Transmission mechanisms and inflation targeting: the case of Colombia's disinflation

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Abstract

Colombia has been on a steady disinflation path since the early 1990s. In this paper, we model the transmission mechanism of monetary policy during this disinflation. We describe how inflation evolves in response to important shocks that occurred during disinflation such as the terms of trade and to the risk premium, comparing the responses across different assumptions about inflation persistence. Disinflation itself is captured by a permanent shift to the inflation target. We judge to what extent a shift towards a more forward-looking wage and price-setting determines the sacrifice ratio under disinflation.

1 The targets and channels of monetary policy in Colombia

Figure 1 depicts the turbulent history of monetary policy in Colombia. Large monetary contractions in 1983 and 1998 were interrupted by a huge expansion in 1992. During the 1990s, changes in monetary policy stance became even more frequent: the real interest rate jumped from a low of zero in 1992 to a peak of 12% in 1994 and from this peak to a low of 6% in 1997 and back to a peak of 18% in 1998.

The wild swings in interest rates reflected the authorities' attempts to stabilise capital flows, demand and inflation in a rapidly changing and unpredictable economic environment. The high interest rates of 1984 may be understood as an antidote to the risk of capital outflows as a balance of payments crisis loomed. The low interest rates of 1992 were intended as a treatment for the exact opposite 'malaise': an inflow of capital that, given the exchange rate objective, was jeopardizing stable money growth and inflation. Interest rates scaled heights again in 1994 in order to decrease the expansion of aggregate demand and excessive credit growth. The 1999 peaks, on the other hand, were a response to a mix of underlying developments. At that time the crawling exchange rate band had to be defended in the face of a risky international environment and a deterioration of the domestic political situation. The threat to be averted was the scenario of an exchange rate crisis that leads to both a burst of inflation and (as borrowing costs mount) a deep recession, as suffered by Mexico in 1995.

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Both inflation and output were important for the determination of the monetary policy stance during these years. The instruments used and intermediate targets pursued by monetary policy were also diverse. Targets for money supply, the exchange rate and the interbank interest rate were all used, often simultaneously. Even within the crawling band exchange rate regime, there was a system of 'mini' narrower bands.

All that began to change gradually as the exchange rate policy became increasingly flexible and ever more subservient to the inflation target, culminating with a float in 24th September 1999 (as Figure 1 shows).[2] Hence Colombia is considered by some analysts to be an early inflation-targeter.[3] Indeed price stability was made a formal mandate of the central bank by the constitution and inflation targets first defined in 1991. But Inflation Reports where the setting of interest rates based on the inflation forecast was emphasized have only been published since 1998. The point at which all other central bank policy objectives became truly subordinated to the inflation target, however is open to discussion.[4] What is remarkable about Colombian inflation is that it kept to the low double digits for the last quarter of the twentieth century (Figure 2). It was only during the 1990s, following the implementation of policies placing greater emphasis in monetary policy on stabilising inflation at lower levels, that inflation entered a steady downward path. This trend culminated in a major disinflationary impetus in 1999 that took inflation down to 9.2%. The public's expectations of inflation were of less than 10% for the year 2000, a figure that would last have been conceived as plausible in the 1960s. And the inflation targets for the following years were set to decrease inflation further. If sustained, this trend would put an end to the world's longest experience of moderate inflation (Dornbusch and Fischer, 1992)

How was this disinflation achieved in Colombia? The sustained falls in inflation have been associated with rises in unemployment. In Figure 3, we can see that the heights hit by interest rates in 1983-84 were accompanied by rapidly increasing unemployment. The behaviour of inflation suggests that these rises in unemployment were above the natural rate of unemployment. Almost a decade later, the low real interest rates of 1992 may have contributed to relatively low unemployment, at levels probably below the natural rate. As a consequence inflation peaked at over 30% in 1992 and only began decreasing thereafter when high real rates pushed up unemployment again.

Monetary policy has also affected inflation through the exchange rate. In the short run, changes in the rate of nominal depreciation have important consequences for imported price inflation but not for the other parts of the CPI basket. In the longer run, exchange rate changes do spread, though. During the 1980s when the rate of nominal devaluation was relatively high, inflation in the domestic price of imported goods was above total CPI inflation but pressures on the cost of production eventually drove up total CPI inflation (Figure 4). In the 1990s, the pattern was reversed: the rate of nominal depreciation was smaller than CPI inflation and this may have helped the disinflation in the long run by decreasing the cost of imported inputs.

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[2] A more detailed description of the evolution of the nominal exchange rate regime is in Villar and Rincón (2000).

[3] In 1997, five countries, including Colombia, was selected from among 150 developing and transition countries as possible candidates for the future adoption of an inflation-targeting framework (Masson, Savastano and Sharma 1997). Colombia may soon be fully considered an inflation-targeting country.

[4] For a discussion on inflation-targeting, see Mishkin (2000) and Masson, Savastano and Sharma (1997).

2 The main shocks to the Colombian economy in the nineties

Since 1998, the monetary policy regime in Colombia resembled more the template set by other inflation-targeting countries. A key step in this direction was the decision to have Inflation Reports focus on explaining the future effects on inflation and output of likely economic developments. As a contribution to this effort in this paper we develop an understanding of how key shocks and structural changes affect inflation in Colombia.

2.1 Shift in the inflation target

The Colombian disinflation is modelled as a previously unexpected permanent decline in the inflation target. Simulating the effects of this shock would help us quantify the effect of the macroeconomic program agreed with the IMF that set an inflation target path of 10%, 8%, and 6% for 2000, 2001 and 2002 respectively (Figure 5). Although these targets were not compulsory, they were part of the overall macroeconomic programme and as such acted as the monetary policy anchor.

2.2 Supply shocks in the agricultural sector

In 1991 the weather phenomenon El Niño drove food price inflation up beyond 30% (Figure 6). The post Niño weather brought good harvests and with it temporarily low food-price inflation: 10% in 1993. The cycle repeated itself later with food-price inflation of 25% in 1998 followed by 2.5% in 1999. As food items are 30% of the CPI, changes in the relative price of food may continue to be an important source of short-term shocks to inflation.

2.3 Terms of trade

Since coffee and oil and derivatives amounts to 11.4% and 32.5% of exports in 2000 respectively, the fluctuations in the international market price is an important source of variability to the Colombian economy. (Figure 7). Movements in the terms of trade are quantitatively large; for instance, the increase in the terms of trade in the third quarter over the first quarter of 1994 was 41.3%.

2.4 Risk premium

The foreign exchange risk premium has also been, on occasion, an important source of uncertainty for Colombia. The risk premium can be swayed by domestic economic factors, such as the evolution of public finances and developments in the conflict with guerrilla groups, or external developments, such as international financial crises. Since the risk premium affects the exchange rate, it may have important consequences for inflation. From May to June 2000, the spread of Colombian bonds in the international markets increased by about 200 basis points (Figure 8). This was most probably spurred by political events.

2.5 Changes in interest rates

Our final experiment is to simulate an unexpected temporary monetary policy impulse so that we can discuss the effects of both temporary and permanent shifts in the monetary stance.

3 A model of the transmission mechanisms of monetary policy in Colombia

The transmission mechanisms of monetary policy can be summarised in a flow chart (see Figure 9) and formalised into a model. All models are simplifications and should be used flexibly, adjusting as the economy and our understanding of it develops. In this spirit, the model in this paper does not discuss all factors that contribute to Colombian inflation and does not necessarily correspond to the view of the Board of the Banco de la República.

We now briefly describe each transmission channel, highlighting what we estimate to be their lags and their relative strength.

Most important appears to be an aggregate demand channel whereby an increase in the interest rate raises the real rate and leads, with a one-quarter lag, to a fall in investment and consumption. After a further one-quarter lag, that drop causes a fall in output below its potential level and decreases inflation.

Also in play is a direct exchange rate channel, whereby an increase in interest rate leads to an immediate appreciation. After a one-quarter lag the appreciation causes a decrease in inflation largely through a fall in the rate of inflation of prices of imported goods. This small immediate effect of the direct exchange rate channel on inflation may eventually build up and spread to the prices of other goods, starting with the prices of import substitutes, if the increase in the exchange rate is sustained. That would be the case for a sustained fall in the risk premium.

Monetary policy matters, too, through an indirect exchange rate channel, whereby the immediate appreciation affects the real exchange rate and causes a fall in net exports and so output. The decrease in output is small and only leads to a slight decrease in inflation, after a lag of one-quarter.

An expectations channel is also important. A credible monetary policy action lowers expectations of future inflation rate, pushing down current inflation. The size of the expectations effect on current inflation depends on the weight of expectations of future inflation expectations compared to lagged inflation on the righthandside of the price equation.

