lending) channel of monetary policy is fully active. However, the central bank would have had only limited power to reduce the credit supply of the commercial banks, at least until 1996-97, through the reduction of the financial funds due to the existence of alternative external sources of funding for the banking system, neutralising the possible impacts of monetary policy on domestic credit to the private sector.

Just by looking at the credit series we cannot identify which part of the credit variations represents changes in the supply of funds (associated with the credit or lending channel) and which part is accounted for by changes in the demand for credit (mainly associated with the money channel).

We can indirectly identify these monetary policy channels using the supply and demand shocks structural VAR procedure. Thus if there are demand shocks, we can expect positive variations in both domestic currency credit and foreign currency credit in the domestic market. If there is a negative supply shock in the credit market, we can expect a negative reaction of domestic currency credit and a positive reaction of foreign currency credit considering the substitution of flow-of-funds capacity of the banking system. With these basic assumptions we decompose the variance of the change in domestic currency and foreign currency credit.

In this way, we can identify what percentage of variation in domestic credit is due to supply and demand shocks respectively. Graphs 12 and 13 show that during 1979-2000, the variance in domestic currency credit due to supply shocks is 20%, while the variance in foreign currency credit due to supply shocks is more than 90%.

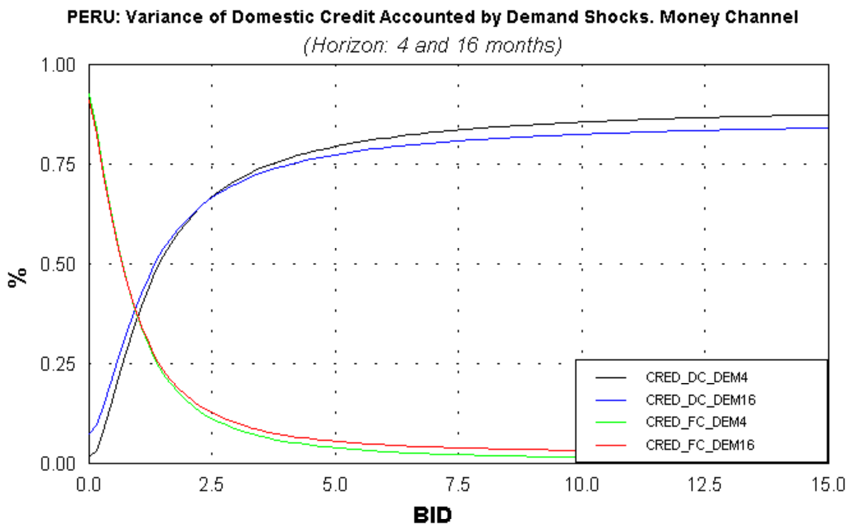
Graph 12



Furthermore, we can identify that the variance in domestic credit explained by demand shocks represents around 80%, while the variance in foreign currency credit explained by demand shocks is almost zero. It is clear that 80% of the variation in domestic currency credit resulted from monetary transmission through the money channel.

Thus it seems clear that the credit channel is neutralised by the funding substitution possibilities of the banking system.

Graph 13



6. Conclusions

The inflation process in Peru is driven by demand shocks, with monetary shocks accounting for a range of 30-40% of the variance in the inflation rate.

In identifying the best indicator of the monetary policy stance, we found that different studies for Peru on this topic have shown that money aggregates are the best indicators of the monetary policy stance.

The time horizon of monetary policy transmission is between eight and 16 months. This result is consistent with a small open economy with partial dollarisation such as Peru. Another finding is that every 10 additional percentage points of variation in base money generate an additional 3.8% of inflation. A 10% depreciation of the exchange rate generates 1.2% of additional inflation.

The empirical results show that the money channel seems to be effective in Peru. There is no clear evidence of the effectiveness of the credit channel.

The dollarisation process in Peru is mainly of the asset substitution type. Domestic currency is used for current transactions and is closely related to the inflation rate. Since cash holdings represent 75-80% of base money, there should not be any problem in considering base money creation an intermediate target.

The non-recursive identified model estimations reflect clearly the fact that the current account performs adequately as a predictor of the inflation rate, a sign of a good operational instrument of monetary policy. A positive shock to the commercial banks' current account at the central bank leads to an increase in base money and in the inflation rate within a time horizon of eight to 16 months.

The change in the identification procedure, preceding as if the overnight interest rate played the role of operational target for monetary policy, shows that this variable can be used as the indicator of the monetary policy stance in Peru. There is a clear negative reaction of the inflation rate against positive shocks to the commercial banks' overnight interest rate.

Appendix:
Model of supply, demand and money shocks used by Machado et al (1994)

This is a VAR model with inflation, GDP growth and money as dependent variables. In this model the innovations to the economy belong to two possible types, “supply” or “demand” shocks, and money shocks are accounted as monetary policy shocks. As in Blanchard and Quah (1989), names are given to the innovations according to the particular means of identification, since these shocks are unobserved - that is, not directly related to the left-hand side variables. These shocks completely describe the set of structural disturbances in the economy.

The model is described as follows:

$$Y_t = \begin{pmatrix} \Delta \ln P \\ \Delta \ln y \\ \Delta \ln M \end{pmatrix} = \sum_{i=1}^{8} C_i Y_{t-i} + \eta_t \tag{1}$$

The Wold representation is $Y_t = \hat{D}(L)\eta_t$, where $\eta_t = (\eta_p \quad \eta_y \quad \eta_m)'$.

The MA representation is $Y_t = A(L)\varepsilon_t$ where $\varepsilon_t = (\varepsilon_{s,t} \quad \varepsilon_{d,t} \quad \varepsilon_{ms,t})'$ is the vector of structural shocks in supply, demand and money supply respectively, and its variance-covariance matrix is given by:

$$\Sigma_\varepsilon = \begin{pmatrix} \sigma_s^2 & 0 & 0 \\ 0 & \sigma_d^2 & 0 \\ 0 & 0 & \sigma_{ms}^2 \end{pmatrix}, \quad B_0 = \begin{pmatrix} -1 & b_{id} & b_{im} \\ b_{ys} & 1 & b_{ym} \\ 0 & 0 & 1 \end{pmatrix}$$

The matrix B_0 needs to be fully identified. It is important to define a set of minimal assumptions and a long-run restriction to fully identify B_0.

Minimal assumptions

The minimal assumptions now specify the direction of the effect of an innovation in money growth on inflation and output growth. According to the standard IS-LM model, an innovation in money will increase both prices and output[5] (ie $b_{im} \geq 0$ and $b_{ym} \geq 0$). On the other hand, it is assumed that money growth is not affected contemporaneously (ie within a quarter) by either supply or demand shocks.

This set of assumptions, together with the relation $\hat{\Sigma}_\eta = B_0 \Sigma_\varepsilon B_0^T$ specifies a system of six equations and seven unknowns (four parameters in B_0 and three variances in Σ_ε). Thus, there is one degree of freedom to choose between b_{id} and b_{ys} while satisfying the relation

$$b_{ys} = \frac{-\hat{\sigma}_{im}\hat{\sigma}_{ym} + b_{id}(\hat{\sigma}_{ym})^2 + \hat{\sigma}_{iy}\hat{\sigma}_m^2 - b_{id}\hat{\sigma}_m^2\hat{\sigma}_y^2}{(\hat{\sigma}_{im})^2 - b_{id}\hat{\sigma}_{im}\hat{\sigma}_{ym} + b_{id}\hat{\sigma}_{iy}\hat{\sigma}_m^2 - \hat{\sigma}_i^2\hat{\sigma}_m^2} \tag{2}$$

Notice that in this relation all variables but b_{id} and b_{ys} can be estimated from the VAR. Moreover, b_{im} and b_{ym} are uniquely determined and are not affected by the specification uncertainty on b_{id} and b_{ys}: $b_{im} = \frac{\hat{\sigma}_{im}}{\hat{\sigma}_m^2}$, $b_{ym} = \frac{\hat{\sigma}_{ym}}{\hat{\sigma}_m^2}$ (3)

5 See Sargent, T (1987), Chapter 2.

The minimal assumptions imply a positive relation between b_{id} and b_{ys} and therefore do not set an upper bound for these parameters. This does not pose a major problem for the results of the variance decomposition under specification uncertainty.

In this model there is a range of feasible values for b_{id}. However, this kind of uncertainty does not affect the fraction of the variance of inflation or GDP accounted for by monetary shocks, which is the same for any value of b_{id}. Again, values bigger than three do not lead to different behaviour in the decomposition of variances, so they are taken out of consideration.

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The monetary transmission mechanism and the structural modelling of inflation at the National Bank of Poland

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1. Introduction

The implementation of a direct inflation targeting (DIT) strategy creates the need for a deeper understanding of country-specific relations between monetary policy instruments and economic processes. The DIT strategy had been introduced before the Polish economy had achieved a sufficient level of macroeconomic stability and before the behavioural patterns of economic agents had matured, these patterns thus being subject to many changes. Permanent changes to market institutions in Poland also compelled agents to modify their methods of adjustment. It forced statistical offices to verify (and change) definitions of economic variables and their measurement methodology. In these circumstances any investigation of economic features based on statistical (econometric) techniques and available statistical data (in particular time series) has been very imprecise, and quite often misleading. However, the progress made in transforming the system in Poland and the development of market institutions have created the opportunity to enhance and intensify research, in particular modelling. Part of the research activity at the NBP aimed at supporting monetary policy in Poland can be classified into two groups:

- The study of monetary transmission mechanisms.

  This line of research focuses on examining the current state of the links between monetary policy instruments and the main economic variables such as inflation, money supply, industrial production, GDP growth, unemployment, and external and internal equilibrium indices. VAR modelling methodology is the main tool used in this area of research. An example is presented in the second section of this paper.

- Structural modelling of selected features of the Polish economy.

  Structural models of inflation attempt to describe a stylised version of the market economy rather than the current state of the transition process in Poland. These models mimic basic inflation-generating mechanisms and how the economy reacts to the policy instruments (in particular interest rates) used by decision-makers. In this area of modelling, data congruency is not a main criterion of the model quality, so that the model - primarily - reflects the author's way of thinking rather than providing a precise picture of the real economy. One of these models (MSMI-1) is described in the third section of the paper.

2. The role of interest rates in the monetary transmission mechanism in Poland (by E Wróbel)

Studies of the transmission mechanism in Poland using a VAR approach (Christoffersen and Wescott (1999), Kokoszczynski et al (1999), Wróbel (1999), Rybinski (2000)) have stressed the role of the exchange rate channel in the monetary transmission process. Using the Bernanke-Blinder restriction, they show that over the period 1992-99 the exchange rate channel strongly dominated the interest rate channel. The impact of exchange rate shocks on inflation, as well as on output growth and

[1] The paper, prepared for the workshop on modelling aspects of the inflation process and the monetary transmission mechanism in emerging market countries, expresses the authors' point of view.

nominal wage rates, was found statistically significant and fairly quick whereas interest rate shocks usually produced impulse response functions of nonsensical shape. This relatively strong impact of exchange rate shocks plausibly stemmed from the role the exchange rate traditionally played in inflationary expectations and from its direct impact on import prices. Unsatisfactory results in previous papers led me to repeat the transmission exercise with new assumptions, paying more attention to carefully isolating the monetary policy shock and skipping the period when, as one might suspect, the interest rate could not play any significant role in the monetary transmission mechanism.

2.1 Monetary policy in Poland

In Poland changes in monetary policy regimes and operating procedures were quite frequent. In particular, the exchange rate regime underwent multiple changes, evolving from a fixed to a pure float.

At the initial stage of the transformation, the exchange rate was fixed to the US dollar and then to a basket of five currencies. In late 1991, the fixed exchange rate regime was replaced by a preannounced crawling peg. In 1995, that was in turn replaced by a fixed rate with a crawling band. Central parity then ceased to be an official exchange rate and served only to set the band within which the currency could fluctuate. Instead, the fixing rate played the role of an official exchange rate. This regime survived until April 2000 but in the meantime the NBP gradually widened the band - from ±7% in 1995 to ±15% in 1999. Finally, in 1998 the NBP suspended interventions in the foreign exchange market and in April 2000 the złoty was fully floated. To avoid excessive exchange rate volatility and exchange rate appreciation independent from the current state of the economy, a special account was set up in 2000 for the incomes derived from privatisation.

Changes in the set of intermediate and operational targets add to the picture of continuous monetary policy modifications. An initial trial in the use of the interest rate as an operational instrument failed since, as Kokoszczynski and Stopyra (1996) point out, banks were accustomed to the credit limits applied in the 1980s and therefore were insensitive to the NBP interest rate policy. Banks sharply increased credit due to overoptimistic estimates of future aggregate demand. Insufficient skills on the part of banks' credit inspectors as well as inadequate NBP supervision and regulation also played an important role. This led the NBP to resort once again to credit ceilings. Thus, over 1990-93 the NBP targeted net domestic assets with credit limits serving as an operational instrument. They were in use up to 1992 and weakened agents' already weak sensitivity to the interest rate policy.

Over 1994-97 the NBP officially targeted the broad money supply. At first, the interest rate was adopted as an operational target, but then there was a two-year episode of monetary base targeting. In practice, the NBP put more stress on the exchange rate than on money and intervened in the exchange rate market whenever it considered that the current exchange rate of the złoty could jeopardise exports. On the other hand, it also tried to avoid an undesirable fall in the interest rates sterilising capital inflow. As a result, during this period monetary policy was eclectic with no clear-cut operational variable. Since 1999 Poland has abandoned intermediate targets and implemented direct inflation targeting, using the interest rate (28-day NBP bills) as the main instrument of monetary policy.

This short description of changes in monetary policy shows only a small portion of the difficulties, risks and challenges one faces when trying to build a structural model of inflation or to analyse the transmission mechanism using a VAR approach. When analysing the results obtained from the VAR presented in this paper, one must bear in mind that not only monetary policy but also fiscal policy underwent important changes that affected domestic demand. Due to the small sample these effects cannot be separated from the interest policy impact.

2.2 Estimation method and data

To examine the monetary transmission mechanism, I use a vector autoregression (VAR) approach and follow the Christiano, Eichenbaum and Evans (CEE 1994, 1998) identification method of a structural VAR (SVAR). SVAR is used to determine the monetary policy shock and then to examine the reaction of other endogenous variables to the defined monetary impulse.

The CEE identification procedure requires assumptions about variables the central bank looks at when setting an operating instrument and supposition about the nature of the interaction of the policy shock with the variables in the feedback rule. Namely, the monetary policy shock is identified with a disturbance term in a regression equation of the form:

$$S_t = \psi(\Omega_t) + \sigma\varepsilon_{st}$$

where S_t is the monetary policy instrument, ψ is a linear function, Ω_t is the information set available to the central bank when the monetary policy instrument is set, σ is a positive number, and ε_{st} is a serially uncorrelated shock that is orthogonal to the elements of Ω_t and has variance unity. The assumption of orthogonality means that variables of the information set react to a monetary policy shock only with a lag. This is a plausible assumption for high-frequency data. In the estimation I use monthly data. On the other hand, if Ω contains variables other than monetary variables, such as prices and output, the assumption that the central bank reacts to their contemporaneous values is controversial. In fact, the NBP obtains final data on retail prices and provisional data on output only two weeks after the end of a month.

Including too few variables in a VAR may lead to a misspecification problem; nonetheless, I decided to use a relatively modest set of variables, bearing in mind the small sample and the fact that long lag lengths in a VAR system quickly consume the degrees of freedom. These variables are the consumer price index (CPI), credit to the non-financial sector (in real terms) and the NBP intervention rate as a policy instrument. For pre-1998 this is the 14-day reverse repo rate converted for comparability reasons to a 28-day rate. Since 1998 this has been the 28-day NBP intervention rate.

I assume that, over 1995-2000, in setting the level of the interest rate, the NBP mainly considered the inflation rate and the rate of growth of credit to the non-financial sector. This set of variables has been important for the interest rate setting bodies at least since 1995, when the so-called "second" credit boom started (Figure 2.1). Including credit instead of production in the information set is untypical for that sort of analysis and therefore needs comment.

Up to the present there has been no robust relationship between inflation and the output gap, obtained by the most common method such as HP and Kalman filters. The most plausible reason is that the Polish economy was undergoing rapid structural changes and that supply shocks were playing an important role in output behaviour. Moreover, deriving the output gap requires data covering at least one full business cycle. This condition was not fulfilled, making all estimates highly uncertain.

With uncertain and lagged information on the output gap,[2] credit growth was carefully analysed and used as an indicator of domestic demand pressure. Moreover, since consumer demand was heavily oriented towards imported goods, it served as a leading indicator of changes in the trade balance (the rate of growth of household credit Granger-causes changes in imports after nine months).

