The Implementation of Inflation Targeting in Colombia

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1 Background

Explicit inflation targets have existed in Colombia since the early nineties[1] . The Colombian authorities announced a quantitative inflation target for the first time in 1991. The announcement was made by the Minister of Finance, at a time when there was no clear distinction between the tasks of the central bank and those of the government with respect to macroeconomic management, nor there was any autonomy in the design and execution of monetary policy.

In 1991, a new Constitution assigned the design and conduct of monetary, exchange, and credit policies exclusively to the Board of Directors of Banco de la República and made the central bank independent from the central government. According to the Constitution, "The State, through Banco de la República must preserve the purchasing power of currency". In addition

[1]This section is based on (Uribe et al., 1999).

to the constitutional mandate, in 1992 the Central Bank Law stated that the Board of Directors must announce each year a quantitative inflation target.

The reduction of inflation in Colombia has faced several hurdles. To begin, the introduction of explicit inflation targets in Colombia had two special features. First, unlike other countries, the inflation target was not initially announced as part of a policy framework to achieve price stability. Second, there was a marked deviation between observed inflation and the first announced target. Thus, inflation targeting in Colombia started with low credibility and confusion about its nature and operational meaning.

Throughout the period of inflation targeting there has been an expansive fiscal policy. NFPS expenditure rose from 24.4% in 1990 of GDP to 34.8% in 2000. This increase has been financed with tax hikes, privatization revenues and a large build-up of domestic and external public debt. Even though there has not been direct loans from the central bank to finance the public deficit, the fiscal stance has conditioned the execution, credibility and results of monetary policy. When foreign finance was abundant, fiscal policy implied pressures toward a real appreciation of the currency in a country characterized by a strong lobby for depreciation. When foreign finance was scarce, the fiscal stance forced the adjustment of the external deficit on the private sector.

In addition, it must be remembered that Colombia began targeting inflation after more than twenty years of moderate inflation. Between 1972 and 1992 the inflation rate hovered around the 22-23% level and Colombians were able to live with this inflation through the informal or formal indexation of wages, taxes, mortgages and the prices of some financial assets.

Low credibility and widespread backward-looking indexation are known to increase the short-run costs of disinflation. Furthermore, in a context of widespread indexation and a long history of moderate inflation, society has been particularly reluctant to accept the short-run costs of disinflation. Hence, there has been no strong political and public support for inflation reduction.

In fact, inflation has fallen gradually and only after 1997 it was at or below the announced targets (Figure 1). The process of disinflation has taken place over a complete business cycle (Figure 1), starting in 1990 when CPI inflation was 30% and continuing today with inflation levels close to the 8% target for 2001, in the midst of a slow recovery from the first output contraction in decades. In the early years of this period, inflation reduction was accompanied by a real appreciation of the currency (Figure 1). However, the sharpest drop in inflation occurred between 1998 and 1999, when it fell from 16.7% to 9.3% and, at the same time, output declined by 4.2%.