Finally there is a cost-push channel whereby final goods price inflation is dragged down by a moderation in the costs of domestic and imported inputs into production. Domestic costs are dominated by wage costs, and the incorporation of this channel requires us to model the labour market. These cost changes transmit credible, sustained monetary policy changes into final goods prices.

3.1 Price equation

3.1.1. Estimation

In what follows we present our estimates of the different equations of the model. We chose to estimate the equations of this model separately, using instrumental variables if necessary.

As part of our estimation of the price equation, we needed to calculate how expectations of future inflation affect current inflation. There are currently only eight data points available on inflation expectations data as measured by the return on nominal and real bonds, and only two data points for directly survey-based measured inflation expectations in Colombia. So we had to use actual data on future inflation. We estimated the price equation using the method proposed by McCallum (1976); lags of the explanatory variables (lagged values of inflation and the output gap) acted as instruments for expected inflation.

The price equation should be dynamically homogeneous to reflect our a priori assumption that permanent changes in the inflation target do not affect long-run output. Accordingly, the coefficients on righthandside inflation terms were restricted to add up to one.

The restricted estimates of the price equation are

$$\begin{aligned}\pi_t - \pi_{t-1} &= \underset{(1.607)}{3.757} + \underset{(0.143)}{0.299}(\pi_{t+1} - \pi_{t-1}) + \underset{(0.146)}{0.287}(\pi_{t-3} - \pi_{t-1}) \\ &+ \underset{(0.089)}{0.289}\, y_{t-1} + \underset{(0.028)}{0.089}\, \chi_{t-1} + \underset{(0.075)}{0.285}\, \pi_t^R - \underset{(0.014)}{0.026}\, z_{t-4} + \varepsilon_t^{\pi}, \text{ [5]} \quad (1)\end{aligned}$$

3.1.2 Definitions

π_t is the annual inflation rate defined as $\pi_t = 100(\log P_t - \log P_{t-4})$. P_t is the monthly geometric average of the CPI for the corresponding quarter. y_t is the output gap defined as $y_t = 100(\log Y_t - \log Y_t^P)$, where Y_t^P is potential output level estimated with the multivariate HP filter and Y_t is the real GDP level. χ_t is the annual change in the real exchange rate; calculated as $\chi_t = q_t - q_{t-4}$ where $q_t = P_t^M / P_t$ and P_t^M is the PPI for imports. $\pi_t^R = 100(\log P_t^R - \log P_{t-4}^R)$ is annual food-price inflation relative to total inflation; $P_t^R = P_t^A - P_t$ is the relative price of food and P_t^A is the food price component of the CPI. We will discuss the definition of the real exchange rate in the section on uncovered interest parity. z_t is the deviation of the log of the price level from its long-run value, calculated as $z_t = 100(\log P_t - 0.7\log W_t - 0.3\log P_t^M + 0.004t)$ where W_t is the nominal wage rate (measured in retail trade sector) and t is a time trend that takes account of labour productivity.[6] [7] The sample period is 1990Q1-2000Q1.

[5] The estimation method is GMM-IV. The sample period is 1990Q1-2000Q1. R^2=0.417. The standard error of residuals is 1.002 and the p-value of Lung Box Q statistic is 0.000.

[6] The results also hold for a geometric average of wages in the retail trade and industrial sectors.The trend is needed to approximate the change in productivity because the quarterly employment figures are not available for the entire economy but only for the main cities.

3.2.3 Results

This dynamic price equation has three features that make it attractive and we would argue, more realistic, for monetary policy modelling. It contains both forward-looking and backward-looking elements; it is dynamically homogeneous and it is statically homogeneous. It is forward-looking because it takes into account the expectations of future inflation. Dynamic homogeneity is implied by the fact that coefficients on explanatory inflation terms in the price equation add to one. Static homogeneity follows because in the long-run error correction term, the sum of the coefficients on the nominal variables affecting long-run prices is one.

We estimate that the forward-looking versus backward-looking weight on inflation is about 0.3. The persistence of inflation that this indicates implies that disinflation is costly in terms of output in Colombia.[8] In our model, not only the large coefficients on past inflation terms but also the length of their lags make for costly disinflation.

Dynamic homogeneity means that, although there is a trade-off between economic activity and inflation, that is limited to the short run. The level at which inflation settles in the long run is determined entirely by the target rate of inflation even though the path by which inflation achieves this target rate implies a particular level of cumulated output loss or gain. From low levels in the 1960s, Colombian inflation increased and became stuck at a higher levels by 1973. For the near future, the goal is to make it return to and settle at a lower rate, reflecting the consensus view that as monetary policy cannot stimulate economic activity in the long run, it can hence at best aim for a low and stable inflation rate (Mishkin, 2000).

In the long run, the price level is determined by wages and imported costs with coefficients that sum up to one.[9] Static homogeneity, by which the price equation is neutral in nominal variables, means that the long-run values of real variables are independent of shocks that shift the price level permanently but affect the rate of inflation only temporarily.

We estimate regressions with all available data since 1983. The long-run restrictions were comfortably satisfied but the coefficient estimates only narrowly accept the dynamic homogeneity property in this full data set.[10] One reason could be that during the 1990s, the shift to more flexible exchange rates may have altered the dynamics of inflation. We decided then to restrict ourselves to regression estimates using 1990s data where dynamic homogeneity is accepted.

3.2 Aggregate demand

[7] In this as well as in the next estimated equations, the lag structure was chosen so that the lags were statistically significant and the impulse response functions well behaved.

[8] Chadha, Masson, and Meredith (1992) show how the cost of disinflations is decreasing in the weight on future inflation.

[9] Cointegration tests indicate that the CPI, import prices, nominal wages and a time trend are cointegrated.

[10] As inflation is measured at an annual rate, to make the coefficients comparable to coefficients of Phillips curves estimated with quarterly inflation, the coefficient on the gap should be divided by four.

3.2.1 Estimation

The estimates of the equation determining aggregate output, the IS curve, are

$$y_t = \underset{(0.490)}{1.055} + \underset{(0.140)}{0.464}\, y_{t-1} + \underset{(0.140)}{0.422}\, y_{t-2} - \underset{(0.057)}{0.185}\, r_{t-1} + \underset{(0.053)}{0.029}\, q_{t-1} + \underset{(0.030)}{0.090}\, \tau_t + \varepsilon_t^y \; ^{11} \quad (2)$$

$$r_t \equiv i_t - \pi_t \quad (3)$$

3.2.2 Definitions

y_t is the output gap, r_t is the annualised real interest rate and i_t is the annualised nominal interest rate, measured on the 90 day Certificates of Term Deposits (DTF). τ_t is the deviation of terms of trade from its HP filtered value; defined as $\tau_t = 100(\log \tau_t^{NHP} - \log \tau_t^{HP})$, where $\tau_t^{NHP} = P_t^X / P_t^M$, and P_t^X and P_t^M are the producer price indices of exports and imports respectively. The sample period is 1990Q1-2000Q3.

3.2.3 Results

Our unrestricted estimates of the IS curve implied that the sum of the estimated coefficients on lagged output (persistence) was greater than one; which would mean that aggregate demand would not converge following temporary shocks to the real interest rate. Hence it was necessary to impose the coefficient value on lagged output that Goméz and Julio (2000) calculated (0.88).

In theory, Equation (2) could have an endogeneity problem since interest rate would be endogenous to the output gap. However, as explained in the introduction during the eighties and nineties interest rates increased and decreased with capital outflows and inflows and also to defend the exchange rate. There could only be an endogeneity problem since September 1999 when the inflation targeting framework was adopted and specially since the second half of 2001 when interest rates were decreased on the basis of an inflation targeting model. But this possibility is out of the estimation range.

We attempted to include the US output gap in the equation but it was not significant on the past data set. In the model as it stands, we would have to incorporate the effect of the recent shift in US economic activity on the Colombian business cycle by residual adjustment.

The real interest rate is defined on past inflation instead of expected inflation. The reason is that the series available for inflation expectations is very short. The few data available, however, do show that expectations are mainly backward looking since they are basicaly explained by observed inflation. Hence it appears more convenient to define the real interest rate on the basis of observed inflation.

[11] The estimation method is restricted OLS. The sample period is 1990Q1- 2000Q3. R^2=0.777.The standard error of residuals 1.363 and the p-value Lung Box Q statistic: 0.458.

3.3 Wages

3.3.1 Estimation

Our estimates of the wage equation were as follows:

$$w = -\underset{(8.898)}{22.308} + \underset{(0.136)}{0.309}\, w_{t-1} + \underset{(0.131)}{0.528}(y_t - y_{t-1}) - \underset{(0.066)}{0.161}(y_{t-2} - y_{t-3})$$
$$- \underset{(0.066)}{0.161}(y_{t-2} - y_{t-3}) - \underset{(0.066)}{0.161}(\log W_{t-4} - 0.6\log(Y_{t-4}/L_{t-4}))^{12} \quad (4)$$

3.3.2 Definitions

w_t is the annual growth rate of real wages, $w_t = 100(W_t - W_{t-4})$. W_t is the real wage, calculated as the geometric average of retail trade and industrial sectors and L_t is the level of employment (of the seven main cities). Sample period 1990Q1-1999Q3.