Over 1995-2000 the role of credit in financing investment and private consumption steadily increased - the amount of total assets due from the non-financial sector in relation to GDP rose from 18.4% to 30.1%. It should be stressed, however, that the share of credit in foreign currencies, ie credit that is independent of the domestic interest rate policy, amounted to about 12-22% of total credit.[3] In 1999 the private sector financed about 18% of investment outlays with domestic credit and about 63% from its own financial sources.[4] The share of consumer credit in private consumption more than quadrupled, increasing from as low as 2.5% in 1995 to 10.8% in 2000. Excluding long-term credit, ie credit with a maturity of over five years that was mostly utilised by households for financing expenditures for housing purposes, these figures drop to 2.2% in 1995 and 7.9% in 2000.

As the discussion in Section 2.1 shows, it is much easier to make assumptions about the NBP information set than to choose the operational variable. Changing monetary policy regimes together with increasing financial deregulation and rapid financial sector development leave the identification procedure open to criticism, since using it I cannot take into account all these factors. Due to the small sample I cannot test the sensitivity of the results to different sample periods. The Bernanke-Mihov (1998) identification method allowing for more than one operational variable may be a solution for a future study.

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[2] In Poland quarterly data on GDP are released three months after the quarter-end.

[3] These data are for 1996-2000.

[4] The latest available data are for 1999 ("Investment and fixed assets in the national economy", *Information and Statistical Papers*, CSO, Warsaw 2000). These data cover entities employing more than 20 staff.

To check the impact of monetary shocks on other variables, such as industrial output, retail sales, monetary aggregates and yields on T-bills, I included them in the VAR system one by one. Throughout the paper I ordered the variables as follows: CPI, credit in real terms, and the NBP intervention rate. Variables related to economic activity such as industrial output and retail sales are ordered just before the interest rate, since it is assumed that monetary policy has no contemporaneous impact on the real sector.

There is no agreement in the literature about what identification method to use to isolate monetary shock, but there is a broad consensus on the impact of a contractionary monetary policy shock. Short-term interest rates increase, while monetary aggregates as well as output, employment, profits and real wages fall. Price indices, with the exception of raw materials, respond with a considerable delay. To evaluate the identification method, I checked the impulse response functions accordingly. One can, however, easily imagine that in a transition economy some impulse response functions will not have a proper shape in spite of a well identified monetary policy shock. This may happen to variables characterising overregulated markets. The Polish labour market is a good example. At the initial stage of the transition, a system of wage control was aimed at preserving employment. Another factor enhancing temporary labour hoarding was a frequent privatisation clause pressing new owners to keep employment at a pre-privatisation level over a certain period. This period is in many cases coming to an end, depressing employment and increasing the unemployment rate. Moreover, during the period analysed, structural adjustments to some economic sectors such as coal mining and the steel industry were initiated, resulting in lower employment. There are also demographic factors considerably affecting labour supply (the baby boom of the early 1980s). Changes in the social security and health care systems in 2000 led those employed in the hidden economy to register as unemployed to be eligible for social benefits. Another important factor was a change in the national statistics in 2000 - since when CSO data have covered firms employing at least five staff. This very factor was responsible for a decrease of about 340,000 in official employment in January 2000. Thus, to avoid discarding a properly isolated monetary policy shock, I will be considering whether most of the impulse response it causes is reasonable.

Throughout the paper I shall be identifying monetary policy shocks with the exogenous shocks to the preferences of the monetary authority. CEE (1998) provide an appealing interpretation of this type of shock, saying that shocks to the preferences of monetary authorities may be due to stochastic shifts in the relative weight given to inflation and unemployment. There are at least two reasons why this explanation is appealing. The first is that, in countries undergoing transformation, monetary authorities learn on the job, accumulating experience and frequently facing new problems and challenges. This could affect and change the preferences. Second is the institutional change - since 1998 monetary policy in Poland has been conducted by the 10-member Monetary Policy Council.

The estimation covers a relatively short period - 1995.01-2000.12 - whereas transformation in Poland started as early as 1990. Discussion of changes in monetary policy should have shed some light on why I have confined the sample to the last six years. Other arguments, to recall the most important ones, are as follows:

- The first two years of transformation were dominated by so-called correctional inflation (considerable changes in relative prices).
- In limiting estimation to the period 1995-2000, I skip the fixed exchange rate regime period and almost totally the preannounced crawling peg period. Since May 1995 the exchange rate regime has gradually been growing more flexible.

All variables, except for interest rates and the unemployment rate, are in the log levels. Monetary data are from the NBP, and all other data from the CSO. To choose the lag length, the Akaike criterion was used. It suggested three lags, but due to problems with residual autocorrelation in most cases four lags were used. Data were seasonally adjusted with X-11; seasonal dummies were used to eliminate the remaining traces of seasonality. A temporary huge credit growth in the last days of June 2000 connected with the privatisation of one of the biggest Polish enterprises was removed from the data.

2.3 Estimation results

The estimation results are shown in Figures 2.2 and 2.3. VAR satisfies the stability condition (no root lies outside the unit circle). Residuals were examined for autocorrelation with the LM test up to 12 lags. The test indicates that the residuals are not serially correlated. Diagnostic statistics are presented in the Appendix.

Figure 2.2 shows that a contractionary monetary policy shock leaves industrial output practically intact: it falls with a considerable delay and the reaction is not statistically significant. A striking effect - not predicted by the theory - is a temporary increase in output after a shock; only after six months does output start to decline, becoming negative after nine months. A similar result is obtained by Millard (1998) for the United Kingdom.

Retail sales[5] react in a more conventional way - they fall temporarily after the shock. An ad hoc explanation is that this may be the result of exports cushioning for some time a fall in domestic demand. The Johansen test for cointegration of industrial output and retail sales rejects H0 of no cointegration at the 1% significance level; the LR test indicates one cointegrating equation at the 5% significance level. A forecast of industrial output from the short-term dynamic model shows that in some periods (such as the second half of 1999 and 2000, Figure 2.4) industrial output predicted from the level of sales was much lower than actual output in spite of a serious monetary policy tightening. Since the analysed sample is relatively small, it may be the case that periods of depressed domestic demand simply coincided with higher foreign demand. But another plausible explanation could be that a corporate sector faced with depressed domestic demand switched to exports.

A strong and relatively quick response from retail sales to monetary shocks at first glance stands in stark contrast to the common view that in Poland private consumption tends to be rigid. The simplest explanation is that the retail sales comprise not only private consumption but also sales of non-consumption goods, such as building materials and goods for agricultural production like seeds, fertilisers, agricultural machinery and equipment to name only a few. Investment goods are likely to react more readily to interest rate shocks, making the variable less stubborn than consumption towards the monetary policy shocks. Another reason is that in the aftermath of an interest rate shock consumers may switch to smaller retail outlets (bazaars) not fully covered by the official statistics.

There is a temporary price puzzle in Figure 2.2. It tends to become smaller but does not disappear if prices of other assets - such as the nominal exchange rate - are included in the VAR. The effect is well described in the literature and seems to be a common result in empirical works using the VAR method (Walsh (1998)). In Poland the maximal effect of a monetary policy shock on the price level appears 20 months after the shock. In Figure 2.2 the impulse response function of real wages in the corporate sector to a contractionary monetary policy shock is also presented. Real wages seem to increase temporarily after a shock. Millard (1998) reports the same result for the United Kingdom. Then they start to fall, but the overall reaction is statistically insignificant and short-lived. This result may suggest that wages are more rigid than prices, probably due to widespread explicit and implicit indexation mechanisms, the power of trade unions, and competition from imports in the goods market. The increase in industrial output that occurs after a shock can be another reason for the real wage increase. To check this result, a quarterly VAR was built, covering the period 1992-99 with the log of the consumer price index, logged wages and the index of labour productivity (the log of). The output gap, proxied by the difference between current and HP-filtered GDP, entered the VAR exogenously. Impulse response functions and variance decomposition showed that wages tended to be more responsive to prices than prices to wages.

The unemployment rate and employment were the last variables from the real sector of the economy examined for their reaction to the contractionary monetary shock. The responses are not shown - both of them have a nonsensical shape (the unemployment rate decreases while employment increases after a brief and short-lived decline). It is not a totally unexpected result, bearing in mind the role of structural adjustment and administrative regulations in the labour market.

As presented in Figure 2.3, a contractionary interest rate shock affects narrow money (M1) and broad money (M2) as well as three-month and 12-month T-bill rates in a conventional way. Both M1 and M2 fall after a shock, but the fall of M2 is more prolonged. The short-term rate rises more than the long-term one.

The results of the VAR with the monetary policy shock identified in the spirit of CEE (1994, 1998) are in most cases reasonable even though monetary policy underwent several regime changes over the

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5 Data on retail sales cover the sale of consumer and non-consumer goods from retail sales outlets, catering entities and other sales outlets (ie warehouses, storehouses) in quantities indicating purchases to meet the needs of individual customers.

period examined. An interesting feature of Polish monetary transmission is that it seems to be evolving towards a mechanism with an increasing role for the interest rate. Moreover, there are signs that the transmission resembles more a textbook one than in the previous studies of monetary transmission. On the other hand, the labour market is the exception, but due to the reasons presented above it will probably never behave in a way the classical model predicts. It is also unclear if the labour market will come to resemble the Layard, Nickell and Jackman vision of the market. Therefore the labour market and its impact on inflation will need particularly careful analysis. Persistence in this market and the cost of disinflation in terms of unemployment seem to be a key issue. A brief assessment of unemployment persistence in Poland using the Cochrane test[6] shows that shocks to unemployment have a very long-lasting effect, suggesting the existence of hysteresis.

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[6] Cochrane (1998) measures a random walk component in a series (originally GNP) from the variance of its long differences, in particular ($kVar(\Delta xt)/(\Delta kxk)$). I replicated an exercise with the unemployment rate from (Millard et al (1999)). As they point out, a simple explanation of the test is that if a variable is a random walk (ie the best forecast of the variable next period is equal to its current value), then the further ahead in time one goes, the more uncertainty there is about the variable. The variance of two-period changes in the variable should be twice the variance of one-period changes, the variance of three-period changes in the variable should be three times the variance of one period, etc. For Poland I used a small sample corrected version of the Cochrane test. If the test has a value near to zero, then the permanent shocks are of less importance. If the value is near one, then permanent shocks are important. If it is above one, the effect of shocks is amplified over time. The authors report that for the United Kingdom the test statistic is near five. The test statistic calculated for Poland on the basis of the sample 1992-2000 is even higher - between five and six for seasonally unadjusted (quarterly) data and between eight and nine for seasonally adjusted (quarterly) data.

Figure 2.1

Credit to private individuals and corporate sector in real terms (y/y)

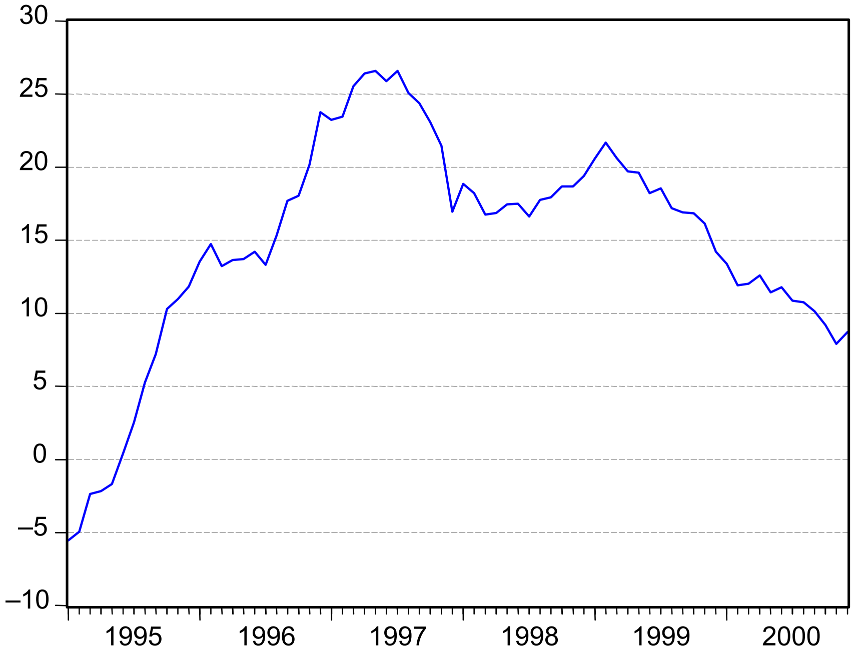


Figure 2.2

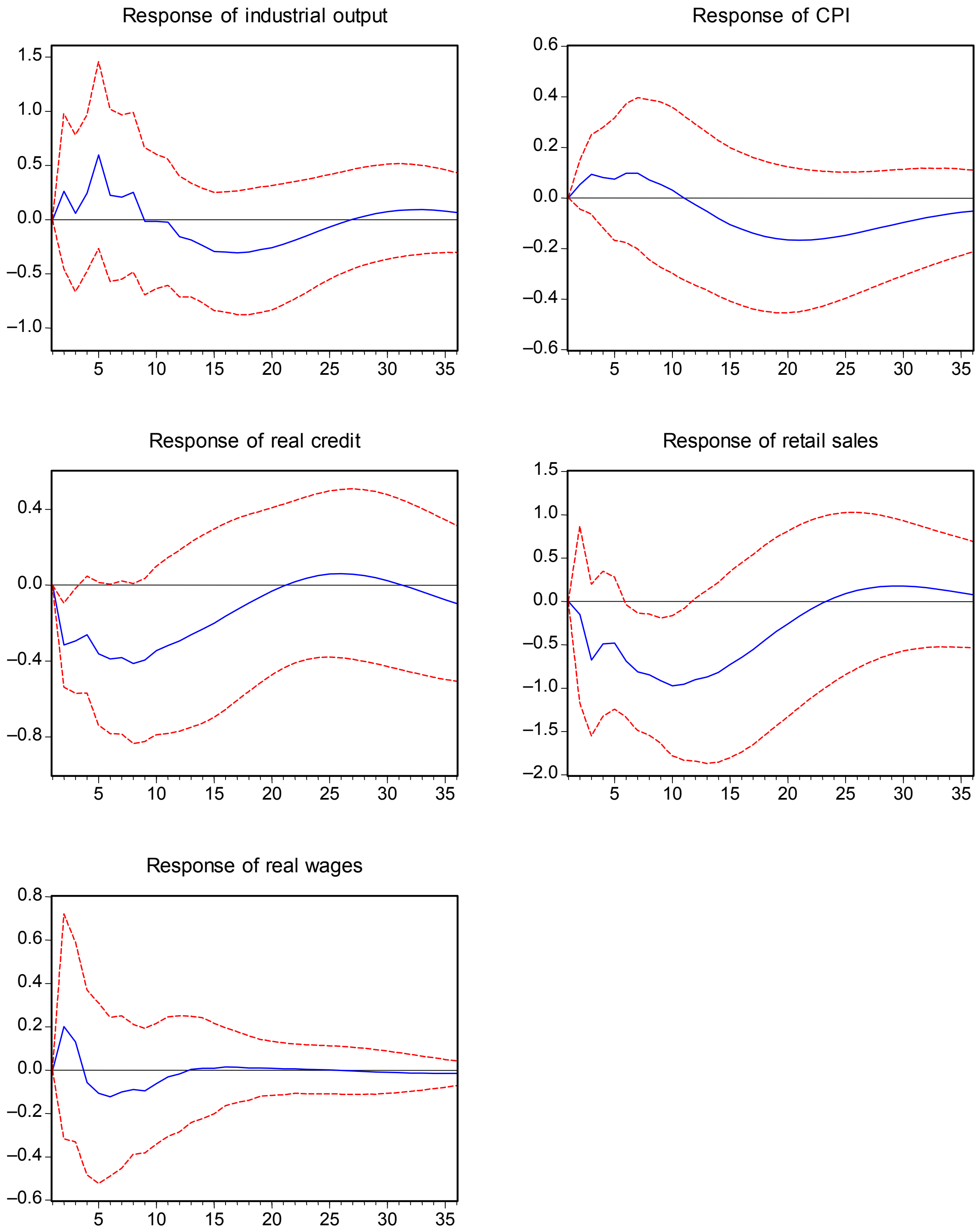
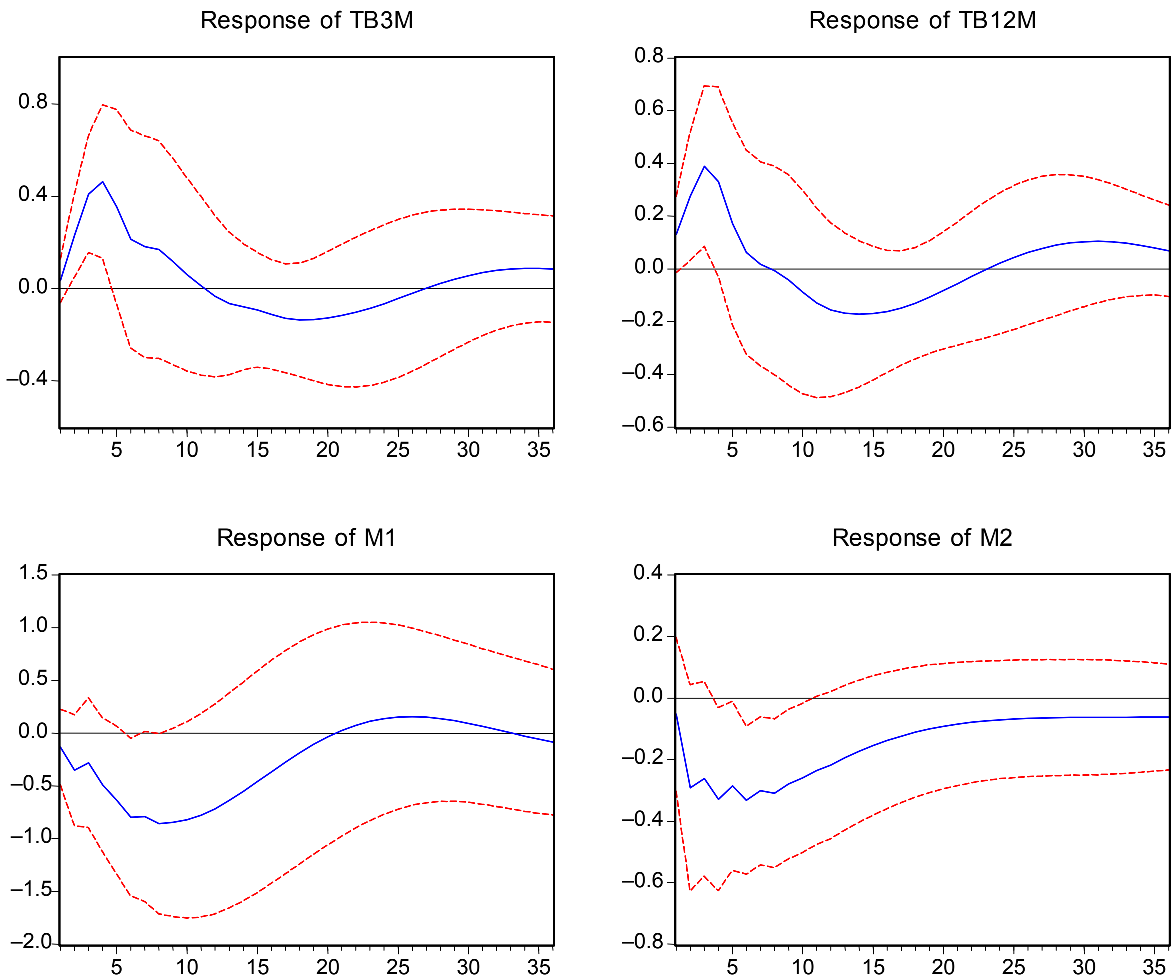