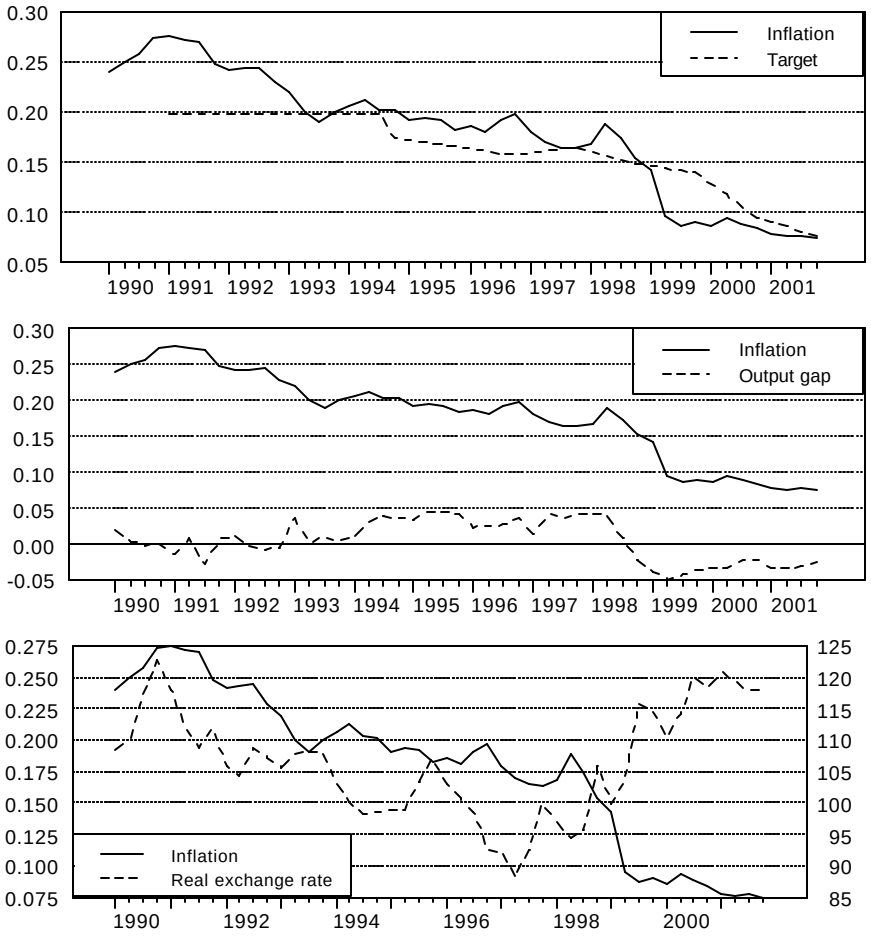


Figure 1: Inflation, inflation targets, economic activity and the real exchange rate

2 The Monetary Policy Strategy in Colombia

Between 1992 and 1999 monetary policy was conducted on the basis of an intermediate monetary target and a crawling band for the exchange rate. The inflation target was used to compute the slope of the exchange rate band and the growth rate of the expected path for M1 or the monetary base. This framework was set up on the grounds of a relatively stable money demand in Colombia and after decades of a crawling peg regime. It was believed that the width of the band (± 7 per cent for most of the period) would allow the exchange rate to absorb most of the shocks to the foreign exchange market and would minimize the conflict between the monetary and exchange rate targets. At any rate, at some point it was announced that, in case of conflict, the highest priority would be given to the monetary targets. In reality, the targets for the monetary aggregates were missed or changed on several occasions, while the exchange rate band was appreciated once in late 1994, and devalued twice between 1998 and 1999, following the Russian crisis and the loss of credibility of fiscal and monetary policy.

The first elements of an inflation targeting strategy, beside the targets themselves, were introduced in 1995, when several models for forecasting inflation were developed and a monthly internal Inflation Report started to be produced. In December 1998 the Inflation Report began to be published quarterly. With time, the Report acquired growing importance in the decision-making process of the Board of Directors.

In September 1999 the currency was allowed to float following a significant real depreciation within the bands system. Structural reforms had already taken place: the current account deficits had been stabilized; the financial system had been strengthened and Colombia had entered a program with the IMF that aimed to correct structural problems with public finances. Shortly after this change was introduced, a clear set of rules for central bank intervention was set up and announced, so that the floating regime could be as "clean" as possible. The move to a floating regime simplified the monetary policy strategy, allowing the central bank to concentrate on inflation targeting.

Thus, at that point, three out of four basic requirements of inflation targeting (Masson, Savastano and Sharma (1997)) were present in Colombia: the first one, an explicit inflation target; the second one, priority of the inflation target over any other objective of monetary policy, and the third one, the existence of at least instrument independence for the central bank. A fourth requirement, namely technical ability to predict inflation reasonably and to understand the transmission mechanisms of monetary policy, had plenty of room for improvement at the time. In fact, the gap between the inflation target in 1999 (15%) and the actual figure for that year (9.3%) is

very telling about the difficulties facing those in charge of forecasting inflation and developing knowledge about the transmission channels. In the case of Colombia, the long history of moderate inflation and the recent experience with disinflation made any statistical modeling of these channels a very hard task.

At the same time, some evidence kept pointing to the fact that monetary aggregates (particularly narrow aggregates) exhibited stable long run relationships with prices and output. Recent evidence seems to confirm that assessment. For example, as documented by Julio (2001), there is a cointegrating relationship between prices, output and the monetary base in a VEC system. In these relationship no variable is excluded, prices are found to be weakly endogenous and the monetary base weakly exogenous. However the monetary base explains only a small fraction of the variability of prices, as reflected by the impulse-response function and the variance decomposition exercise. Another study by Otero and Ramírez (2001) follows the methodology employed by Surrey (1989) and Joselius (1992) in order to determine the importance of monetary, external and labor market factors in explaining inflation in Colombia. They found that monetary disequilibrium and excess demand variables are the most important explanatory variables (after the auto-regressive terms) in the inflation equations for the 1980-2000 period.