3.3.3 Results

The wage equation is estimated for real wages and nominal wages are obtained from this by identity. This implies that nominal wages follow the same pattern of persistence as prices. An alternative strategy would be to allow for nominal shocks to affect real wages by estimating a behavioural equation for nominal wages and deriving real wages as an identity, as in Gómez (2000b).

3.4 Interest rate rule

In the model the interest rate sets interest rate to affect expected future inflation, equation (5) with the forecast horizon set at one year, k=4. This a only a rough approximation of the policy horizon of decisions by the Board of Directors. The optimal targeting horizon as well as the optimal weights on influences in the forecast rule should depend on the source of the inflation and output disturbance. In particular not all decisions should be made with a one-year horizon, and indeed in one of our experiments, we used a two-year horizon, k=8. The forecast rule could in principle allow for interest-rate smoothing, via the smoothing parameter φ. But given the history of large changes to the interest rates in Colombia, this was set equal to zero.

$$i_t^P = \phi i_{t-1}^P + (1-\phi)(\bar{r} + \pi_t) + 0.5(\pi_{t+k|t} - \pi_{t+k}^*) \quad (5)$$

[12] The estimation method is OLS. The sample period is 1990Q1 to 1999Q3. R^2=0.680.The standard error of residuals is 2.133 and the p-value of significance of Ljung Box Q statistic is 0.362.

3.5 Uncovered interest parity

Equation (6) is the uncovered interest rate parity relationship, expressed in terms of the real interest rate;

$$q_t = q_{t+1|t} - 0.25(i_t - \pi_{t+1|t} - \varphi_t - r^*_{t+1|t}) \quad (6)$$

The real exchange rate is forward-looking. Hence we can derive model-consistent solutions for the path of real exchange rates and interest rate differentials that depend in part on the risk premium path and a terminal exchange rate. The latter is the expected value of the real exchange rate at the terminal date and in our case set equal to productivity differentials.

We have defined the real exchange rate as imported goods prices relative to the aggregate CPI level, $q_t = P_t^M / P_t$, as in McCallum (2000). This definition is one among many alternative measures of the relationship between the prices of traded and non-traded goods. We use this definition because it is statistically significant in the price equation and because it enables us to transparently separate the first and second stages of the exchange rate pass-through.

An alternative real exchange rate measure could be derived from defining the price of traded goods as a linear combination of the prices of imports and exports, as in Mundlak, Cavallo and Domenech (1990), and García and Montes (1988). From García and Montes (opcit) it can be inferred that the weight of the price of imports in the traded goods price basket is as large as 80%.[13] Our assumption that all the weight belongs to the import price does not seem to be too out of line with these estimates.[14]

3.6 Foreign real interest rate

For forecasting purposes, future foreign real interest rates can be calculated from data on futures markets, but in a model for simulations, we can postulate a simple autoregressive form for the foreign real rate process. This rule can be adjusted to link foreign real rates to foreign shocks. Our rule was estimated to be

$$r^*_{t+1} = \underset{(0.530)}{2.152} + \underset{(0.082)}{0.622}\, r^*_t + \varepsilon^{r^*}_{t+1} \quad ^{15} \quad (7)$$

[13] See García and Montes (opcit) page 41 .

[14] Another definition of the price of traded goods is a linear combination of the price levels of the main trading partners as in Sjaastad (1998). This is one of the definitions of the Index of Real Exchange Rate (ITCR) that are calculated at the Banco de la República.

[15] The estimation method is OLS. The sample period is 1982Q1-1999Q4. R^2=0.453.The standard error of the residuals is 1.669 and the p-value significance of Ljung Box Q statistic is 0.083.

where r_t^* is the annualised expected foreign real interest rate, $r_{t+1}^* \equiv i_t^* - \pi_{t+1}^*$ and i_t^* is the foreign annualised rate on bonds of three-month maturity. The sample period is 1982Q1-1999Q4.

3.7 Risk premium

Equation (8) illustrates the evolution of the risk premium (φ_t) as an autoregressive process, calibrated to Svensson's (2000) parameters:

$$\varphi_{t+1} = 0.065 + 0.8(\varphi_t - 0.065) + \varepsilon_{t+1}^{\varphi} \quad (8)$$

3.8 Terms of trade

Equation (9) is simulates the evolution of the HP filtered log-level of the terms of trade, also as an autoregressive process[16]

$$\tau_t = \underset{(0.148)}{0.864}\tau_{t-1} - \underset{(0.178)}{0.460}\tau_{t-2} + \underset{(0.159)}{0.365}\tau_{t-3} - \underset{(0.121)}{0.341}\tau_{t-4} + \varepsilon_t^{\tau} \;^{17} \quad (9)$$

3.9 Pass-through

3.9.1 Calibration

The pass-through equation allows for partial adjustment for inflation of import prices (measured in domestic currency) in response to nominal exchange rate depreciation:

$$\pi_t^M = \gamma \pi_{t-1}^M + (1-\gamma)\varepsilon_t \quad (10)$$

where γ=0.3.

3.9.2 Definitions

[16] The sample period is 1990Q1-2000Q1.
[17] The estimation method is OLS. The sample: 1990Q1-2000Q1. R^2=0.850.The standard error of the residuals is 4.850 and the p-value of the significance of the Ljung Box Q statistic is 0.339.

π_t^M is inflation of import prices in domestic currency, defined as $\pi_t^M = 100(\log P_t^M - \log P_{t-4}^M)$. ε_t is the annual rate of nominal depreciation, defined as $\varepsilon_t = 100(\log E_t - \log E_{t-4})$ where E_t is the nominal exchange rate level.

3.9.3 Results

The final form for the equation (10) was derived by testing down from a more general version where the current depreciation rate, three lags of depreciation and four lags of the inflation of import prices were all included as explanatory variables. The coefficients on these explanatory terms were restricted to sum to one, so that dynamic homogeneity holds. Insignificant lags were then gradually deleted and at each step a simulation of a permanent shift in the inflation target using that particular equation was carried out in the model. The specifications with implausible dynamics were rejected, leaving us with a final regression where the explanatory variables were only lagged import price inflation and the current depreciation rate, equation (10).

3.10 The interest rate and the policy rate

3.10.1 Estimation

The estimated equation is[18]

$$
\begin{aligned}
i_t - i_{t-1} &= \underset{(0.077)}{0.380}(i_{t-1} - i_{t-2}) - \underset{(0.069)}{0.162}(i_{t-2} - i_{t-3}) + \underset{(0.063)}{0.120}(i_{t-3} - i_{t-4}) \\
&\quad + \underset{(0.014)}{0.169} i_t^P - \underset{(0.021)}{0.144}(i_{t-1} - 1.064 i_{t-1}^P) \qquad (11)
\end{aligned}
$$

3.10.2 Definitions

i_t^P is the policy rate, the annualised interbank interest rate (TIB).

3.10.3 Results

Econometric tests reveal that the deposit interest rate and the policy rate are cointegrated and that the policy rate is weakly exogenous to the estimate of the long-run coefficients on post-1990 data. That the policy rate is weakly exogenous in this sample is plausible because, after the 1990s, policy rates were less directed at offsetting risk premia (which would have destabilised both market rates and the exchange rate) and rather more at stabilising future inflation. As the

[18] The estimation method is OLS. The sample period is 1990M1-2000M7. R^2=0.613.The standard error of the residuals is 1.049 and the significance of Ljung Box Q statistic is 0.099.

policy rate is weakly exogenous, this does not rule out that we can estimate the above equation consistently by OLS. We use monthly data because we believe there is much information in movements that die out after a quarter.

A one percentage point increase in the policy rate results in the following increases in the deposit interest rate: 0.169 in the first month, 0.511 in the third month, 0.829 in the sixth month, 1.035 in the twelfth month and 1.064 since the second year.