Response of industrial output
1.5
1.0
0.5
0.0
−0.5
−1.0
5 10 15 20 25 30 35
Response of CPI
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
5 10 15 20 25 30 35
Response of real credit
0.4
0.0
−0.4
−0.8
5 10 15 20 25 30 35
Response of retail sales
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
5 10 15 20 25 30 35
Response of real wages
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
5 10 15 20 25 30 35

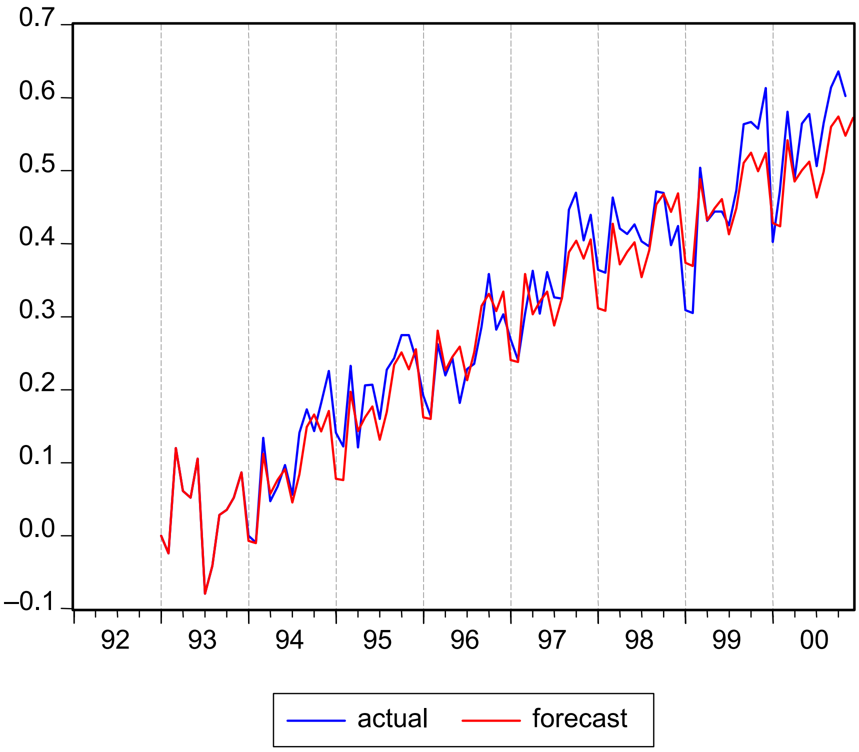
Figure 2.3



Response of TB3M
0.8
0.4
0.0
−0.4
5
10
15
20
25
30
35
Response of TB12M
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
Response of M1
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
Response of M2
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8

Figure 2.4

Actual and forecast industrial output



2.5 Appendix

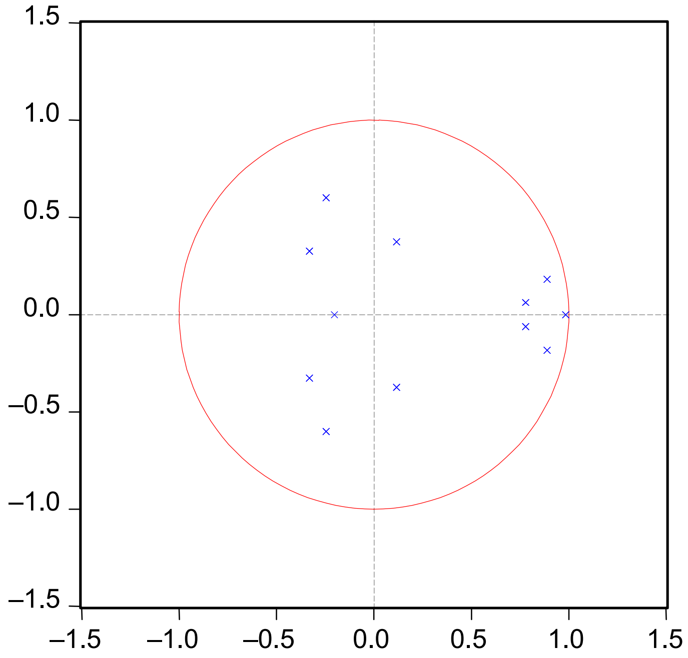
VAR residual serial correlation LM tests
H_0: no serial correlation at lag order h
Sample: 1995:01-2000: 12
Observations included: 67

Lags	LM-Stat	Prob
1	8.356672	0.4986
2	11.68689	0.2315
3	4.537902	0.8726
4	6.602488	0.6784
5	14.26531	0.1132
6	9.584925	0.3851
7	7.112851	0.6254
8	8.107002	0.5234
9	5.171880	0.8191
10	5.808371	0.7589
11	7.358047	0.5999
12	15.03845	0.0899

Note: Probs from chi-square with 9 df.

Figure 2.5

Inverse roots of AR characteristic polynomial



3. Structural modelling of inflation - some selected ideas concerning MSMI (by B Kłos)

3.1 Main assumptions of MSMI-1[7]

Ongoing structural changes in agents' behavioural patterns and a shortage of data are the main obstacles to the structural modelling of a transition economy. Econometric textbooks suggest several more or less sophisticated methods to model regime changes and structural breaks (for example, random or deterministic switching regression models, time-varying parameter or random parameter models) but the usefulness of these methods seems to be limited in the case of transition economies. All these methods require large samples in order to estimate parameters consistently. Besides, any estimates depict outdated (past) structure, so that a model is not very useful when policymakers consider changing the policy mix or analysing economic prospects. Therefore our structural model of inflation attempts to describe the future state of the economy. It is assumed that the transition process forces economic agents to learn and use market adjustment methods. The progress made with system transformation should make behavioural patterns more similar to those observed in developed market economies. The results of empirical investigation based on VAR methodology seem to support that point of view (see for example the previous section). The idea of modelling the future state of a transition economy rather than its current (interim) structure is accepted by several model builders but it usually has a hidden assumption.[8] This assumption simplifies the specification of equations because a stylised or even textbook description of the market economy may be used as theoretical background to the model. In addition, there are many empirical macromodels of small open market economies, and hence many good patterns to follow.

"Forward-looking" specification requires non-standard techniques to evaluate the structural parameters of the model since either statistical data do not contain information on parameters or the information is present in the sample but hidden by transition-specific phenomena. The idea of a calibration method applied to evaluate the parameters of the first version of the model (MSMI-1) is presented in the third part of this section.

Our understanding of the inflation process in a market economy suggests that sources of inflation cannot be reduced to just one root - say, exogenous money supply. There are several mechanisms responsible for inflation and the model of inflation should capture at least some of them.[9] MSMI-1 attempts to include the following inflation-generating mechanisms:

- The result of imperfect competition and wage bargaining in the labour market - a wage-price spiral.
- The result of tensions in product and labour markets when aggregate supply and aggregate demand are equalised. This is usually approximated by the concept of the output gap.
- The impact of expectations on inflation.
- The role of external supply and demand shocks transmitted into the economy directly and indirectly (by shifts in the endogenous exchange rate).

These mechanisms could influence inflation in the short and the medium run. It is assumed that the price level is determined by money supply in the long run. No attempt is made, however, to capture structural reasons for inflation specific to the transition process in Poland. The transition-specific events may be important but they are temporary. The mechanisms are interdependent and in order to take account of all these inflation-generating mechanisms, the model should describe the supply as well as the demand side of the economy. For this reason our small structural model of inflation is in

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[7] This section shows the main characteristics of the first version of structural model inflation in Poland, MSMI-1 (see Kłos (2000) for more details). The model was put into practice in spring 2000. In late 2000 and early 2001 new versions of the model were developed. The latest version being used is MSMI-3.

[8] See, for example, Gionelly and Rovelly (1999) and Charemza (1996).

[9] See Brädsen et al (1999), Layard et al (1991), and Carlin and Soskice (1990).

fact a small structural model of the economy as a whole (a macromodel). The attempt to see inflation in the wider context of other macroeconomic features is also considered important by the author.

3.2 Stylised macroeconomic equilibrium

The macroeconomic context of the inflation process requires an answer to the question of how the different inflation-generating mechanisms are linked. It is therefore assumed that there are three markets in the economy: product market, labour market, and money and foreign assets market. These markets are interdependent but different, taking into account the type of competition and speed of adjustment. Adjustment is very fast in the money market because of free competition in this sector of the economy. Imperfect competition and nominal rigidities are responsible for the sluggish absorption of shocks in the labour market. In any case, unabsorbed disequilibrium spills over into other markets. Therefore the inflation process may be seen as a result of disequilibrium. This occurs in the product market.

Chart 3.1 presents a stylised and simplified picture of (static) short- and medium-run general equilibrium in MSMI-1. This version of the model assumes exogeneity of the short-term interest rate and endogeneity of the exchange rate; therefore the exchange rate is acting as a money market clearing price (see the lower part of the diagram). Certainly, inflation (a result of spillover effects) and (exogenous) interest rate policy may influence the way shocks are absorbed by the money and foreign assets market. Money market conditions impact on aggregate demand. Exports, imports and household incomes are not shown in the chart but exist in the model and influence aggregate demand and the equilibrium point.

The labour market and product market seem to be fairly standard (see the upper part of the diagram). Labour market conditions define the aggregate supply curve. Producers set their prices using a mark-up formula, and the bargained real wage (or expected real wage) rises with the level of employment. In those circumstances, the labour market exhibits features similar to those described by Layard et al (1991). The chart shows static equilibrium, so acceleration of inflation cannot be noticed.

3.3 Formal structure of MSMI-1

The formal structure of MSMI-1 is similar to many contemporary macroeconometric models, which mimic the short-run dynamics of variables as well as depict (local) long-run equilibrium (steady state) using a direct error correction mechanism (DECM).[10] The use of global long-run equilibrium equations and indirect error correction mechanisms (IECM) is less common.[11]

A long-run static equation often does not define causality in the economic sense. It is up to the researcher to assign the endogeneity (exogeneity) status of variables included in the equation.[12] It is also up to the researcher to investigate or to assume the direction of causality. If a static equation contains just one endogenous variable, an error correction mechanism specific to that particular endogenous variable may be built. Hence, there are local long-run equilibrium and direct error correction mechanisms. The static equation may, however, include two or more endogenous variables. At the point of long-run equilibrium the causality could be undetermined. In that case, the long-run relation defines global equilibrium and one has an opportunity to build direct (DECM) as well as indirect error correction mechanisms (IECM). The idea of the DECM and IECM is shown by the following example:

$$y_t = \alpha_0 + \alpha_1 x_{t1} + \alpha_2 x_{t2} + \varepsilon_t \qquad \text{(Static long-run equation)}$$

$$ECM_{t-j} = y_{t-j} - (\alpha_0 + \alpha_1 x_{t-j1} + \alpha_2 x_{t-j2})$$

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10 See, for example, Whitley (1994) and Chan et al (1995).

11 Of course, the idea of global, direct and indirect error correction mechanisms is taken from the Johansen procedure. See also Charemza (1996), Garratt et al (1998), and Kłos (1999).

12 In the framework of the Johansen procedure, the weak exogeneity of the variables may be tested. Weak exogeneity is a statistical (econometric) term, however. In this paper a specific meaning of this term is used, namely the endogenous and exogenous status of variables implies direction of causality (in the general, not statistical, sense).

$$\Delta y_t = \beta_1 \Delta x_{t1} + \beta_1 \Delta x_{t2} - \delta_d\, ECM_{t-j} + \ldots + u_t \qquad j = 1,\ldots \qquad \text{(DECM)}$$

$$\Delta x_{t1} = \beta_1 \Delta x_{t2} + \beta_2 \Delta y_t + \delta_i\, ECM_{t-j} + \ldots + u_t \qquad j = 1,\ldots \qquad \text{(IECM)}$$

The ECM variable, by definition, is a measure of disequilibrium, so that variable may be used as an indicator of spillover effects. The formal scheme of the mechanism, called spillover disequilibrium mechanism (SDM), is as follows:

$$\Delta w_{t1} = \beta_1 \Delta z_{t1} + \beta_2 \Delta z_{t2} \pm \delta\, ECM_{t-j} + \ldots + u_t \qquad j = 0,\ldots \qquad \text{(SDM)}$$

Direct and indirect error correction mechanisms stabilise the model, but the SDM indicates a need for adjustment, so it usually pushes the left-hand variable out of the long-run equilibrium point. Applying the SDM requires some caution. The SDM usually does not define the proper steady state solution of the left-hand variable, so the equation should contain some additional factors or have a feature maintaining the desired long-run solution.

The MSMI-1 model is composed of 12 stochastic equations; two of them are static (long-run). The full list comprises:

- Static (long-run) equations: production function and money-price relationship.
- Dynamic (short-run) equations: internal demand, exports, imports, demand for money, import prices, consumer prices, producer prices, wages, employment, exchange rate.

There are 15 identities and deterministic equations. These equations define expectations (consumer prices and nominal wages), the index of fixed assets, some specific quantity indices and GDP. Expectations concern consumer prices, nominal wages and the złoty/dollar exchange rate. None of these is forward-looking.