Hence, by 1999 when the exchange rate started to float, the central bank staff and the Board of Directors found themselves in a situation in which the inflation forecasting ability and the knowledge of the transmission mechanisms of monetary policy were not very reliable, while a stable relationship between money, output and prices seemed to persist. Then, the Board of Directors of Banco de la República decided to follow a strategy of "transition" toward inflation targeting. According to this strategy, shifts in the stance of monetary policy will be triggered either by clear signals about increased probability of missing the inflation target coming from the Inflation Report (particularly from the forecast models), or by significant deviations of the monetary base from its "reference line". The latter is a path for the monetary base constructed on the basis of the inflation target and estimated to be compatible with the achievement of that target, once the lagged effects of past monetary behavior are taken into account. It was also announced that if the monetary base deviated from its reference line and the Board of Directors did not take any action, the reasons will be clearly explained to the public, presumably on the grounds of the information coming from the Inflation Report.

So, the monetary base was in effect abandoned as the official intermediate target, although it continued to receive considerable emphasis in the policy decision process, while the forecasting ability and the knowledge of the transmission mechanisms of monetary policy improved to the point of

being perceived as reliable by the bank's staff and its Board of Directors. This system has worked well so far. In February 2000, for example, monetary policy was rightly tightened after the monetary base exceeded its "reference line" for a reason that could not be related to a shift in money demand. On that occasion, the information included in the Inflation Report did not signal the need of such a movement. On several other occasions, the monetary base has exceeded its "reference line" because of the effects of the financial transaction tax introduced in late 1998. At those times, the stance of monetary policy has not been changed on the basis of the conclusion extracted from the Inflation Report and the reason has been clearly explained to the public.

At the same time, a small macro model describing the main transmission mechanisms of monetary policy (the "Modelo de Mecanismos de Transmisión" (MMT)) was being developed and improved, and has recently begun to be used in the preparation of the Inflation Report, for forecasting inflation and growth and also for policy analysis. Other models of the transmission mechanisms of monetary policy, e.g. the credit channel, are in development. On the other hand, there has been a considerable effort towards improving the forecasting ability of the bank's staff, as it will presented in detail below. As this process and the related research agenda show progress, the strategy of monetary policy will move faster toward pure inflation targeting.

Operationally, the adoption of the new strategy after floating the exchange rate has been compatible with a policy of decreasing the volatility of the interbank overnight interest rate by means of a gradual narrowing of the policy rate range. This movement will probably improve the transmission of shifts in the policy stance to the longer term interest rates and, ultimately, to inflation.

3 Operational Issues

3.1 The Nature of the Targets

3.1.1 The Price Index

The Colombian monetary authorities chose to use all-items CPI in defining the inflation target[2]. Prices of volatile items or energy prices are not excluded from that index. The rationale is that "headline" CPI is the most widely known and the best-understood index. Thus, the use of the CPI facilitates communication with the public on the main objective of monetary policy. Moreover, prices, wages and financial contracts have traditionally been linked to total CPI. Therefore, it is assumed that any other measure

[2]This section is based in (Uribe et al., 1999).

of inflation will not receive public support or serve as a guideline for economic decisions. The same applies to the idea of introducing some caveats to enable deviations form the targets in the event that these are caused by factors beyond the control of central bank.

In practice, the Board of Directors has often based its policy decisions on the behavior and forecasts of measures of core inflation. This has been particularly the case when identifiable temporary supply shocks hit the headline index (e.g. food price shocks). On these occasions, the Board has opted to explain its actions to the public, in these cases the results have been satisfactory. Once the credibility of monetary policy has been enhanced, this practice can be conducted more easily. Nevertheless, there are still doubts as to the appropriate use of measures of underlying inflation. Although the Bank has identified a small group of indicators for core inflation that seem to filter out short-term supply shocks adequately, the Board and the technical staff do not have a strong opinion about whether one of these indicators can (or should) be adopted as the target of monetary policy. If a decision were to be taken, it is not clear which of the measures of underlying inflation should be chosen.