4 Comparison with other estimates

It is interesting to compare our findings with those for the US of Rudebusch and Svensson (1998). Their estimates of the Phillips curve and aggregate demand relationship are

$$\pi_t = \underset{(0.08)}{0.70} - \underset{(0.10)}{0.10}\pi_{t-2} + \underset{(0.10)}{0.28}\pi_{t-3} + \underset{(0.08)}{0.12}\pi_{t-4} + \underset{(0.03)}{0.14}y_t + \varepsilon_t^{\pi} \quad (12)$$

and

$$y_t = \underset{(0.08)}{1.16}y_{t-1} - \underset{(0.08)}{0.25}y_{t-2}\,\underset{(0.03)}{0.10}r_{t-1} + \varepsilon_t^{y} \quad (13)$$

The coefficient for the interest rate is also comparable across their and our equations since both interest rates are defined in annual terms. The estimate of -0.185 for the short-run effect of real interest rates on output in Colombia is larger in absolute size than Rudebusch and Svensson's estimate of -0.10 for the US. The long-run semi-interest rate elasticities are ((-0.185)/(1-0.464-0.422))=-1.622 and ((-0.10)/(1-1.16+0.25))=-1.11 for Colombia and the US, respectively. The multipliers suggest that the real interest rate effect on inflation via the aggregate demand channel is strong in Colombia, and stronger than one would expect for a relatively open economy.[19]

5 Simulating the transmission of shocks

Having outlined our model and described our econometric estimates, we now model the effect of some key shocks on Colombian output and inflation. In the Banco de la República's Inflation Report, the Board of Directors periodically publishes its views on the shocks affecting the economy and how they will affect inflation. We have chosen to model some of the important shocks that feature in this discussion.[20]

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[19] The share of imports in GDP is 20.8% in Colombia, compared to 13.5% in the US.

[20] Of course there are many other types of shock to the economy that are not fully and explicitly treated in the core model. Satellite models may help us to understand the effect of these shocks on inflation and may suggest how the aggregate model can be adjusted.

5.1 Permanent shift in the inflation target

As soon as the inflation target is decreased, nominal interest rates are raised permanently. The increase in interest rates leads immediately to a faster nominal exchange rate appreciation. That appreciation passes very quickly, although not immediately, to lower the rate of inflation in the price of imports. Acting through the exchange rate channel, one quarter after the shock, inflation decreases. This effect of the direct exchange rate channel on inflation is, however, small.

Not only nominal but also real interest rates increase on impact. The real rate remains positive for ten quarters. This creates a recession that lasts for several years reaching a trough in the seventh quarter. From the fourth quarter onwards, the aggregate demand channel kicks in to accelerate the disinflation process. Inflation decreases 75 basis points by 10 quarters and 95 basis points by 13 quarters (Figure 10). The sacrifice ratio, or the cumulative loss of output per unit of annual inflation reduced, is 0.786.

The lowest chart on the righthandside of Figure 11 compares the responses of two measures of the real exchange rate (RER). The measure that uses the domestic currency price of imports calculated with equation (10) demonstrates a sluggish pass-through. An immediate pass-through if it were assumed instead that $\pi_t = \varepsilon_t$, that is, that the inflation of import prices is equal to the rate of depreciation. It is evident that there is not much difference between the responses of the two exchange rates.

5.2 A supply shock in the agricultural sector

Disturbances to relative food prices make inflation volatile (Figure 11). Food items are a small share of GDP but a fairly large share of CPI. As in the model, monetary policy often has to respond, at least to the second-round effect of the shocks on inflation. The extra real interest rate volatility adds some extra variability to real variables over and above those directly associated with the change in the agricultural sector's production conditions.

5.3 A shock to the terms of trade

More favourable relative prices boost the demand for exporting sectors' outputs. But in our simulations we assume that potential output is slow to adjust and hence that there is an increase in the output gap. That increase in the output gap increases inflation to some extent, precipitating an interest rate increase. Acting through all transmission channels, monetary policy dampens aggregate inflation. The direct exchange rate channel contributes with its immediate but small effect, and the aggregate demand channel with its lagged and strong effect (Figure 12). The lower lefthandside chart compares the real exchange rate calculated with sluggish and immediate pass-through, again showing no difference.

5.4 A shock to the exchange rate risk premium

As investors demand a higher return on Colombian assets, the nominal and real exchange rates depreciate on impact. Real exchange rate depreciation leads directly to inflation. Interest rates are raised to combat future inflationary pressures, rather than to defend an exchange rate. Although trade improves on impact, eventually the higher real interest rates cause a real exchange rate appreciation and a recession. Both outcomes act to move inflation back to target (Figure 13).

6 Disinflation and the sacrifice ratio

The sacrifice ratio has mostly simply been defined in the literature as $1/\alpha_y$. A more intuitive measure would be the outcome of an experiment where we simulate a permanent one percentage point decrease in the inflation target in our model. The sacrifice ratio is calculated as the cumulated loss in the output gap per unit rate of annual inflation reduced. Using the estimated coefficient $\alpha_y = 0.289$, we estimate a sacrifice ratio of 0.786 for Colombia.[21] The estimate of α_y is associated with a 95% confidence interval (0.114, 0.464). The low end of the confidence interval, 0.114, implies a sacrifice ratio of 1.785, while the high end of the interval, 0.464, implies a sacrifice ratio of 0.500.

Figure 14 compares the cost of disinflation for two price equations. Simulations with our estimated price equation (with a weight of 0.3 on forward-looking versus backward-looking inflation) are described by the solid lines. The dotted lines describe the responses from the forward-looking calibrated version (with a weight of 0.5 on forward-looking versus backward-looking inflation). The sacrifice ratio decreases from 0.786 to 0.322.

Estimates of the sacrifice ratio are uncertain and we should be cautious in placing too much emphasis on these findings. But it does seem plausible that further disinflation will be costly. Inflation in 1999 was around 9%. Using our estimate of α_{y}, this model indicates that if inflation were taken down from 9% to 2%, the 7 percentage points disinflation would incur a cost of 5.6% of output loss in 1992 (2.2% with the calibrated more forward-looking price equation).

The policy implication is that the cost of disinflation can be reduced by using forward looking arguments in the setting of administered prices, the minimum wage, and public wages.

7 Conclusion

Despite large and frequent changes in the monetary policy stance, Colombia has experienced a long history of moderate inflation. Monetary policy has pursued targets for money, and the exchange rate, and short-term targets for interest rates. The temporary defence of the exchange rate, supporting exporters' and borrowers' short-term interests, led to large expansions and contractions in the real interest rate. During the 1990s, the exchange rate policy gradually became more directed at stabilising inflation. The consequence was a historically unprecedented disinflation in 1999 with current plans for future decreases in inflation targets.

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[21] This sacrifice ratio lies within the interval (0.0, 3.6) found by Ball (1994) for a sample of 28 disinflation episodes in nine countries.

To explain this disinflation, our model estimates identifies three key aspects of the Colombian transmission mechanism: an inflation process that it is persistent; a strong aggregate demand channel and relatively weak and indirect exchange rate effect.

We showed how the model can describe plausible responses to shocks that are particular to Colombia: a permanent shift in the inflation target, a temporary surprise monetary policy action, a supply disturbance in the agricultural sector, a change in the terms of trade, and a shift in the risk premium.

We found that monetary policy has a greater effect on inflation when inflation is dominated by forward-looking elements. More inertia in inflation rates, on the contrary, imposes higher demands on monetary policy.

This model's estimate of the cost of disinflation, as measured by the sacrifice ratio, is -0.788, although ratios between -0.500 and -0.786 are also plausible.

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Figure 1. Decreasing emphasis in exchange rate targets