The list of exogenous variables comprises: the internal short-run interest rate, effective tax rates (indirect taxes, personal income taxes, corporate income taxes), nominal government expenditures, the short-run external interest rate, world prices, world production, world oil prices, and the euro/dollar exchange rate. The model does not impose any balancing constraints except GDP identity. There is no state budget balance or balance of payments account, nor is public debt explained.

3.4 The technique of parameter calibration

The calibration procedure is based on an idea of M-estimators. Many standard estimators are examples of unconditional optimisation. For example, the ordinary least square technique uses a sum of squared residuals as a loss function and that function is minimised to obtain estimates of parameters. The method applied to calibrate parameters of MSMI-1 is also a case of seeking minima. The loss function is taken from the generalised method of moment (GMM), namely I use a form of the GMM loss function suitable for M-equation non-linear systems:[13]

$$H(a,b) = \sum_{i=1}^{M}\sum_{j=1}^{M} \sigma_{ij} \left(y_i - f_i\left(a_i(L)Y, b_i(L)X\right)\right)' Z A Z' \left(y_j - f_j\left(a_j(L)Y, b_j(L)X\right)\right)$$

where:

σ_{ij}	= a component of the inverted error term covariance matrix,
Z	= a matrix of instrumental variables,
A	= a positive defined matrix,
y_i, Y	= a vector (matrix) of endogenous variables,
X	= a matrix of exogenous variables,
a_i, b_i	= vectors of parameters to be calibrated,

[13] See Davidson and McKinnon (1993).

$f_i(.,.)$ = a structural equation of the model.

The standard GMM method minimises the loss function *H(.,.)* unconditionally. The calibration method is the case of conditional optimisation. The parameter space is restricted and the restrictions supplement the statistical sample. This is a standard method of including non-sample information in the estimation process. However, a typical estimation procedure uses a very limited number of restrictions (but so-called null restrictions). In the case under consideration, a single solution (in the formal sense) to the unconstrained problem may not exist since the sample is very small. Therefore restrictions are also necessary to identify parameters.

The constraints applied in this exercise define the lower and upper limits of each parameter (but constants and dummies). The limits are taken from a comparison of estimated models of developed market economies (France, Finland, the United Kingdom, etc). Some of the constraints are the results of multiplier analysis. Certainly, there are some constraints which cannot be justified on theoretical grounds, but just express the author's point of view.

In practice, the calibration procedure is more sophisticated and it is composed of several steps. The model contains some long-run (static) equations (used to define the global ECM) and some deterministic equations. In order to calibrate the system as a whole, parameters of static and deterministic equations of the model as well as the matrix of σ_{ij} should be given. Therefore, one calibrates parameters of deterministic equations and estimates static equations in the first step. In the second step, each behavioural (dynamic) equation is calibrated separately to compute residuals. These residuals are used to evaluate the covariance matrix $[\sigma_{ij}]$. The calibration of the system as a whole is carried out in the final step.

3.5 The results of calibration

In the case under review the parameters of the model were calibrated over the quarterly sample 1994:3-1999:4 (2000:1). The equations fit the sample data fairly well and the model was able to replicate past events of the Polish economy quite well too.[14] Charts 3.2 to 3.4 show the results of some simulation exercises performed to analyse dynamic features of MSMI-1. In all cases an exogenous variable was changed permanently and the results are measured as a percentage difference from the baseline value.

The first chart (3.2) shows the impact of changes in effective tax rates on inflation and GDP. In each case the effective rate of taxes rises by one percentage point. The pattern of time paths suggests that the rise in the indirect tax rate (*txo*) and that in the corporate income tax rate (*txp*) are the cases of supply shocks since the shift in rates pushes GDP and prices in opposite directions. The increase in the personal income tax rate (*txd*) seems to be a demand shock in the MSMI-1 model. The rise in personal taxes reduces disposable income, so aggregated demand declines as well as inflation. The magnitudes of the effects are interesting. The charts prove that indirect taxes have the strongest impact on inflation and GDP but GDP is more sensitive to change in personal income tax than to change in corporate income tax.

The second chart (3.3) shows the results of a 1% rise in nominal government expenditures. This exercise is not very informative since, in the period under consideration, the real value of expenditure changes as well the ratio of expenditures to GDP. Nevertheless, some pieces of information may be recovered. There is no budget constraint in the model, so it may be assumed that the increase in government expenditures should increase GDP permanently and the inflation cost may not be important. This is not the case due to supply constraints. Moreover, the maximum value of the government spending (interim) multiplier is around 1.08, hence the balance of costs (in terms of GDP) may be negative.

The last exercise depicts the influence of the nominal short-term interest rate on GDP and inflation. The permanent rise in the short-run interest rate (by one percentage point) suppresses inflation, but this effect is not permanent. The rise in the interest rate suppresses GDP, but this is not an efficient method to compress internal demand as well. After six to eight quarters, due to substitution effects,

[14] The employment equation is an exception.

cheaper imported goods replace internal production. Clearly, this is the result of a rise in real government expenditures. Nominal expenditures are kept at the level of base simulation but the drop in inflation raises real expenditures. The rise in internal demand increases the general price level in subsequent quarters. This is shown in Chart 3.4.

The calibration technique gives values of structural parameters but standard errors of estimates are not available. Most of them cannot be computed because they do not exist. This is a major drawback of many calibration procedures, so the only way to validate the model is perhaps to analyse goodness-of-fit measures and the responses of the model to standard shocks. Reasonable dynamic multipliers and data congruency of the variables do not prove the relevance of the ideas applied in a model or of the model as a whole. Moreover, it may be suggested that data congruency is a disadvantage of the model, since it proves the “backward-looking” specification of the model. Nevertheless, provided that the economic background of the model is accepted, the model may be a useful tool for medium-term scenario analyses. Calibrated structural models may not paint a precise picture of the real economy. These models are also not very precise forecasting tools as far as short-term predictions are concerned. Nonetheless, the calibrated structural macromodels (including MSMI-1) can be used to build medium-term scenarios and detect the possible effects of external and internal shocks. They can also be used to design a slightly better macroeconomic policy mix.

3.6 Further development of the structural models

A better understanding of transition-specific events, a slightly more informative sample,[15] and wealth of experience gained since the first version (MSMI-1) was put into practice allowed the author to change the modelling methodology and the specification of the model. Both are more standard now. Newer versions of the model (MSMI-2 and MSMI-3) still attempt to describe the future rather than the current (interim) behavioural patterns of agents. However, using a limited information version of the GMM technique, it is now possible to estimate the short-run dynamics of the equations (but this is not very sophisticated). The long-run part, error correction mechanisms, is still assumed or calibrated.[16] There are some changes in the macroeconomic background of the model as well. The most important one concerns the long-run roots of inflation. MSMI-3 assumes a very limited long-run impact of money supply on inflation but links inflation to the condition of external markets through a version of the PPP paradigm. MSMI-3 allows an interest rate rule to be chosen, so the interest rate and inflation define the money market clearing mechanism. The role of the exchange rate is now very standard. Newer versions of the model introduce the forward-looking behaviour of the money and foreign assets market as well.

The MSMI parameters are re-estimated at least every quarter. The volatility of estimates suggests, however, that the economy (the adjustment method applied by agents) is still far from mature. Nevertheless, if allowance is made for the disadvantages of this model, and the limitations of models in general, it is an indispensable tool for scenario and policy analyses. Despite a lack of data and permanent structural shifts, which constrain the credibility of our models, structural models are becoming an important component of the toolkit of decision-makers.

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[15] The Polish economy has been exposed to several supply and demand shocks during the last two years. The impact of the shocks on the economy has been rather destructive but, paradoxically, it has provided an additional opportunity to observe how economic agents attempt to absorb shocks and adjust. It made the sample more informative. On the other hand, some institutional changes were introduced in 1999 and 2000 and, for this reason, many macroeconomic variables are now measured less precisely.

[16] There are some exceptions. For example, long-run import prices are estimated in an error correction equation and long-run demand is estimated using the Johansen procedure.

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Chart 3.1
Short- and medium-run equilibrium

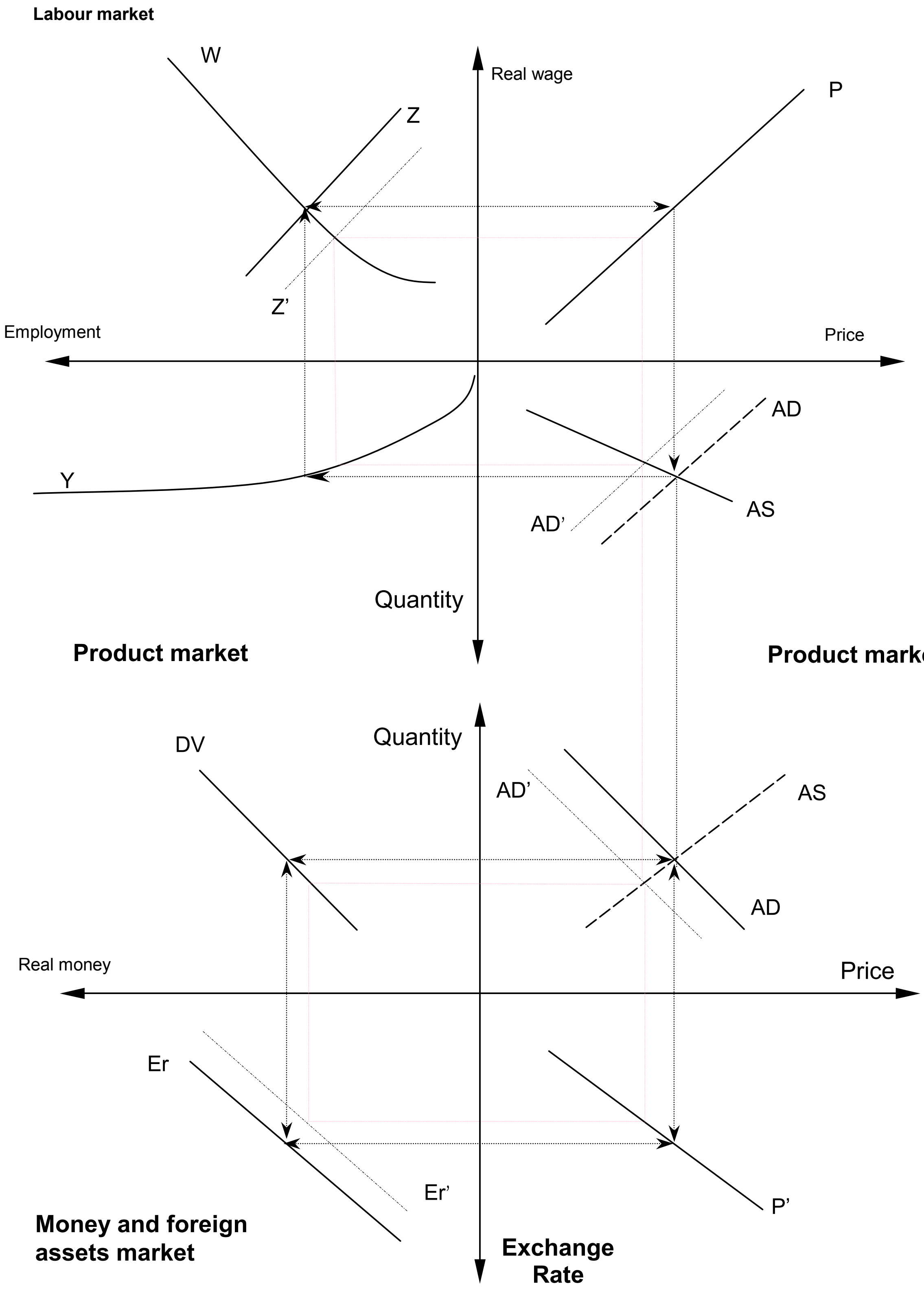


Chart 3.2
Change in inflation (left-hand panel) and GDP (right-hand panel) due to changes in tax rates

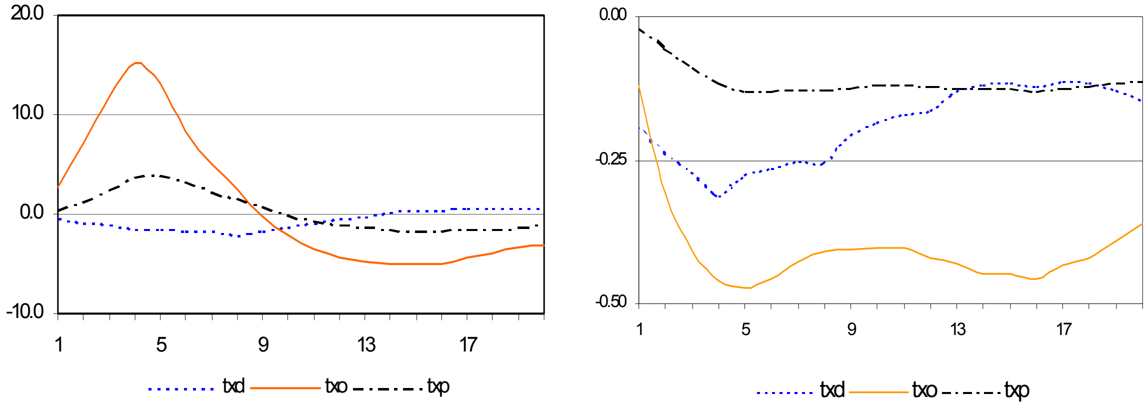


Chart 3.3
Change in inflation and GDP due to rise in government expenditures shock

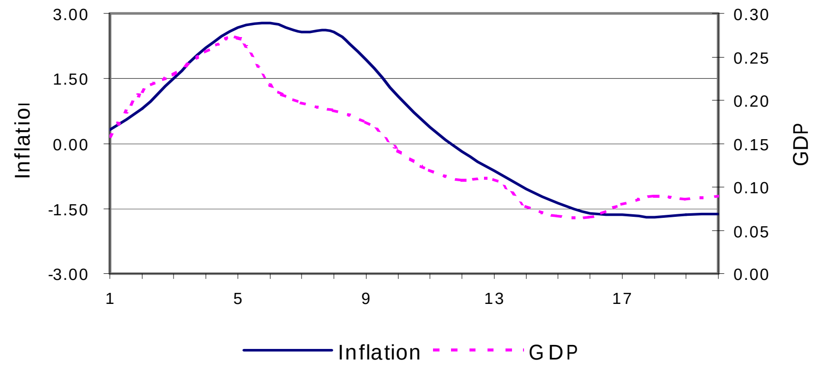
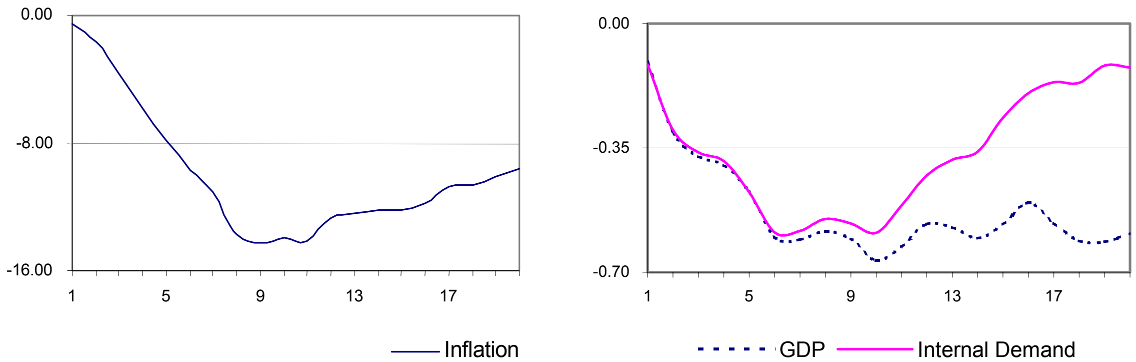


Chart 3.4
Changes in inflation and GDP due to rise in short-term interest rate



4. Final remarks

The important branch of research carried out at the National Bank of Poland aimed at supporting monetary policy attempts to study the current state of monetary transmission. This line of research monitors the evolution of the immediate and delayed responses of the economy to standard shocks. The results of these investigations suggest that the Polish economy is slowly resembling a typical market economy. Obviously, there are some country-specific features and some reactions to standard shocks are also country-specific. The VAR analyses provide us with a kind of benchmarking, even though the author finds some of the results not fully reliable, in particular the reaction function of industrial production and unemployment rate. However, it is quite a good starting point to develop the second line of research, namely structural modelling. Our structural macromodels still, primarily, exhibit the authors' view of the economy. It is not a "true" picture of the economy since the sample is still too small and the structure investigated still too volatile. However, having such benchmarking at least makes it possible to evaluate the dynamic multipliers of structural models and check the validity of calibrated (or conditionally estimated) structural models of the economy.