3.1.2 The targeting horizon

By law, each year the Board of Directors has to announce its quantitative inflation target for the following year. Until 1997 the announcements were made as late as December of November. Since then, inflation targets have been informed with increasing anticipation. For example, the target for 2002 was announced in November 2000 and the target for 2003 will be probably announced in November 2001. This has been a clear improvement on the previous practice, provided that there is evidence that the Banco de la República's policy actions affect inflation with long lags, with the main effects occurring after six to eight quarters. If that evidence is correct, short-horizon inflation targets in Colombia might not be achievable by monetary policy and, therefore, may be interpreted by the markets as simple forecasts of inflation instead of policy commitments.

3.1.3 Point target

Until 2002 inflation targets in Colombia had always been formulated as point targets. It was considered that a single figure provided a better guide than a range for the formation of inflation expectations and communicated greater commitment by the central bank to reach its inflation goal. On the other hand, the monetary authorities were well aware that their control over inflation was too imprecise to make that type of commitment credible, especially in a setting where the target is defined in terms of the volatile

headline CPI instead of a measure of core inflation. In addition, given a point target, a short horizon makes monetary policy more active, thus generating more variability in interest rates, the exchange rate, and output.

However, it is well known that under imperfect credibility, the use of target ranges encourages the public and financial markets to focus on the upper limit of the band. In addition, it was believed that deviating from a target range reduces the credibility of the monetary authorities more than missing a specific target. Hence, the problems arising from the credibility of the inflation target in Colombia did not support the move towards a range for inflation targets.

In recent years, however, the credibility of monetary policy in Colombia has been enhanced by the achievement of an inflation path generally below the announced targets. In addition, one digit inflation levels have been reached and inflation will be approaching its steady state level in a few years. Considering these developments, at the end of 2001 the Board of Directors of the central bank decided to adopt a 4%-6% *range* for the inflation *point* target in 2003. By the end of 2002 the point target for inflation will be set within the announced range. The mid point for the range will be used operatively for policy decisions. At the same time, a 3% the long term inflation target was also announced.

3.1.4 The speed of disinflation and target definition

The first target of 22% inflation for 1992 was followed by a target of 22% for 1993, 19% for 1994, 18% for 1995, 17% for 1996, 18% for 1997, 16% for 1998, 15% for 1999, 10% for 2000, 8% for 2001 and 6% for 2002. This shows an gradualism in the pace of disinflation. Due to the extensive history of moderate inflation with strong informal indexation mechanisms, it has been thought that the reduction of inflation should be gradual in order to maintain the society's support and avoid extremely high disinflation costs.

In defining the inflation target, the Banco de la República's staff carries out three types of technical tasks:

−Detailed assessment of the inflationary pressures existing in the short and medium term.

−Inflation projections using econometric models.

−Financial programming in the International Monetary Fund (IMF) tradition.

The evaluation of inflationary pressures is based on an analysis of the recent evolution of consumer and producer prices; the behavior of different core inflation indicators; the trends of monetary aggregates and their deviation from their guidelines; the evaluation of economic activity in relation to different estimates of potential GDP; the surveys of inflationary expectations; the behavior of the nominal exchange rate, among others. This

evaluation of the inflation outlook is complemented with:

−The inflation forecast and balance of risk derived from the MMT. This assessment includes an evaluation of the impact of foreseeable supply shocks.

−Inflation forecasts coming from monthly auto-regressive models.

−A inflation forecasts produced with a Combination of Structural Single Equation Models (CSM) reduced form quarterly econometric models including among its explanatory variables the stock of money, the nominal exchange rate, wages and the output gap.

The inflation target is also established on the basis of a financial programming exercise a-la-IMF. The estimate of Gross Domestic Product (GDP) growth implicit in the national government budget and a preliminary inflation target produce an initial estimate of nominal spending growth to be financed with the creation of liquidity. This figure, together with forecasts of the capital account of the balance of payments and the external and internal credit requirements of the Government, enables the assessment of i) the coherence of financial flows among the different sectors of the economy and ii) the price, exchange rate and interest rate effects of monetary and fiscal policies implicit in the exercise.

If the results show lack of coherence between monetary and fiscal objectives, either spending adjustment alternatives are analyzed or the exercise is carried out again with different assumptions about inflation, output growth, and exchange and interest rates. The final version of the financial programming exercise - completed by the technical staff of the Central Bank and the Ministry of Finance- and its conclusions are submitted for study and approval by the Bank's Board of Directors. The Board then examines all the information available and decides and announces the quantitative inflation target.