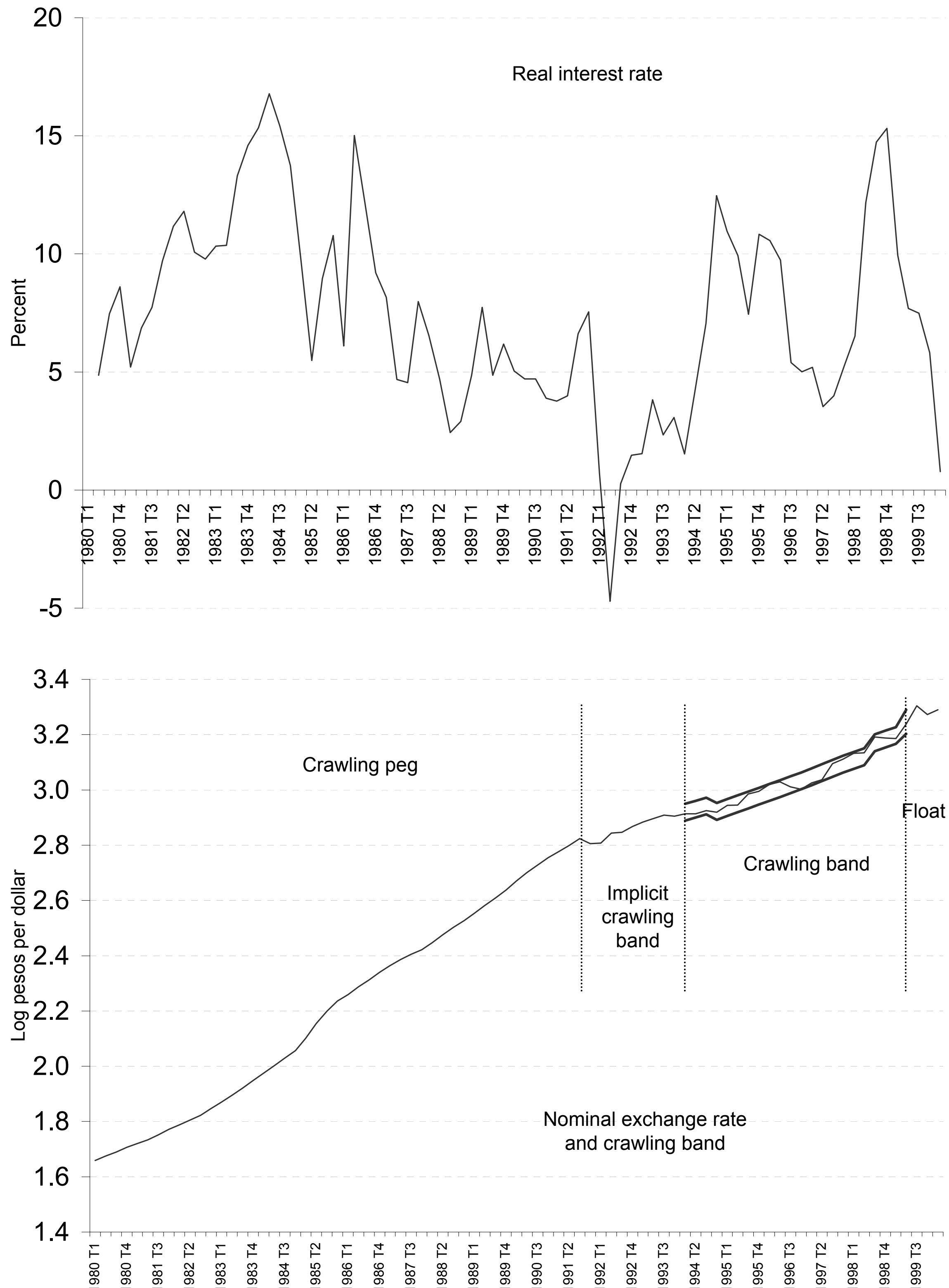

Figure 2. Inflation in Colombia

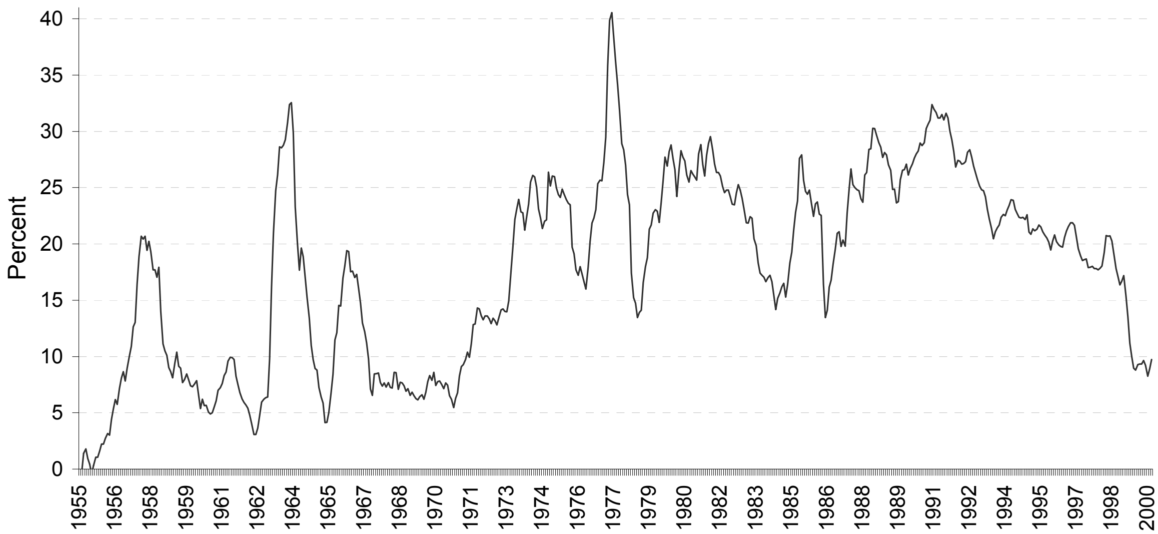

Figure 3. Monetary policy, economic activity and inflation

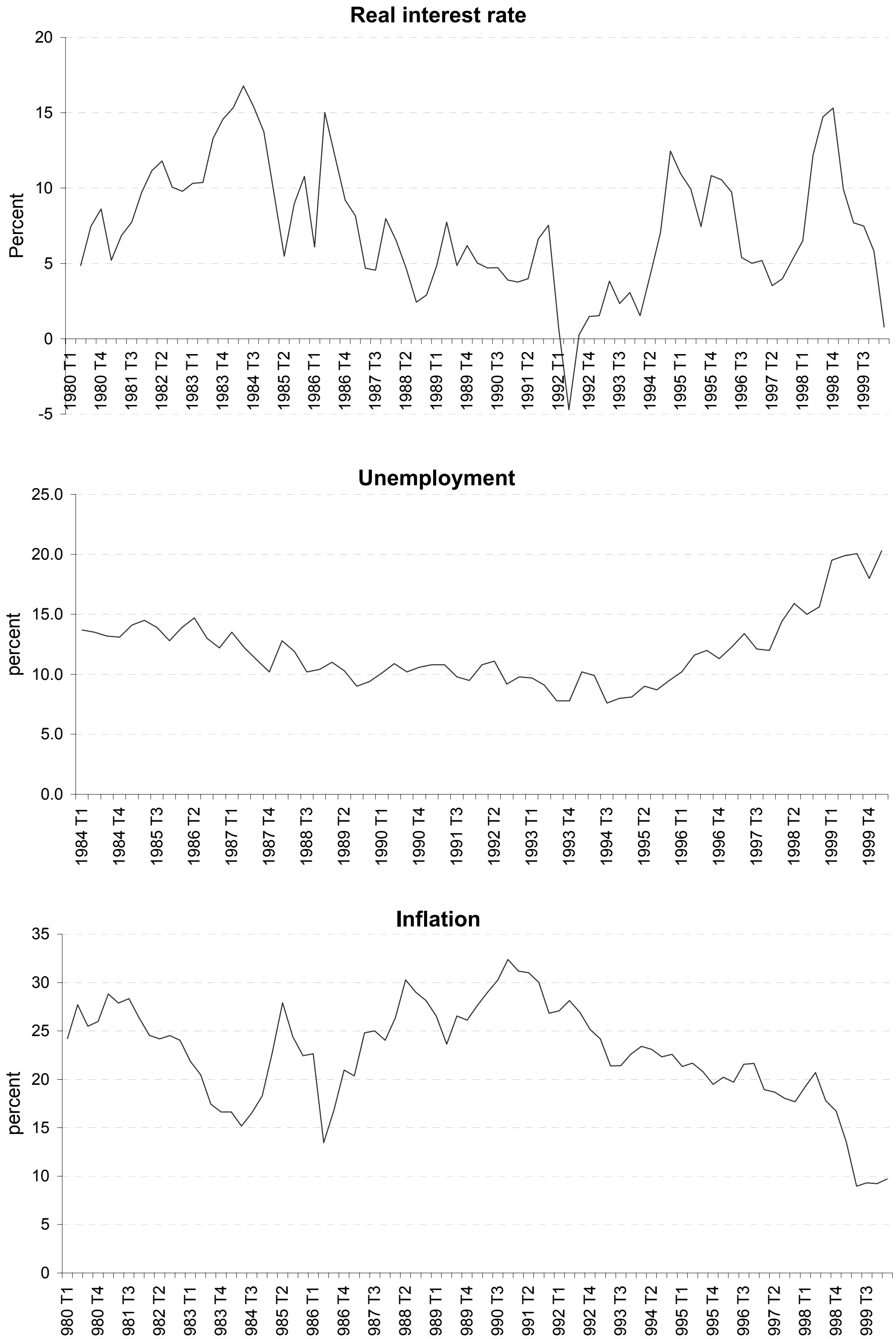

Figure 4. Nominal depreciation, inflation of the domestic price of imports and CPI inflation