Modelling the inflation process in Thailand

Atchana Waiquamdee, Bank of Thailand

Modelling the inflation process or any other mechanism in the economy is a challenging task for the central bank. The model should not only represent relationships between variables that are consistent with economic theory, but also produce reliable forecasts of key variables in order to assist the monetary policymaking process.

This paper consists of three sections. Section 1 provides a historical overview of the inflation process and describes how inflation is measured in Thailand. It also discusses the relationship between core inflation and headline inflation. Section 2 illustrates the macroeconometric model employed by the Bank of Thailand (BOT) in the formulation and implementation of its monetary policy, with special focus on the inflation modelling process. Section 3 explains how fan charts and probability distributions are used to reflect the uncertainties surrounding the forecasts. The application of the model in policy optimisation, as well as the limitations of the model and the inflation equation, is also discussed in this section.

1. Measures of inflation in Thailand

During the 13 years before the switch of exchange rate regime in mid-1997, Thailand maintained a commendable record on inflation, averaging around 4%. Inflation remained at a level comparable with that in the United States (whose weight accounted for more than 80% of the exchange rate basket) and was in line with inflation in other countries in the region (computed as the simple average of inflation in Indonesia, Malaysia, the Philippines, Singapore and Taiwan[1]). Nevertheless, by 1994 the economic boom, with growth rates exceeding 10% and sizeable capital inflows, had exerted additional upward pressure on inflation, resulting in a divergent inflation performance between Thailand and its trading partners (see Figure 1). Eventually, this led to the exchange rate crisis in 1997.

There were several explanations for the BOT's good record on inflation management. First, the fixed exchange rate regime during 1984-97 provided an effective nominal anchor for inflation in Thailand. Second, careful management of macroeconomic policies with a countercyclical monetary policy and a cautious fiscal stance helped to keep domestic demand in line with production capacity. Third, labour costs in Thailand increased at a moderate rate (only 7%) during 1985-95. Finally, Thailand's emphasis on export-led growth, coupled with trade liberalisation, intensified competition among domestic manufacturers, providing incentives for cost reduction while containing the price level.

The calculation of the headline consumer price index (headline CPI) in Thailand consists of two major steps: (1) surveying the prevailing market prices; and (2) weighing the surveyed prices according to the corresponding items' relative importance in the representative basket that comprises 270 items. As shown in Table 1, weights and selected product items are derived from the 1994 socioeconomic survey conducted in urban areas among families of between two and six persons, with monthly income ranging from 6,000 to 36,000 baht.

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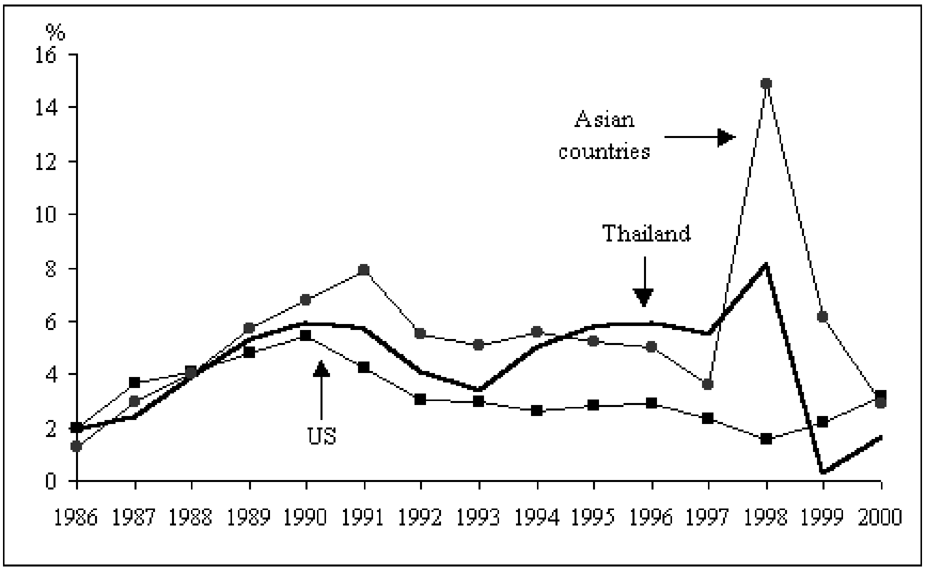
[1] Taiwan, China. Subsequent references to "Taiwan" are to be understood as references to "Taiwan, China".

Figure 1

Inflation in Thailand, the United States and Asian countries[1]



[1] Indonesia, Malaysia, the Philippines, Singapore and Taiwan.

Sources: Ministry of Commerce; IMF, *World Economic Outlook*.

Table 1

Components and weights of the CPI basket

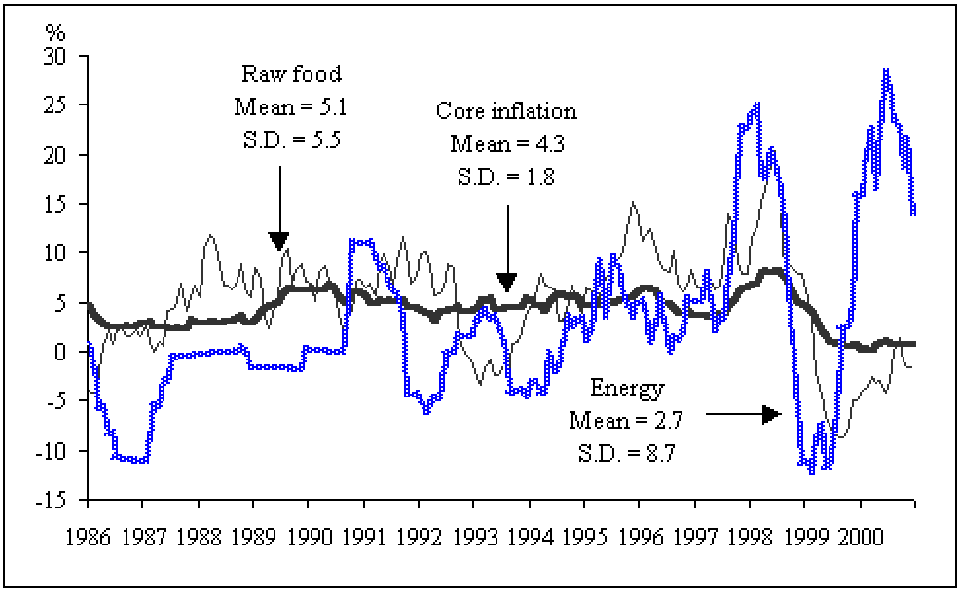
Component	Weight
Food and beverages	35.28
of which:	
Rice and cereal products	2.43
Meat, poultry and fish	5.64
Vegetables and fruits	4.63
Eggs and milk products	2.25
Other food bought from market	2.04
Non-alcoholic beverages	1.60
Prepared food	16.70
Non-food	64.72
of which:	
Clothing	5.61
Housing and furnishing	24.01
Medical and personal care	6.34
Transportation and communication	17.45
Recreation and education	7.80
Tobacco and beverages	3.51

Source: Ministry of Commerce.

As a measure of price stability, the core consumer price index (core CPI) provides a more accurate measure of underlying prices and is better suited to monetary policy decision-making. Following the adoption of the inflation targeting framework by the BOT on 23 May 2000 (which specified core inflation as the main target of monetary policy), the Ministry of Commerce released a new series of core CPI which excludes raw food and energy prices from the CPI basket. Figure 2 reveals that raw food and energy prices were much more volatile than measured core inflation: their standard deviations for the period 1986-2000 were 5.5 and 8.7 respectively, whereas that of core inflation was only 1.8.

Figure 2

Raw food and energy prices



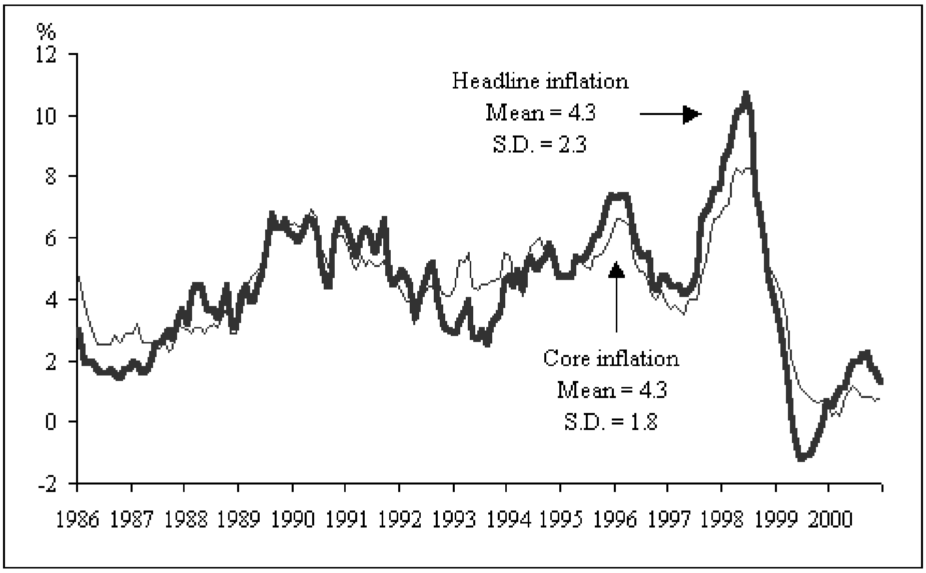
Source: Ministry of Commerce.

Despite the exclusion of raw food and energy items, a large share of information is still retained in the measure of core inflation, accounting for about 80% of the data used in the construction of the consumer price index. In addition, historical data show that core inflation is less volatile in the short run. In the long run, however, movements of both core and headline inflation closely track one another. Figure 3 shows that both measures of inflation have averaged 4.3% over the past 15 years, while the standard deviation of headline inflation in this period was higher than that of core inflation.

Given the cointegration between the two measures of inflation, the maintenance of price stability in terms of core inflation will lead to stable prices overall. Currently, both core and headline inflation are within the target range of 0-3.5%.

Figure 3

Headline and core inflation



Source: Ministry of Commerce.

2. Modelling inflation in Thailand

2.1 General features of the BOT macroeconometric model (BOTMM)

The BOTMM is a system of equations representing mechanisms in the economy and the complex relationships between economic variables. The model is one of the necessary tools for monetary policymaking and is used at the BOT for several purposes:

1. Providing the Monetary Policy Board (MPB) with information about the prospects for growth and inflation and assisting the MPB in its monetary policy decisions;
2. Aiding in evaluating the effects of changes in economic environment and policies on the economy, such as the impacts of oil price and exchange rate variations; and
3. Estimating the relationship between monetary policy and inflation, in terms of both magnitude and lags of policy effects.

However, the result of the model does not fully dictate the setting of monetary policy. The MPB, comprising experts and distinguished economists, uses its own judgement on both the results obtained from the model and the issues involved, as well as any other factors unexplained by the model, in making monetary policy decisions.

The core model is a macroeconomic model based on quarterly data for 1993-2000. As shown in Figure 4, the model covers four main economic sectors, namely the financial sector, the real sector, the external sector and the public sector, thus enabling analysis based on the financial programming framework.[2] It also includes an array of price equations that capture various price indices and deflators. The core model is used to analyse the impact of changes in policy or external factors on the economy. Incorporating various data and economic indicators, the model is also used to forecast

[2] The salient feature of the macroeconomic model developed by the IMF is the focus on relationships between monetary and fiscal policies and the real sector.

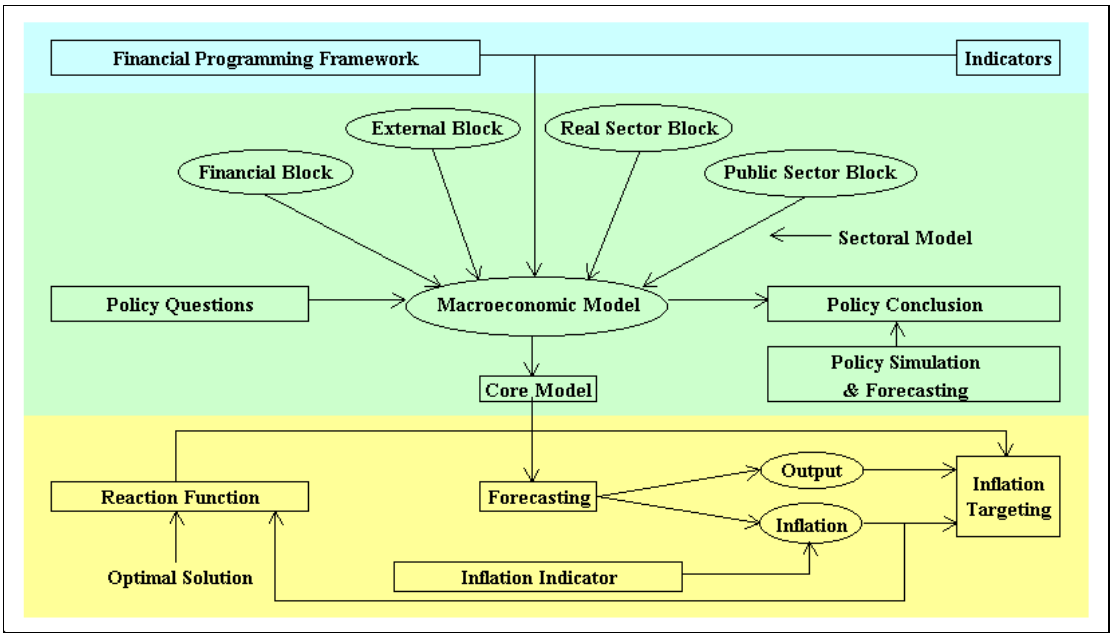
inflation and output growth. The forecasts of these variables are essential to the policy optimisation process discussed in Section 3.3.

Every quarter, the BOT improves the model by incorporating the most recent data as well as reviewing the relationships among variables based on economic theory. The latest model comprises 26 behavioural equations and 14 identities. Most of the behavioural equations are in the form of difference equations, which is appropriate for the estimation since many variables in the model are non-stationary.[3]

Extensive tests were performed on all these equations and yielded a total of 17 equations with error correction model (ECM) properties. These are equations on private consumption, private investment, export volume, import volume, government revenue, exchange rate, core inflation, raw food price, farm price, non-oil import price, energy price, domestic retail oil price, public investment deflator, government consumption deflator, export price and import price. The ECM will over time adjust the short-run relationship to the long-run relationship of the variables. All estimated equations have significant statistical values and the coefficients have signs complying with economic theory.

Figure 4

Components of the macroeconomic model



The inflation process in Thailand is captured by a set of equations that form part of the BOTMM. These equations show the key determinants of inflation and the linkages between core inflation and headline inflation. As with many equations in the model, most price relationships have short-run and long-run characteristics, and the ECM is used to capture the long-run equilibrium.

A notable feature of this model, which makes it distinctive from all other models previously used at the BOT, is the inclusion of forward-looking inflation expectations. The private sector is assumed to have rational expectations, whereby expectations are adjusted rationally and promptly once new information is obtained. In planning their consumption or investment, consumers and investors would take into account the cost, or the interest rate, in comparison with the expected future inflation rate. Such a modelling structure ensures an effective transmission mechanism from monetary policy to the target variables.

However, a number of equations require dummy variables due to significant changes in the economic and financial structure during the observation period. Nevertheless, before adopting the model the

[3] Harris, R I D (1995): *Using cointegration analysis in econometric modelling*, Prentice Hall/Harvester Wheatsheaf.

BOT conducted tests of its predictive power by dynamic simulation. The results showed that endogenous variables would, to a satisfactory extent, follow the turning points of actual values, particularly in the case of the inflation rate. Moreover, most of them had root mean squared percentage errors of less than 5%.

2.2 Relationships in the model

The relationships among the main variables in the BOTMM have the following features:

1. Relationships in the real sector follow the Keynesian Approach, where GDP is determined by both short- and long-term demand through private and public expenditures as well as international trade. Exogenous variables affecting GDP are economic and financial conditions of main trading partners, interest rates, government expenditure and tax rates.