3.2 Monitoring

Monetary variables are monitored continually: The Economic Research and Monetary Operation Departments produce, once a week, two reports including the most recent behavior of monetary and credit aggregates, new data on Treasury transactions, the latest interest rate figures, the behavior of open market transactions, and monthly projections of the monetary aggregates, among others[3]. These documents are presented at a weekly meeting of the members of the Board of Directors of the Central Bank, representatives of the Treasury, the Public Credit office, and members of the technical staff of Banco de la República. The nature of any deviation in monetary aggregates from their "reference lines" is studied.

Similarly, in tracing progress towards the inflation target, since 1993, the

[3]This section is based in (Uribe et al. , 1999).

technical staff has produced a comprehensive Inflation Report every month. Since the first report, the format has undergone a number of changes. In its current form the Inflation Report is divided into five sections. The first one reviews the latest information on consumer and producer prices. The second one presents the latest developments in variables that are key in the determination of inflation, including monetary variables, production, wages and capacity utilization. The third part displays results of the Bank's quarterly survey of expectations. The fourth contains a review of recent developments in the Colombia's main trading partners, as well as significant events in international commodity and financial markets. The fifth section lays out inflation forecasts for the next 18 months.

Three sections of the Quarterly Inflation Report deserve special mention. First, the measures of underlying (core) inflation. The Banco de la República has devoted some research effort to applying various statistical methods form distinguishing between permanent and temporary shocks to the price level and to the inflation rate (Jaramillo et al. 1999 and updates). This research underlies the use of several alternative indicators of core inflation that have been used in monetary policy discussions for a number of years. These indicators are evaluated from time to time using different economic and statistical criteria.

Second, section three of the Quarterly Inflation Report presents results of a survey of expectations that is conducted by the Banco de la República. The survey is sent to a large sample of private sector firms (including the financial sector), producers associations and academic centers. The survey asks respondents about their expectations for inflation at the end of the current and following year, and movements in exchange rates, interest rates and production. The survey also includes questions on the perception of current and future liquidity, and on planned wage, price and investment behavior of their firm (or sector). The Banco de la República also uses forward-looking market estimates of inflation, based on the secondary market prices of indexed and non-indexed government bonds of similar maturity.

Third, the final section discusses the general trend in the results from the Bank's forecasting models. These include the MMT, auto-regressive models, a Combination of Structural Single Equation Models (CSM). The forecasting procedure is presented in more detail below.

With the introduction of the MMT in the preparation of the Inflation Report, there are now qualitative and quantitative statements regarding the efforts that will be required to meet the inflation target. There is also an estimate of the lag in the effect of monetary policy on inflation and a detailed discussion of the upward and downward risks to the inflation outlook, as reflected by a "fan chart". Risk analysis is also undertaken by the means of analyzing alternative scenarios. There are no forecasts of output or the real

side of the economy different from those produced by the MMT as an input in the production of the inflation forecast.

3.3 Transparency and Communication Strategy

The response of financial markets to expectations has increased in Colombia in the last few years[4]. With the purpose of guiding the market's expectations, the Banco de la República publishes each year the quantitative inflation target, and the "reference line" of high powered money. With a lag of two weeks, the Central Bank makes weekly results of monetary aggregates and international reserves available to the general public. On the other hand, on a daily basis agents have information on the exchange rate.

Every month, after analyzing the behavior of prices, the Board of Directors, or any of its members, delivers a statement about the new figure for inflation. As stated above, since December 1998 a quarterly Inflation Report, similar to those elaborated by several central banks that have adopted Inflation Targeting as their monetary strategy, has been published. The published Report includes the Banco de la República's inflation forecast and it is accompanied by a statement where the Board of Directors explains any monetary policy decisions made after studying the Report and after examining the behavior of the monetary base with respect to its "reference line". No announcements on future policy are made. In particular, the Bank does not publish the future path of policy rates that it considers to be compatible with the achievement of the inflation target. The publication of the future expected path of interest rates used in the construction of the inflation forecast could be an interesting possibility since, as shown in Tarkka and Mayes (1999), it could reduce output variability by revealing the central bank's estimate of the private sector's expectations. It could also help explain the rationale of the inflation forecast and the policy actions. To convey the Bank's forecasting uncertainty, "fan charts" for inflation and output are published, based on the central view, level of uncertainty and balance of risks of the MMT. The MMT as well as the forecast of other models, mainly the CSM are documented below.