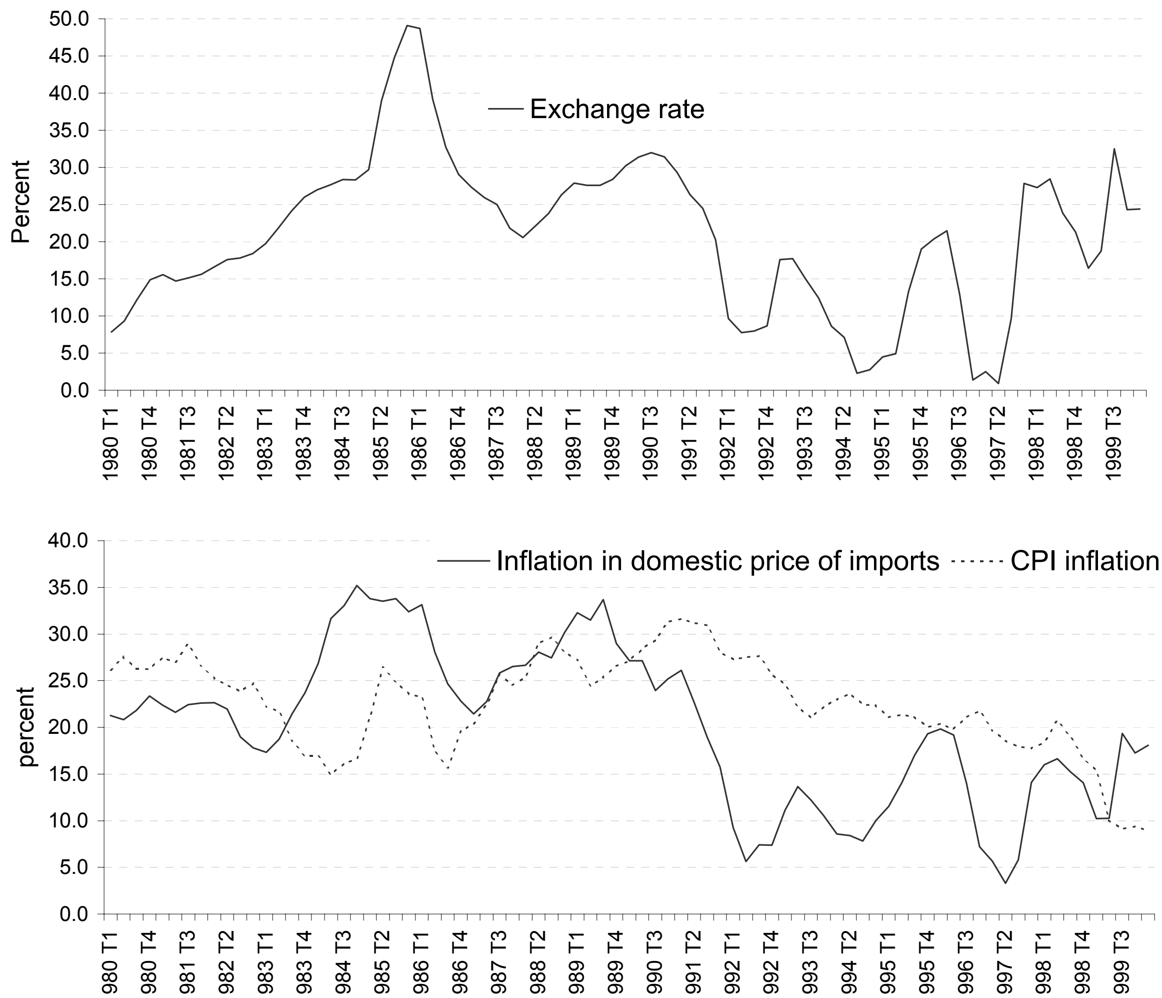

Figure 5. A permanent shift in the inflation target

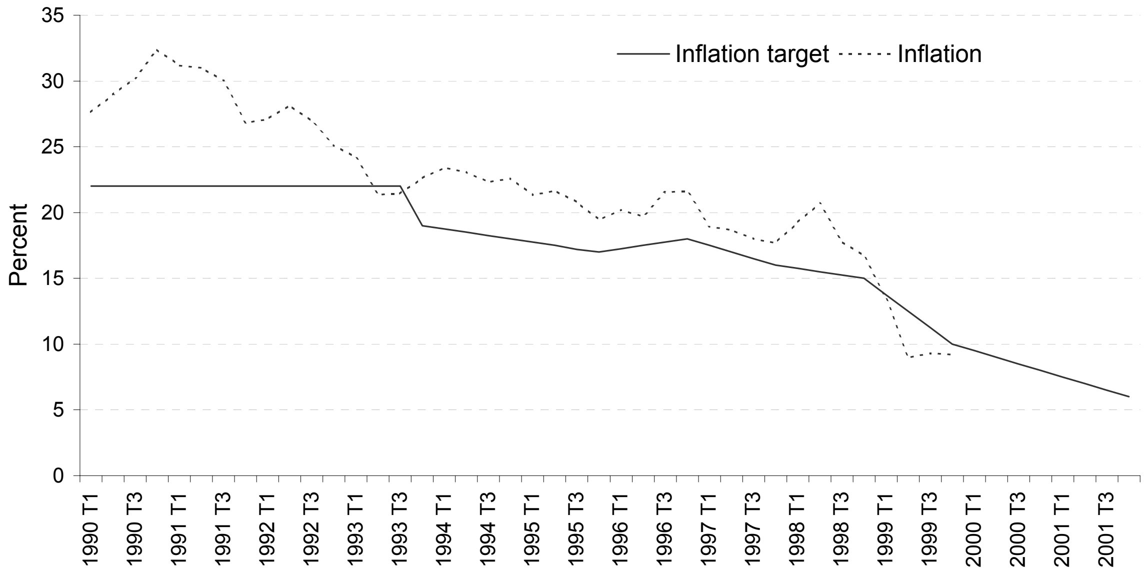

Figure 6. Supply shocks in agriculture

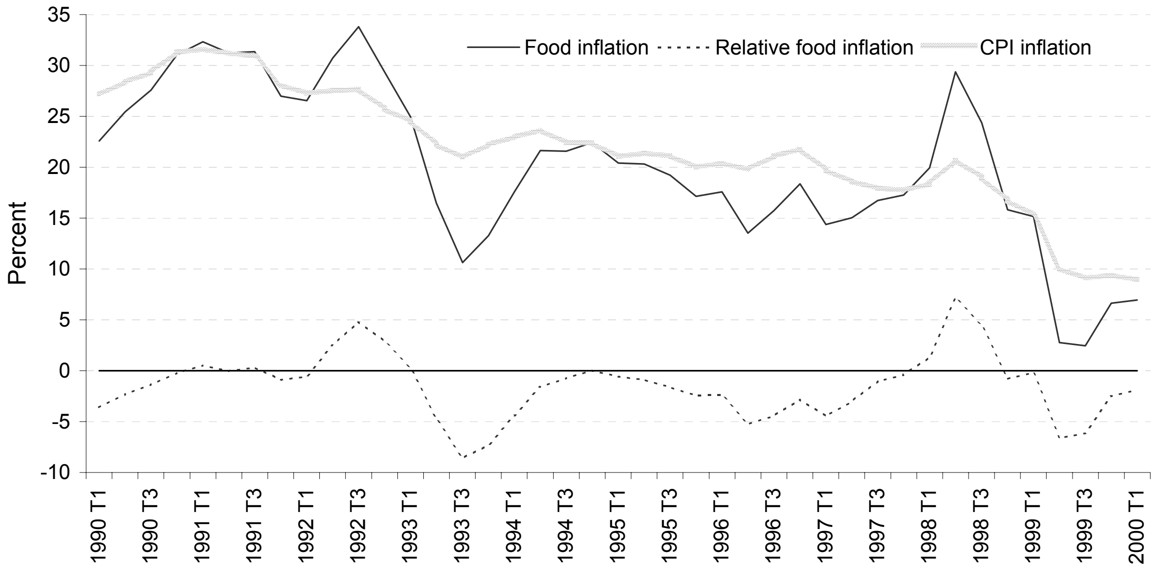

Figure 7. Shocks to the terms of trade

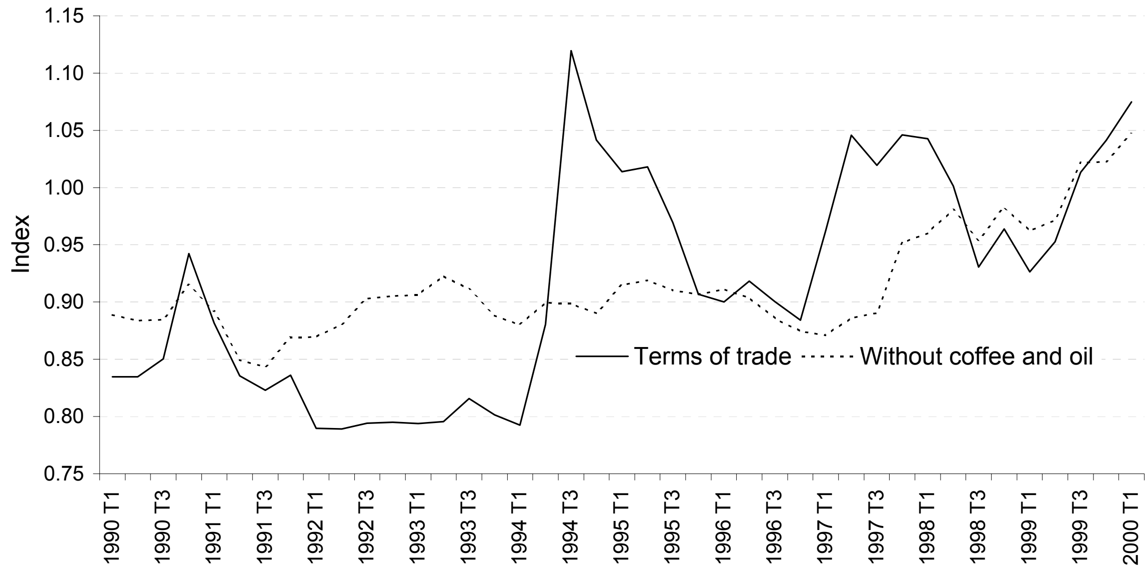

Figure 8. EMBI spread

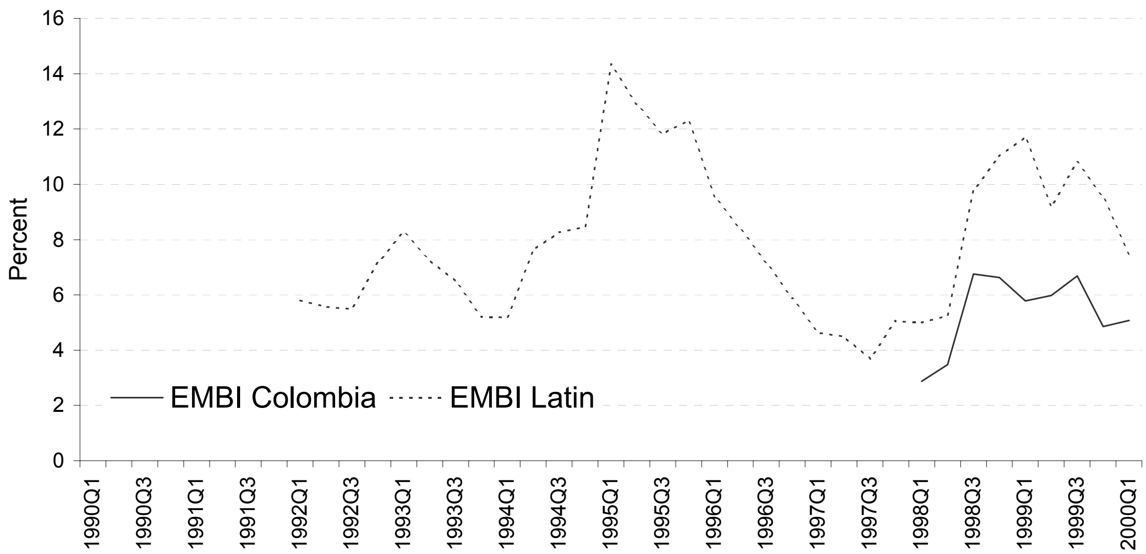