2. The policy rate (14-day repurchase rate) can affect important variables such as inflation and economic growth through four different channels (Figure 5):

    (1) deposit and lending rates, which impact on private credit demand and money supply;

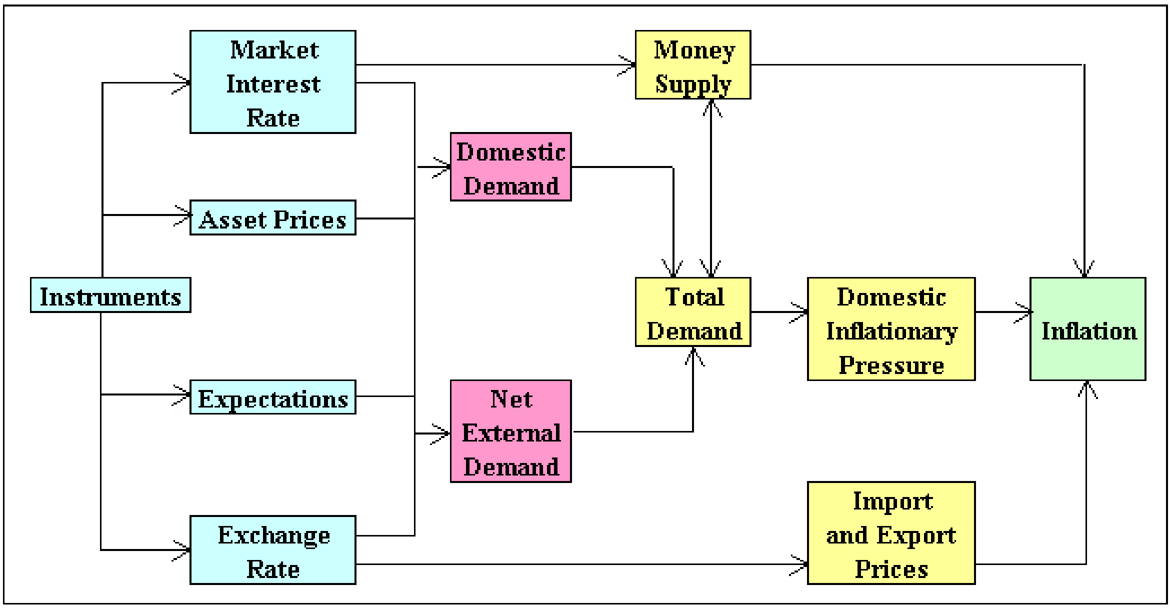
    (2) exchange rates, which impact on international trade, money supply and the price level;

    (3) asset prices, which impact on private consumption and investment; and

    (4) inflation expectations, which impact on private consumption and investment.

Figure 5

Transmission mechanism of monetary policy



3. Real money supply partly determines GDP through private investment, as money supply is an indicator of liquidity or source of funds of private businesses.

4. The real sector in turn affects the financial sector through government demand for credit to finance the deficit, private credit demand, which changes in line with economic growth, and changes in net foreign assets arising from changes in the trade balance, the service account and net capital inflows.

5. Inflation depends on the world crude oil price, prices of agricultural and industrial products in the world market, exchange rates, wages, money supply (an indicator of demand pressure on prices) and inflation expectations of the private sector.

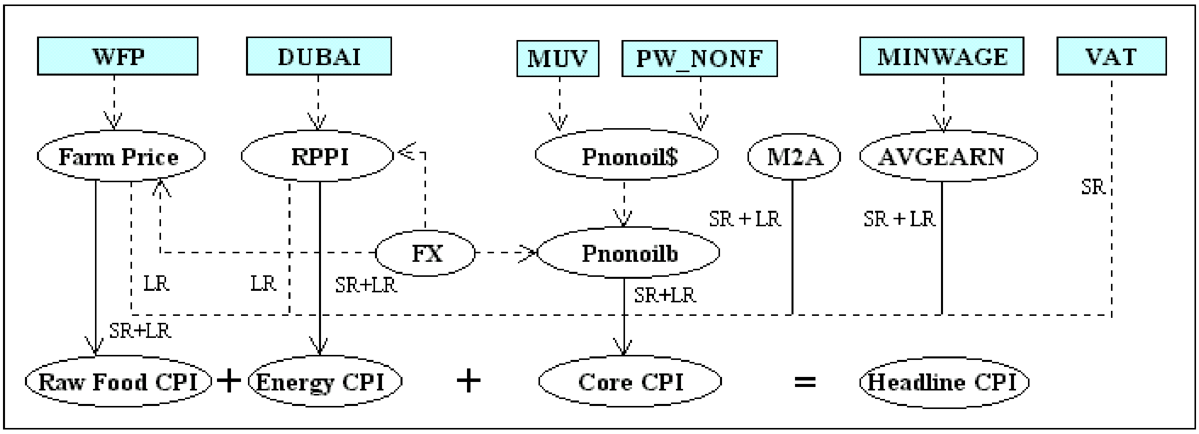
6. The price level is the adjusting factor that brings the economic system into equilibrium.

2.3 Transmission mechanism of inflation

A number of factors have a significant influence on Thailand's inflation rate. Figure 6 depicts the process by which core and headline inflation are determined in the BOTMM. These relationships are supported by economic intuition and econometric evidence based on available data. The determinants of inflation are statistically significant and have the correct signs. In addition, the relevant price equations have low standard errors and satisfy econometric tests of serial correlation. In Figure 6, boxes represent exogenous variables while circles represent endogenous variables. The arrows describe short- and long-run relationships (denoted by the abbreviations SR and LR) between variables, with the causality running from the source at the blunt end of the arrow to the destination at the pointed end. Note that some variables may be related in both the short and long run.

Figure 6

Transmission mechanism of inflation



The section below describes the equations that show the relevant price relationships in the BOTMM. The variables are written in capital letters. Abbreviations are used throughout the model: *sa* denotes seasonally adjusted series, *ln* denotes natural logarithms and *ecm* denotes error correction terms. Where the error correction term appears in the equation, the accompanying long-run equation is also given. Δ indicates first differences and the number in parentheses immediately following the variables indicates the lag period. The numbers in parentheses below coefficients are the t-statistics. Adjusted R-squared values and equation standard errors are given below the equations. LM(2) is the test for second-order serial correlation in the residuals and both the LM statistic and its probability value for each equation are given.

(1) Headline consumer price index

In the BOTMM, core, raw food and energy prices are estimated by separate equations, while headline consumer price is defined by an identity which is a weighted sum of the relevant price indices:

CPI = CORE*(1 – WEN – WRFOOD) + (WEN*CPIEN) + (WRFOOD*CPIRFOOD)

where CPI is the headline consumer price index, CORE is the core consumer price index, CPIEN and CPIRFOOD are the energy and raw food price indices respectively, and WEN and WRFOOD are the energy and raw food weights in the CPI basket respectively.

(2) Energy price index

The energy price is determined by the domestic retail petroleum price (RPPI), with a long-run equilibrium relationship between the variables.

$$\Delta\ln(CPIENsa) = \underset{(7.71)}{0.421}*\Delta\ln(RPPIsa) + \underset{(3.23)}{0.191}*\Delta\ln(RPPIsa(-1)) - \underset{(-1.68)}{0.165}*ecmCPIEN(-1)$$

Adjusted R-squared = 0.78 SE of regression = 0.0150 LM(2) : 0.02(0.98)

ecmCPIEN = ln(CPIENsa) – (1.227 + 0.754*ln(RPPIsa))

(3) Retail petroleum price index

The retail petroleum price is a function of the Dubai crude oil price (DUBAI) and the exchange rate (FX), with a long-run equilibrium. The exchange rate plays an important role as the Thai baht has been floating since mid-1997 and has an impact on the domestic price of oil.

$$\Delta\ln(RPPIsa) = \underset{(6.97)}{0.292}*\Delta\ln(DUBAIsa) + \underset{(6.58)}{0.420}*\Delta\ln(FX) + \underset{(3.66)}{0.319}*\Delta\ln(RPPIsa(-1)) \underset{(-2.64)}{-\,0.366}*ecmRPPI(-1)$$

Adjusted R-squared = 0.81 SE of regression = 0.0232 LM(2) : 2.26(0.12)

ecmRPPI = ln(RPPIsa) – (1.252 + 0.363*ln(DUBAIsa) + 0.701*ln(FX))

(4) Raw food price index

The raw food price is affected by the domestic farm price (FARMPRICE), with a long-run equilibrium. FLOAT is a dummy variable representing the switch of the exchange rate system from fixed to floating, with a value of 1 from 1997 Q3 onwards and zero otherwise.

$$\Delta\ln(CPIRFOODsa) = \underset{(2.88)}{0.007} + \underset{(4.38)}{0.262}*\Delta\ln(FARMPRICEsa) + \underset{(2.01)}{0.140}*\Delta\ln(FARMPRICEsa(-1)) + \underset{(3.91)}{0.056}*\Delta FLOAT \underset{(-2.08)}{-\,0.132}*ecmCPIRFOOD(-1)$$

Adjusted R-squared = 0.65 SE of regression = 0.0139 LM(2) : 0.25(0.78)

ecmCPIRFOOD = ln(CPIRFOODsa) – (0.143 + 0.897*ln(FARMPRICEsa))

(5) Farm price index

The farm price responds to the world farm price (WFP) and the exchange rate, with a long-run equilibrium relationship among the variables. DUMFARM indicates periods when heavy floods occurred and caused farm prices to rise, with a value of 1 between 1995 Q3 and 1996 Q4 and zero otherwise.

$$\Delta\ln(FARMPRICEsa) = \underset{(1.50)}{0.142}*\Delta\ln(WFP(-2)) + \underset{(2.54)}{0.225}*\Delta\ln(WFP(-3)) + \underset{(4.47)}{0.347}*\Delta\ln(FX(-2)) + \underset{(3.57)}{0.038}*DUMFARM \underset{(-2.53)}{-\,0.183}*ecmFARMPRICE(-1)$$

Adjusted R-squared = 0.75 SE of regression = 0.0232 LM(2) : 0.24(0.79)

ecmFARMPRICE = ln(FARMPRICEsa) – (–0.528 + 0.594*ln(WFP) + 0.845*ln(FX))

(6) Core consumer price index

The core consumer price is modelled as a function of money supply (M2A), the non-oil import price (PNONOILB), average earnings (AVGEARN), the value added tax rate (VATRATE) and the FLOAT dummy. Defined as CPI excluding raw food and energy prices, CORE is independent of agricultural and petroleum prices in the short run. However, in the long run farm and fuel prices translate to prices of products in the core CPI basket as businesses pass on the costs of production to consumers.

$$\Delta\ln(COREsa) = 0.003 + 0.168*\Delta\ln(M2Asa) + 0.039*\Delta\ln(PNONOILB(-1))$$

(2.88) (5.89) (6.76)

$$+ 0.058*\Delta\ln(AVGEARN) + 0.003*\Delta VATRATE + 0.004*FLOAT$$

(4.41) (4.28) (3.16)

$$- 0.141*ecmCORE(-1)$$

(–4.69)

Adjusted R-squared = 0.90 SE of regression = 0.0022 LM(2) : 0.78(0.48)

$$ecmCORE = \ln(COREsa) - (0.453 + 0.119*\ln(M2Asa) + 0.067*\ln(FARMPRICEsa(-1))$$

$$+ 0.135*\ln(RPPIsa(-1)) + 0.025*\ln(PNONOILB(-1)) + 0.252*\ln(AVGEARN))$$

(7) Non-oil import price index in Thai baht

The non-oil import price in Thai baht (PNONOILB) is converted from the non-oil import price in US dollars using the exchange rate.

$$\Delta\ln(PNONOILB) = \Delta\ln(PNONOIL\$) + \Delta\ln(FX)$$

(8) Non-oil import price index in US dollars

The non-oil import price in US dollars (PNONOIL$) is driven by industrial commodity prices comprising the world non-fuel commodity price (PW_NONF) and the world manufacturing unit value (MUV). The variables are also related in the long run.

$$\Delta\ln(PNONOIL\$sa) = 0.376*\Delta\ln(PW\_NONF(-4)) + 0.246*\Delta\ln(MUV(-4))$$

(4.03) (1.91)

$$- 0.359*ecmPNONOIL\$(-1)$$

(–2.93)

Adjusted R-squared = 0.51 SE of regression = 0.0130 LM(2) : 1.21(0.33)

$$ecmPNONOIL\$ = \ln(PNONOIL\$sa) - (1.789 + 0.504*\ln(PW\_NONF(-1))$$

$$+ 0.103*\ln(MUV(-1)))$$

(9) Average earnings

Average earnings are determined partly by the minimum wage (MINWAGE) and partly by earnings in the previous period.

$$\ln(AVGEARNsa) = 0.485 + 0.248*\ln(MINWAGE) + 0.802*\ln(AVGEARNsa(-1))$$

(3.12) (2.19) (10.66)

Adjusted R-squared = 0.99 SE of regression = 0.0141 LM(2) : 1.15(0.33)

(10) Inflation expectations

Inflation expectations are estimated by the percentage change in core consumer price from the same period of the previous year.

$$CINFEX = ((CORE(4)/CORE)-1)*100$$

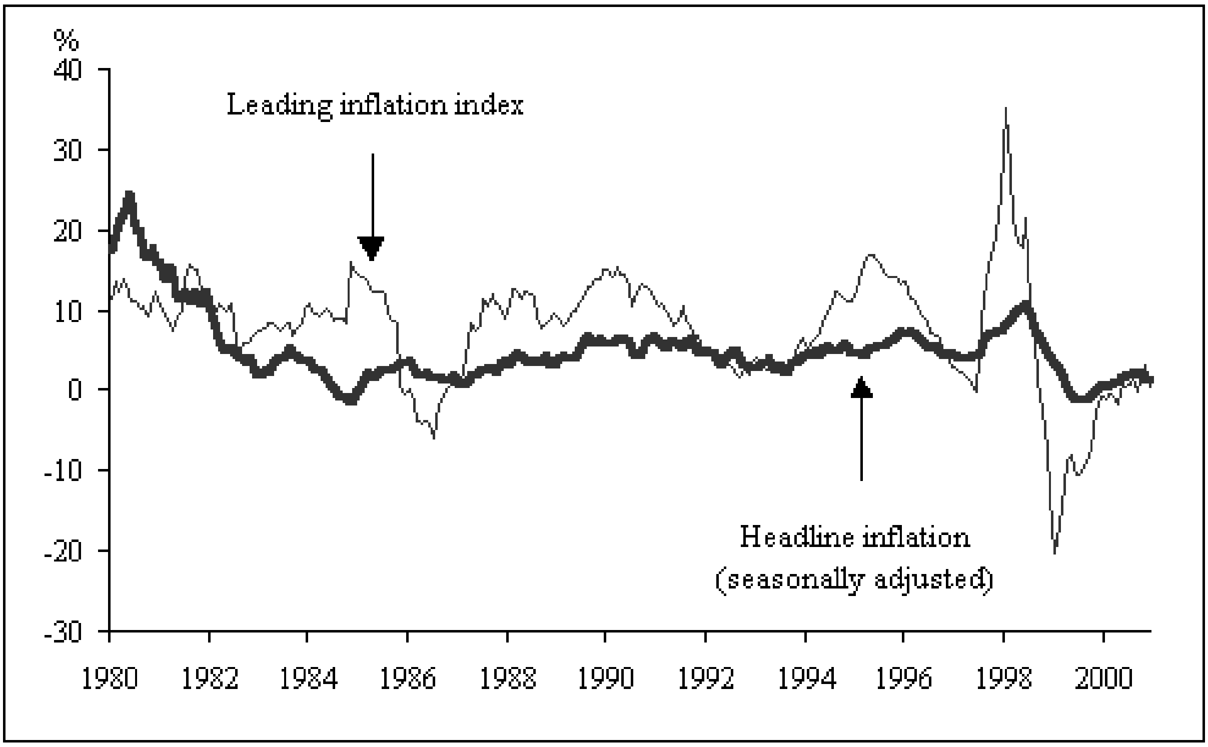
Note from Figure 6 and the equations above that the domestic agricultural price affects the raw food price directly. Similarly, the retail petroleum price translates to the energy price directly. Domestic agricultural and petroleum prices also influence core inflation, albeit only in the long run. Other variables such as the non-oil import price, money supply and average earnings have no impact on raw food and energy prices but affect core inflation in the short and long run.

2.4 Leading indicator of inflation

In addition to the macroeconometric model, the BOT's composite leading inflation index (LII) is calculated each month to predict turning points in headline inflation cycles. This information is useful in assessing near-term inflation. The LII is calculated by combining nine individual indicators (seasonally adjusted) that predict waves of inflation (expansions and contractions): M2A, domestic credit, the stock price index, terms of trade, the Oman oil price index, the import price index, the producer price index (raw materials), the minimum lending rate and the exchange rate. These were selected to broadly represent demand-pull and cost-push factors of inflation in Thailand. The average lead time of turning points in the LII to headline CPI is three to four months. This means that the LII in the current month is used to predict inflation in the next three to four months (see Figure 7). It is often claimed that three consecutive months of increase (decrease) in the six-month smoothed growth rate (annualised) of the LII forewarn of inflationary (deflationary) pressure.