Figure 9. Flow chart of the transmission
mechanisms of monetary policy

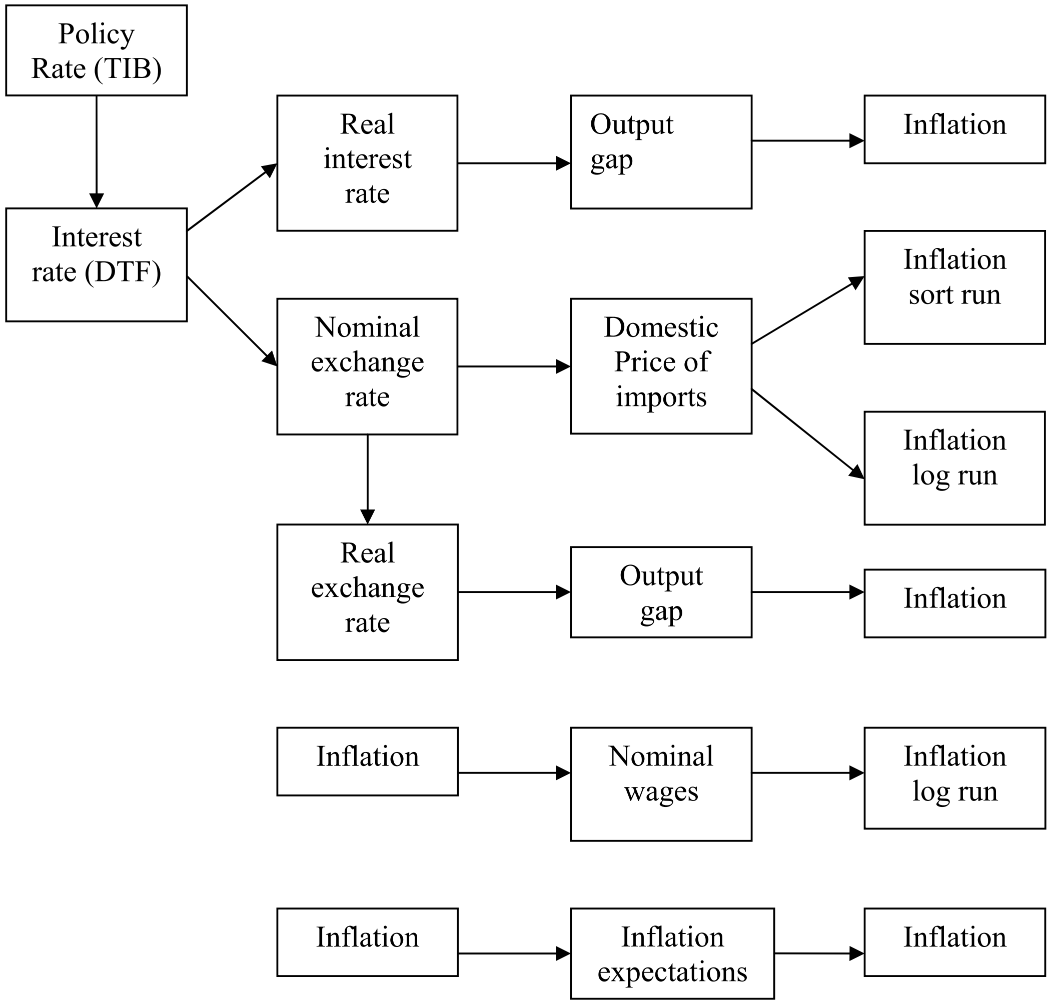

Figure 10. A permanent shift in the inflation target
(Percent deviation from the steady state)

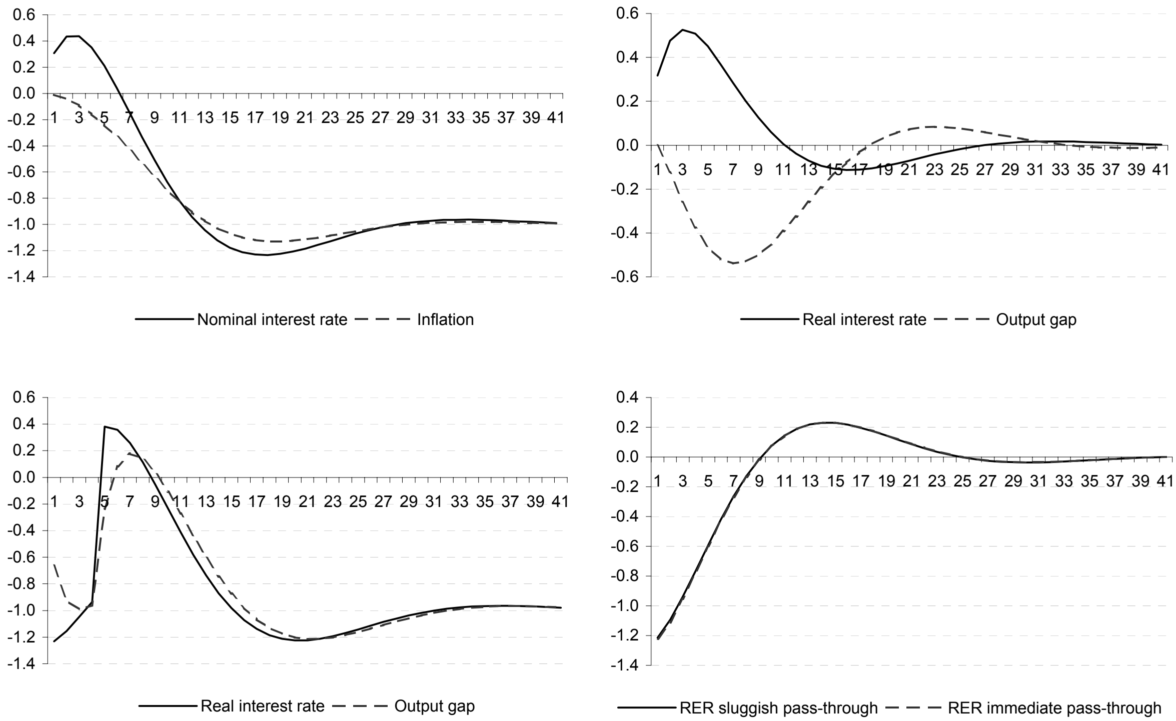

Figure 11. A supply shock in the agricultural sector
(Percent deviation from the steady state)