Figure 7

Headline inflation and leading inflation index



3. Inflation forecasts and model limitations

3.1 Fan charts and probability distributions

In general, model application for economic forecasting uses deterministic simulation. This is done in two steps: (1) evaluating exogenous factors during the forecast period; and (2) setting the error term in each equation to zero. However, in practice, the error terms are subject to high uncertainty especially during periods of rapid change in the economy. The economic forecast must thus account for these uncertainties by using stochastic simulation, which gives fan charts and the probability distribution of the forecast values. The model's result is therefore not a fixed value but a probability distribution of the forecasts.

The MPB makes projections about the future path of the economy in order to determine the direction of monetary policy. In the forecast process, the MPB considers many factors that influence the economy, such as foreign interest rates, exchange rates, oil prices and world farm prices. The fan chart illustrates the probability distributions for the forecasts of inflation and output growth, based on the central projection and the risks surrounding them. It also depicts the increasing uncertainty associated with the forecasts as the time horizon is extended.

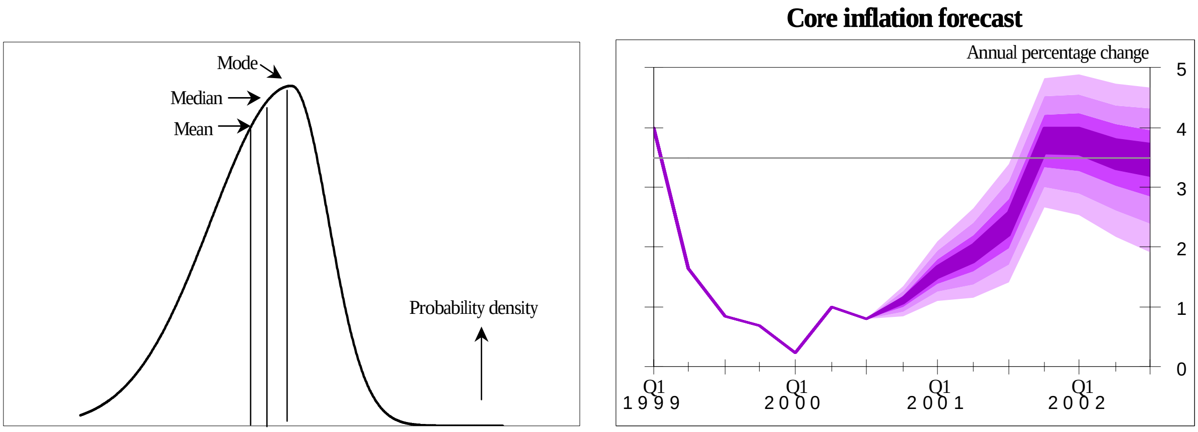
The BOT conducts stochastic simulations of the model, an econometric method that generates separate probability distributions for the exogenous variables, disturbance terms and parameters in the model. The probability distribution is obtained only for disturbance terms in key equations including the core consumer price, the energy price, the retail petroleum price, the raw food price, the farm price, the exchange rate, investment, consumption, exports and imports. It is assumed that the disturbance terms are normally distributed with zero mean and standard deviation equal to the standard error of the equation.

The BOT simulates the model no less than a hundred times to obtain averages of quarterly estimates of inflation and output growth, which are presented to the MPB. These average forecasts represent the most likely outcomes and are represented by the central line in the fan chart. The variance surrounding the central projection produces a spectrum of outcomes, each with a probability distribution through time. When the fan chart is symmetric, the bands are evenly distributed on both sides of the central band.

The MPB takes into account a wide range of data and information about the economy and assesses the risks to the inflation and output growth forecasts. By specifying the variance and the likelihood that the outcomes will be higher or lower than the most likely outcome (mode), a skewed distribution is obtained.[4] Figure 8 illustrates a distribution that is skewed to the left or downwards, which shows that the risks to the forecasts are more on one side of the central projection than on the other. In this case, the fan chart shows that it is more probable that the actual rate of inflation would fall below the modal value in the final quarter of the projection period.

Figure 8

Skewed distribution and fan chart



The shaded area on both sides of the fan chart in Figure 8 begins with the darkest band, followed by successive pairs of bands in increasingly lighter colours. The darkest shaded area represents the most probable range of outcomes in each quarter, with a confidence interval of 25%. In other words, inflation and output growth projections should lie within the darkest band 25% of the time. Each successive pair of bands is drawn to cover a further 25% of the probability, and the confidence level that the forecasts will fall within each band rises to 50, 75 and 90% respectively. If the distribution is skewed, so that the mean outcome is not equal to the modal outcome, the coloured bands may not be evenly distributed. The balance of risks by which the shape of the distribution is determined depends on the judgement of the MPB.

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4 Britton, E and J Whitley (1998): "The Inflation Report projections: understanding the fan chart", Bank of England *Quarterly Bulletin*, vol 1, pp 30-7.

3.2 Policy optimisation

In principle, under the optimisation technique the central bank will minimise the difference between the target and the forecast of target variable (such as inflation or output growth) during the specified period. This difference can be written in the form of a loss function, which is regarded as the target equation for central banks in general. For Thailand, flexible inflation targeting is used, which means that the BOT's loss function consists of two targets, namely inflation and potential output.

The central bank will minimise the loss function during the period in which monetary policy affects on the economy (about one to eight quarters). This can be written in a mathematical equation as follows:

$$MinL = \sum_{t}^{8} \frac{1}{2} \left[\alpha \left(\pi_t - \pi_t^* \right)^2 + \lambda \left(y_t - y_t^* \right)^2 \right]$$

with respect to r_t

subject to the macroeconomic model where π_t, y_t are the inflation and output forecasts; π_t , y_t^* are the inflation target and potential output; r_t is the 14-day repurchase rate; and α, λ are the weights given to inflation and output targets.

The results of optimisation will generate the appropriate path of the policy rate (14-day repurchase rate) which yields the inflation forecast closest to the target and the GDP forecast closest to potential output.

3.3 Limitations of the model and inflation equation

The BOT's macroeconomic model has been developed and tested since early 1999. The statistical tests were found to be satisfactory; yet there remain some limitations, such as the short period of observation and the finding that coefficients in some equations are not very stable. The reason is that the estimation of equations covers periods of both high and low economic growth, including the period in which the economy underwent a severe crisis when financial institutions did not function efficiently and many businesses were in the process of debt restructuring.

In addition, some of the model dynamics need improvement. For instance, the manufacturing capacity utilisation rate or other proxies for the output gap should be included in the core inflation equation to reflect the direct pressures of domestic demand on the price level. However, empirical studies at the BOT indicate that neither the manufacturing capacity utilisation rate nor the output gap based on the Hodrick-Prescott trend method is statistically significant. Alternative measures of the output gap are currently under review.

In order to enhance the predictive power of the forecasts and to induce effective policy setting, the model is constantly improved in terms of data inputs, econometric techniques and relationships among the variables according to economic theory. The model is revised quarterly and appears in the BOT's *Inflation Report*.

Finally, it should be borne in mind that the model serves only as a tool to assist monetary policymaking under the current inflation targeting framework. In determining the direction of monetary policy, the model should be used together with analysis of economic conditions as well as the judgement of the policymakers.

Modelling the transmission mechanism of monetary policy in emerging market countries using prior information

Jeffery D Amato and Stefan Gerlach

1. Introduction

In recent years, central banks in emerging market and transition economies (EMCs) have devoted considerable resources to developing macroeconometric models of the transmission mechanism of monetary policy (MTM). Arguably the most important reason for this is that central banks are increasingly gearing monetary policy directly towards achieving their ultimate goal of price stability - in some cases through the adoption of explicit inflation targeting - rather than indirectly through the use of nominal exchange rate objectives. To bolster efforts to implement a broad-based strategy with flexible exchange rates, it is desirable for policymakers to have a firm sense of the size, lag and duration of the effect of interest rate changes on inflation and macroeconomic conditions more broadly. By contrast, under fixed exchange rates, the setting of interest rates is determined by the need to maintain exchange rate stability. Knowledge of the transmission mechanism is always desirable, but in this case it is not strictly needed.

In addition to helping guide the setting of policy, having explicit models of the MTM is also desirable for a number of related reasons. First, an econometric model can be used to provide forecasts of future macroeconomic conditions. This is one reason why modelling the transmission mechanism is of interest also under fixed exchange rates regimes. Second, econometric models can be used to analyse past policy decisions. This may be particularly useful in reviewing episodes in which policy errors were made. Third, econometric simulations may be helpful in communicating policy decisions to the public. Decisions to change interest rates can thus be motivated by pointing to forecasts of macroeconomic conditions. Finally, econometric models can be used to assess and represent the degree of uncertainty about the likely future course of the economy and the impact of policy measures.

Developing models of the MTM in EMCs involves making important decisions regarding the modelling strategy. One central concern is how to deal with the paucity of data for many of these countries. In this note, we review ongoing work at the BIS on these issues.

2. Modelling approach

An important question in studying the MTM concerns the choice of modelling approach. One aspect of this is the size of the model. While some central banks rely upon large models, comprising potentially several hundreds of equations and identities, others prefer more parsimonious models of, say, fewer than 10 equations. Some models are based explicitly on the optimal decisions of economic agents, others contain directly posited equations that have a vaguer link to economic theory, and still others are merely time series econometric models. Furthermore, there are the questions of how to obtain values for parameters and how to specify shock processes. The main point is that there are many decisions to be made in obtaining a model usable for policy analysis, and the choices across central banks are rarely the same.

The modelling of the MTM currently being undertaken at the BIS focuses on small empirical models. The main reasons for the choice of this approach are as follows. First, given that our interest is in comparing the transmission mechanism in several countries, using small empirical models is particularly attractive. As the dimension of a model increases, the possibility of making meaningful comparisons diminishes. Related to this, small models are inherently more transparent than larger models, so that understanding the importance of any given component in the model is enhanced. The ability to isolate the influence of individual parameters in simulation results is illuminating. More generally, the transparency of a model may be critical in persuading senior central bank staff about the usefulness of econometric models for policy purposes. Third, small models are much easier to handle from a technical perspective. For instance, they may be estimated as a whole in a way that exploits all the information in the data. Moreover, confidence intervals for forecasts and simulations can easily be constructed, which makes it possible to communicate the inherent uncertainty of the monetary transmission mechanism and the future path of the economy. Estimating and maintaining a small group of models is simply more tractable.

Given the preference for small, empirical models of the transmission mechanism, two classes of feasible models come to mind. The first is Structural Vector Autoregressions (SVAR). One argument in favour of SVARs is that they are easy to estimate in that the underlying equations can typically be estimated sequentially using single-equation techniques. However, in order to give the results an economic interpretation, the residuals from the fitted equations must be transformed into structural shocks. This requires some identifying assumptions to be made. While a range of such assumptions have been used in the literature, the results are often surprisingly sensitive to the exact choice of assumptions and, more worrisomely, to seemingly innocuous changes in them. A further problem with SVARs is that it is not possible to give a structural interpretation to estimated parameters. As noted above, this may render it more difficult to persuade the central bank's senior management of the benefits of using a model.

The second class is Small Structural Models (SSM). SSMs also have strengths and weaknesses. One strength is that it is possible to give individual equations and parameters economic interpretation. Thus, it is possible to analyse how the results depend on various critical parameters, such as the slope of the Phillips curve or the real interest elasticity of aggregate demand. However, SSMs rely on even stronger identifying assumptions than SVARs, upon which the interpretation of results crucially hinges.

3. Modelling issues

A major problem in modelling the MTM in emerging market and transition economies arises from a lack of good data. Three factors tend to limit the amount of usable data available. First, data on many important macroeconomic variables are not available at all or only for short time periods. For instance, data on wages, which play a critical role in the inflation process, are typically not available for long time periods. Second, even when extended time series are available, the occurrence of structural breaks frequently limits the "effective" sample length. EMCs typically undergo rapid structural change associated with economic development. Moreover, regulatory and institutional changes, including financial deregulation, may introduce large breaks in economic relationships. Thus, data from the pre-change period may be of little value in assessing the behaviour of the economy more recently. Needless to say, this problem is particularly acute for transition economies, for which data from before the early 1990s may be of no value. Third, the quality of the data may be low. It is well known that many if not most macroeconomic time series are subject to measurement errors of unknown importance. For instance, measurement errors on inflation arise because of changes in consumers' spending patterns and because of changes in the quality of goods purchases. These changes are believed to be particularly acute for EMCs.

The potential importance of data problems has consequences for the modelling of the transmission mechanism, and macroeconomic relationships more broadly, in EMCs. With short sample periods and noisy data, the errors of fitted relationships will have a large variance, implying that the parameters will be imprecisely estimated.[1] This may lead researchers to incorrectly disregard important channels of transmission.

One way to deal with this problem in applied work is to impose values for those key parameters that are imprecisely estimated. This approach has the obvious attraction that while a parameter may be poorly identified in a given sample, there may be other information about its value. Such information may come from past research or studies on other countries, or policymakers may have rules of thumb regarding the size of some economic effects. As an illustration, consider a model builder who has to assess the pass-through of exchange rate changes to inflation in an economy which a year ago

[1] In addition, measurement errors on the independent variables will lead to biased estimates.

adopted floating exchange rates after having operated under fixed exchange rates for a decade or two. While the policy change invalidates estimates of the pass-through based on recent data, it may be that parameter estimates for the pass-through parameters from an earlier period of floating rates can be used. Alternatively, estimates for other countries with a similar economic structure may be used to gauge plausible values for the key parameters.

However, imposing values for parameters is not without problems. To see this, note that although a large error variance (eg due to a short sample period) reduces the significance of an estimated parameter, the fitted value is nevertheless an unbiased estimate of the true parameter (in the absence of measurement error). Moreover, imposing values for parameters amounts to disregarding information in the valid part of the sample at hand. A second problem with imposing values is that it understates the degree of uncertainty about the structure of the economy. Central banks have in recent years increasingly recognised that it is important to assess not only the expected impact of policy measures on the future economic conditions but also the degree of uncertainty inherent in such projections. While model builders may be uncertain about the likely size of a parameter, imposing a value for it is tantamount to pretending to be omniscient about the parameter since estimated confidence bands for impulse responses or forecasts will not reflect the true uncertainty about the value of the parameter. Furthermore, the degree of uncertainty regarding the transmission mechanism affects the optimal strength and timing of policy changes. In the light of these problems, it is desirable to explore ways to combine modellers' prior views of the size of individual parameters with the information in the data, while taking into account the uncertainty about the priors.

4. Mixed estimation

One way to do so is to employ *mixed estimation*, which has a long history in econometrics going back to Theil and Goldberger (1961).[2] The starting point for this analysis is the assumption that the modeller has two separate pieces of information about the structure of the economy. The first of these is a data sample, which can be used to estimate the parameters of interest. For example, consider a linear model, and collect all of the parameters of the model in the vector β. Let $\beta(ols)$ denote a vector of estimated parameters obtained by a conventional classical estimation method (eg OLS), and $\Sigma(ols)$ its covariance matrix. The second piece of information consists of the prior information of the modeller (or policymaker). Let $\beta(prior)$ denote the prior information regarding the vector of parameters of interest, and let $\Sigma(prior)$ denote the associated covariance matrix. The practice of imposing an exact value for a parameter corresponds to assuming that $\Sigma(prior) = 0$.

Given the above information, the estimate of the parameter vector, and associated covariance matrix, that optimally combine the two pieces of information are given by:

$$\beta(post) = F\beta(prior) + (I - F)\beta(ols) \qquad (1)$$

where

$$F = \left[\Sigma(prior)^{-1} + \Sigma(ols)^{-1}\right]^{-1} \Sigma(prior)^{-1} \qquad (2)$$

$$\Sigma(post) = \left[\Sigma(prior)^{-1} + \Sigma(ols)^{-1}\right]^{-1} \qquad (3)$$

Thus, equation (1) implies that $\beta(post)$, the "mixed estimate" of the parameters of interest, is a weighted average of $\beta(ols)$, the OLS estimate, and $\beta(prior)$, the prior estimate. The weight on the prior information depends on the confidence the modeller attaches to it. To see this more clearly,

2 H Theil and A S Goldberger (1961), "On pure and mixed estimation in economics", *International Economic Review*, 2 65-78. Our treatment of mixed estimation also has an interpretation as Bayesian estimation under natural conjugate priors with known covariance matrix of the residual.

consider the case of a single parameter, in which case we have that $\Sigma_i = \sigma_i^2$ for *i = ols,prior,post*. Using this notation, we have that:

$$F = \frac{\sigma_{ols}^2}{\sigma_{ols}^2 + \sigma_{ols}^2} \tag{4}$$

which implies that the weight attached to the prior information is increasing in the uncertainty over the estimate from the sample (σ_{ols}^2) and decreasing in the modeller's confidence regarding the prior information of the parameter (σ_{prior}^2). Note that, if the modeller is certain about the true value of the parameter, and *F* = 1. Thus, the mixed estimate of the parameter will equal the prior value. By contrast, if the modeller is very uncertain about the true value of the parameter, $\sigma_{prior}^2 = \infty$ and *F* = 0, so that the mixed estimate will be based solely on the data sample.

So far the discussion has focused on the implication of prior information for the point estimates of the parameters. However, prior information also influences the uncertainty of the mixed estimates. To see this, rewrite (3) for the scalar case:

$$\sigma_{post}^2 = \frac{1}{\left[\dfrac{1}{\sigma_{prior}^2} + \dfrac{1}{\sigma_{ols}^2}\right]} \tag{5}$$

which has several interesting implications. Note that $0 \le \sigma_{post}^2 \le \sigma_{ols}^2$ and $\sigma_{prior}^2 = \infty$ implies that $\sigma_{post}^2 = \sigma_{ols}^2$. Thus, the precision of the mixed estimate is at least as high as the precision of the estimate based solely on the data, with the former converging to the latter as the degree of prior uncertainty increases.

5. Empirical illustration

In this section, we illustrate how the approach discussed above can be used to provide estimates of the transmission mechanism. The analysis is conducted using a simple model of the economy consisting of two equations. The first of these is an aggregate demand relationship, according to which the output gap, y_t, depends on its own lagged value and the short-term real interest rate (lagged two periods), r_{t-2}, which we take as the policy instrument:[3]

$$y_t = a_1 y_{t-1} + a_2 r_{t-2} + \varepsilon_t^y \tag{6}$$

The second relationship is a backward-looking Phillips curve, according to which inflation, π_t, depends on the lagged output gap, lagged inflation and other (observable) exogenous variables, y_t:

$$\pi_t = b_1 y_{t-1} + b_2 \pi_{t-1} + b_3 z_t + \varepsilon_t^\pi \tag{7}$$

The MTM is straightforward in this model: an increase in real short-term interest rates reduces future output gaps, which in turn reduces future inflation. The key parameters for assessing the impact of policy are thus a_2 and b_1. Of course, a_1 and b_2 are also important in that they determine the dynamic response of the economy to disturbances.

Next, we estimate a version of this model for South Africa, using annual data for the period 1985-2000. To capture open-economy aspects in the model, we specify z_t to be relative import prices (lagged

[3] Constants are omitted.

twice). Table 1 provides OLS estimates of the parameters. As can be seen, the impact of short-term real interest rates on the output gap, a_2, is highly significant. Thus, the first step of the transmission mechanism is well identified. By contrast, the impact of the output gap on inflation, b_1, is highly insignificant. The initial impact of monetary policy on inflation, which occurs with a lag of three years, is given by a_2b_1. The imprecision of this estimate is illustrated in Graphs 1 and 2, which show impulse responses to a 100 basis point increase in the real interest rate maintained for one year.

To illustrate how mixed estimation can be used to study the transmission mechanism, we next assume that we have prior information regarding these parameters.[4] In particular, for one parameter (in this case, a_2), we assume that the prior mean and its variance are similar to the values obtained by OLS estimation. Specifically, our prior for a_2 has a normal distribution with mean -0.3 and a standard error of 0.1.[5] It is worthwhile pointing out that, even when the prior information is similar to that in the data, there may be important benefits in using mixed estimation. To see this, consider Graph 3, which shows the sampling distribution of the OLS estimator, the assumed prior probability distribution, and the resulting distribution of the mixed estimator. Although the assumed prior and the OLS estimates are similar, the distribution of the posterior is considerably more peaked, indicating that combining the information from the data with the prior leads us to a more certain view about the true value of the parameter.

Next we consider prior information regarding b_1, which captures the impact of the output gap on inflation. We assume that this parameter has a mean of 0.2 and standard deviation of 0.1. Thus, the prior mean is somewhat below the OLS estimate of 0.3. The main difference between the prior and sampling distributions, however, lies in their precision: whereas a 95% confidence band based on OLS estimation spans the range -0.22 to 0.82, the assumed prior implies a confidence interval of 0.0 to 0.4. Graph 4 shows the distributions of the OLS estimator, the prior and the mixed estimator. Since the OLS distribution is very flat - reflecting the fact that the data are silent on the true value of the parameter - the procedure attaches considerable weight to the prior information.

Table 1
OLS estimates of parameters

Output equation							
a_1	0.42	a_2	– 0.31			R-sq	0.50
se	(0.20)	se	(0.11)				
Inflation equation							
b_1	0.30	b_2	0.16	b_3	– 0.08	R-sq	0.85
se	(0.26)	se	(0.24)	se	(0.02)		

So far we have demonstrated how the use of the prior information affects the parameter estimates of a_2 and b_1. Next we show how this information changes our view of the transmission mechanism by calculating impulse responses analogous to those reported in Graphs 1 and 2. Consider first the responses of the output gap to a tightening of monetary policy. Comparing Graph 5 with Graph 1, we see that the use of prior information has little impact on the results, although the confidence bands are somewhat tighter. This is not surprising, since the OLS estimate of the impact of real interest rates on output was relatively precise, and we assumed that the prior mean on this parameter was similar to the OLS estimate.

Turning to the impact of monetary policy on inflation, however, Graph 6 shows that using the prior information has a clear impact on the result. While the point estimates are roughly similar to those

[4] For simplicity, each coefficient is estimated individually.

[5] Thus, we assume that a 95% confidence interval spans the range -0.5 to -0.1.

resulting from solely using the information in the data, the estimated confidence band is much narrower. Indeed, the decline in inflation in response to a tightening of monetary policy is significantly different from zero.

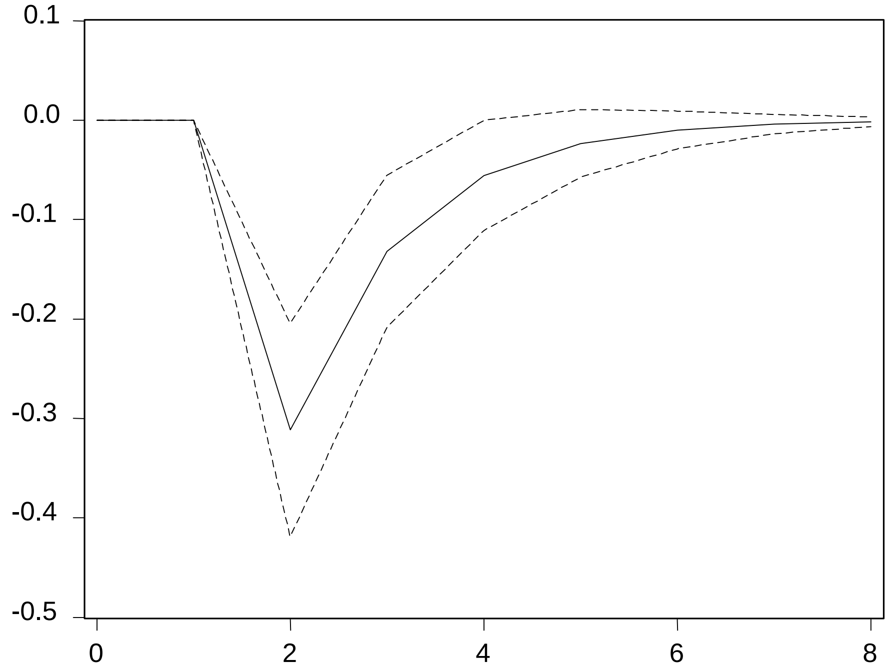
6. Conclusion

This note has illustrated how prior information can be used to study the transmission mechanism of monetary policy in situations in which the data itself are not very informative. While the approach is promising, it should be emphasised that the choice of priors can be a difficult task. Ongoing work at the BIS is focusing on how to specify prior distributions in a systematic and defensible manner.

Graph 1

Responses of output gap

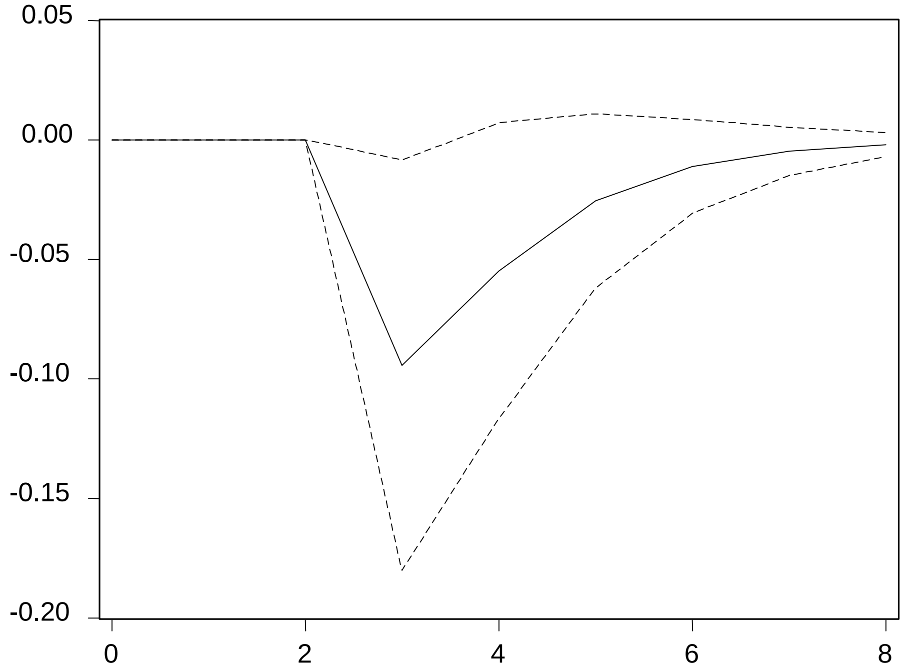
(OLS estimates)



Graph 2

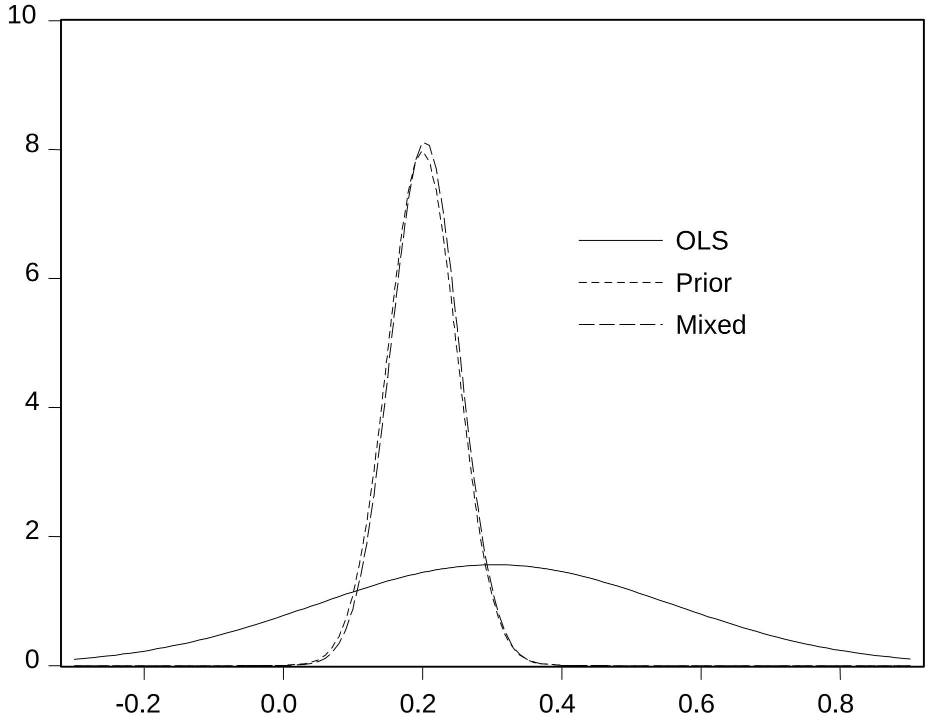
Responses of inflation

(OLS estimates)



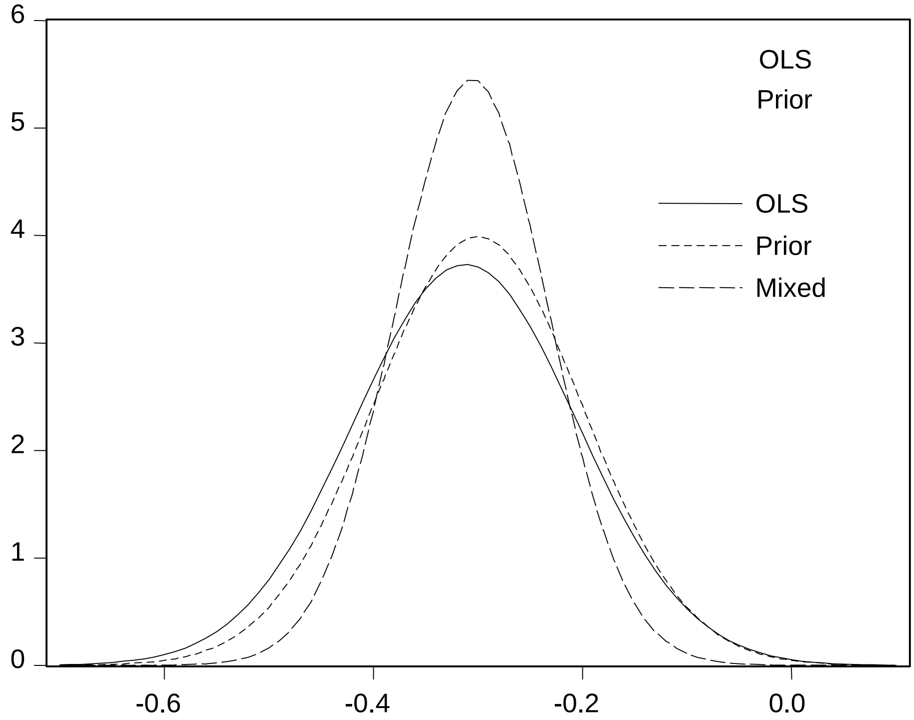
Graph 3

Impact of real interest rate on output



Graph 4:

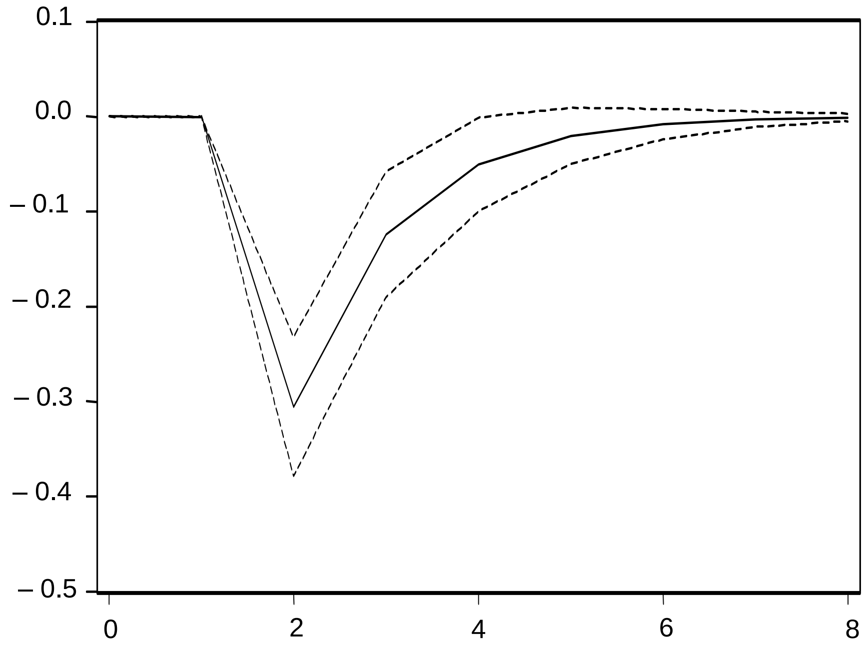
Impact of real interest rate on inflation



Graph 5

Responses of output gap

(Mixed estimates)



Graph 6

Responses of inflation

(Mixed estimates)