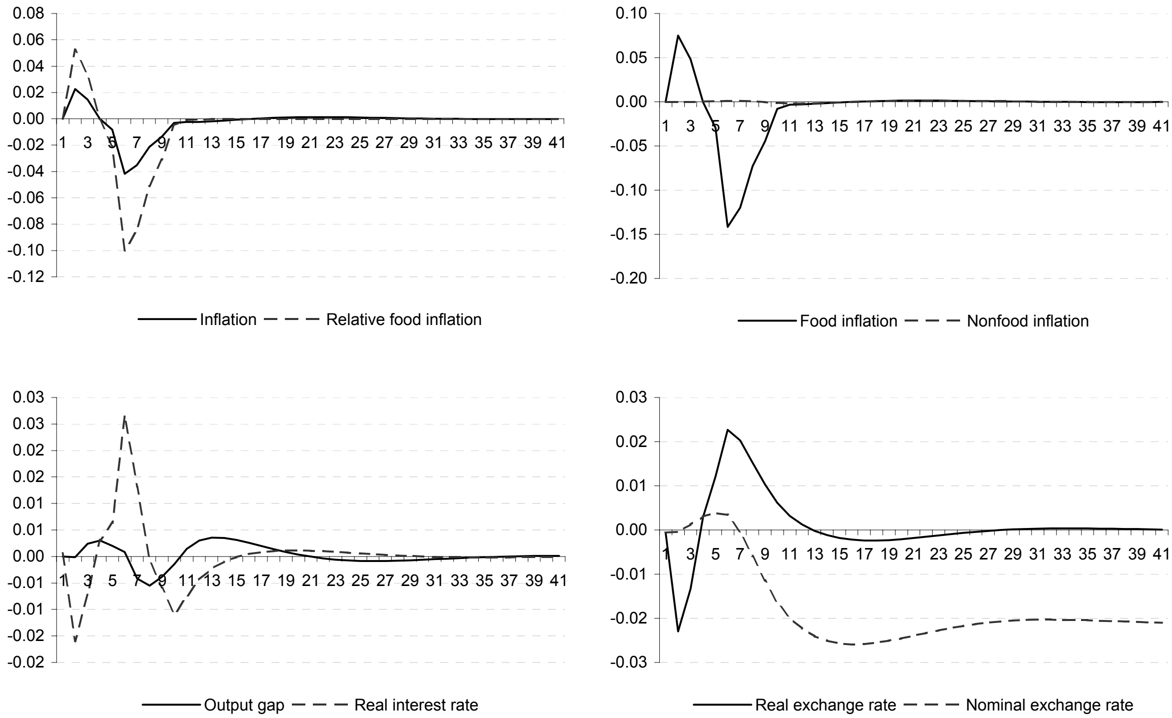

Figure 12. A shock to the terms of trade
(Percent deviation from the steady state)

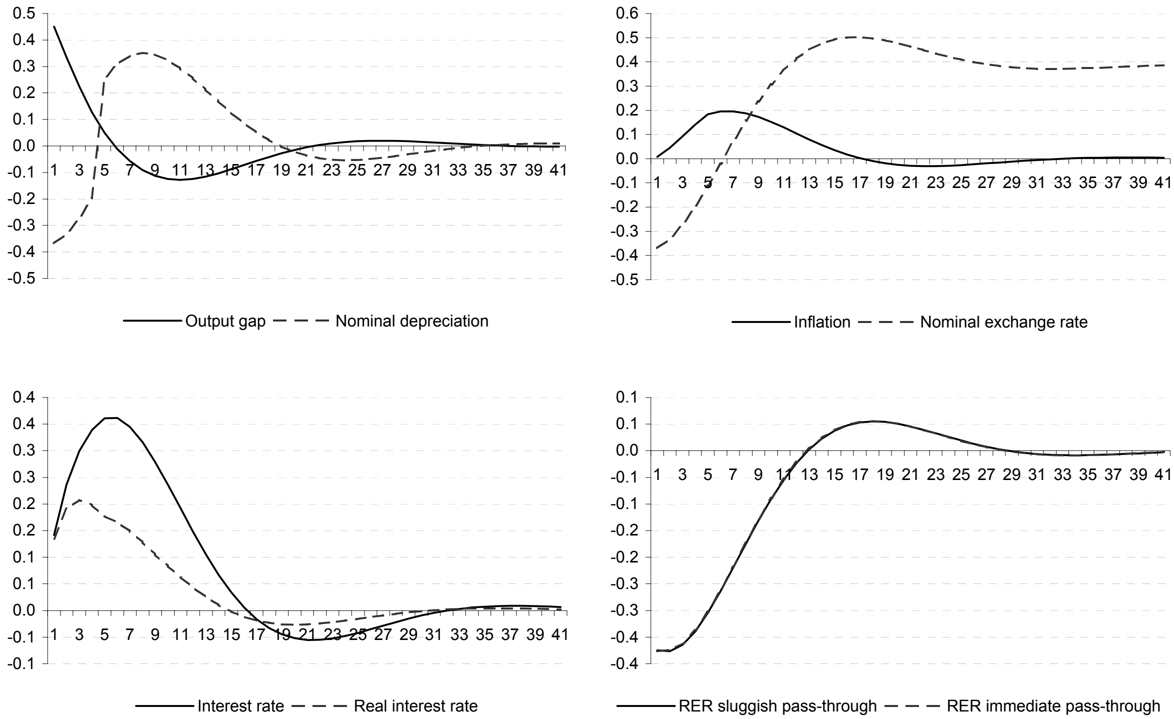

Figure 13. A shock to the risk premium
(Percent deviation from the steady state)

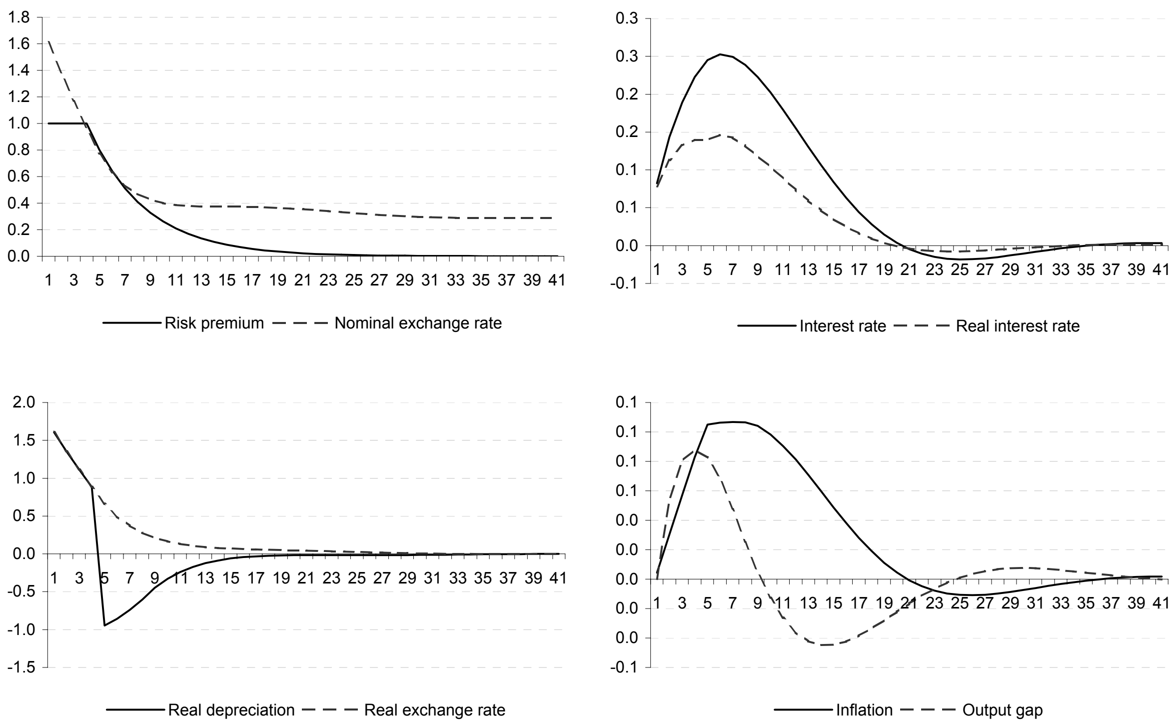

Figure 14. Disinflation and the sacrifice ratio
for different levels of inflation stickiness.
(Percent deviation from the steady state)