Twice a year the Board presents to Congress a report that evaluates the recent evolution of economic policy and the economy. At times, members of the Board participate in academic events and present their personal view regarding the economy's behavior and perspectives.

The measures adopted by the Board of Directors are made public through resolutions, reports and press conferences. The modifications in the Central Bank's intervention interest rates in the money market are informed through press reports and the net results of the OMO are published weekly. The Cen-

[4]This section is based on Uribe et al., 1999, and Tarka and Mayes, 1999).

tral Bank's intervention in the exchange rate market is based on announced rules. Thus, the size of the intervention is announced to the public immediately after it takes place.

3.4 Policy Instruments

The main policy instrument of Banco de la República is the interest rate on its repo and reverse-repo operations. The Bank supplies and withdraws liquidity to the financial system through 1-15 day repo and reverse-repo operations. These operations are conducted by means of auctions. The Board of Directors set the minimum and maximum interest rates for the repo and reverse-repo auctions, respectively, while the amounts of the operations to be auctioned are defined monthly, based on the estimates of the demand for monetary base (approximated by its "reference line") and projections of the supply of base money constructed with expected purchases/sales of international reserves, purchases/sales of government bonds, lender of last resort operations and the monetary effect of Banco de la República's profits and losses. At the same time, Banco de la República provides (withdraws) liquidity from the financial system in unlimited amounts at "punitive" or "Lombard" interest rates.

Thus, there is a range for the policy rates whose lowest end is the "Lombard" contraction rate and the upper end is the "Lombard" expansion rate. The minimum rate for the repo auction is below the "Lombard" expansion rate, but is higher than the maximum rate for the reverse-repo auction, the latter, in turn, exceeds the contraction "Lombard" rate. The "Lombard" rates establish a range where the interbank rate can fluctuate, although such a range may be narrower when the amounts of repo and reverse-repo auctions are large enough to supply (absorb) all liquidity at those rates.

There has been a gradual narrowing of the policy rates range in the past three years. In December, 1999, the distance between the "Lombard" rates was 1200 basis points, while the difference between the minimum and maximum auction rates was 600 basis points. In September, 2001 these distance has been reduced to 650 and 100 basis points, respectively. Such narrowing of the policy rate range has been possible as the monetary policy strategy has become clearer and has contributed to strengthening the link between the policy rates, the interbank rate and longer term rates. This transmission, however, continues to be affected by events in the external sector, namely, the behavior of the external interest rates, and the country and depreciation risk premium. For example, when there is a clear trend toward a fall of the risk premium, the markets may consider that a reduction of the domestic short term rates by Banco de la República may be sustainable, this allows a faster transmission of the shift in the policy stance to the longer term rates.

Beside the repo and reverse-repo operations, Banco de la República provides (mops up) liquidity through purchases (sales) of international reserves, according to the announced rules for intervention in the foreign exchange market, and purchases (sales) of government bonds. These operations are considered to affect the "permanent" supply of monetary base and usually performed by the end of the year, when most of the growth of the demand for monetary base takes place.

4 The Inflation Forecasting System of the Banco de la República

The Inflation Forecasting System of the Banco de la República (Figure 2) consists of the following models:

1. "Modelo de Mecanismos de Transmisión " (MMT), used for forecasting and policy analysis.

2. Combination of Structural (single equation) Models (CSM).

5. A model of food inflation by type of product,

3. A neoclassical growth model, used for forecasting potential output and also for analysis.

6. A supply side output forecasting system (OFS).

4. A set of auto-regressive models.

At the beginning of every month the forecasting procedure begins when the statistics department (DANE) releases the last figure for inflation. In the first forecasting round the MMT, the neoclassical growth model, the auto-regressive models, and the food inflation model are run. The results of these models are evaluated and used as input to the CSM and to the OFS. In the second forecasting round, the output of these last two sets of models combined with the output of the food inflation model is used to feed the adjustments and the asymmetry of the inflation and output fan charts. In preparing the Inflation Report the staff spends seven days from the day CPI data is released to the day the report is presented to the board.

Projections for output, inflation, and interest rates from the MMT are also used as input for an estimation of the demand of monetary base. Given the difficulty in estimating a demand for money, at times the reference line for the monetary base has in effect been abandoned as the nominal anchor. As progress in the development of the Inflation Forecasting System is achieved, the strategy of monetary policy will move faster to pure inflation targeting.

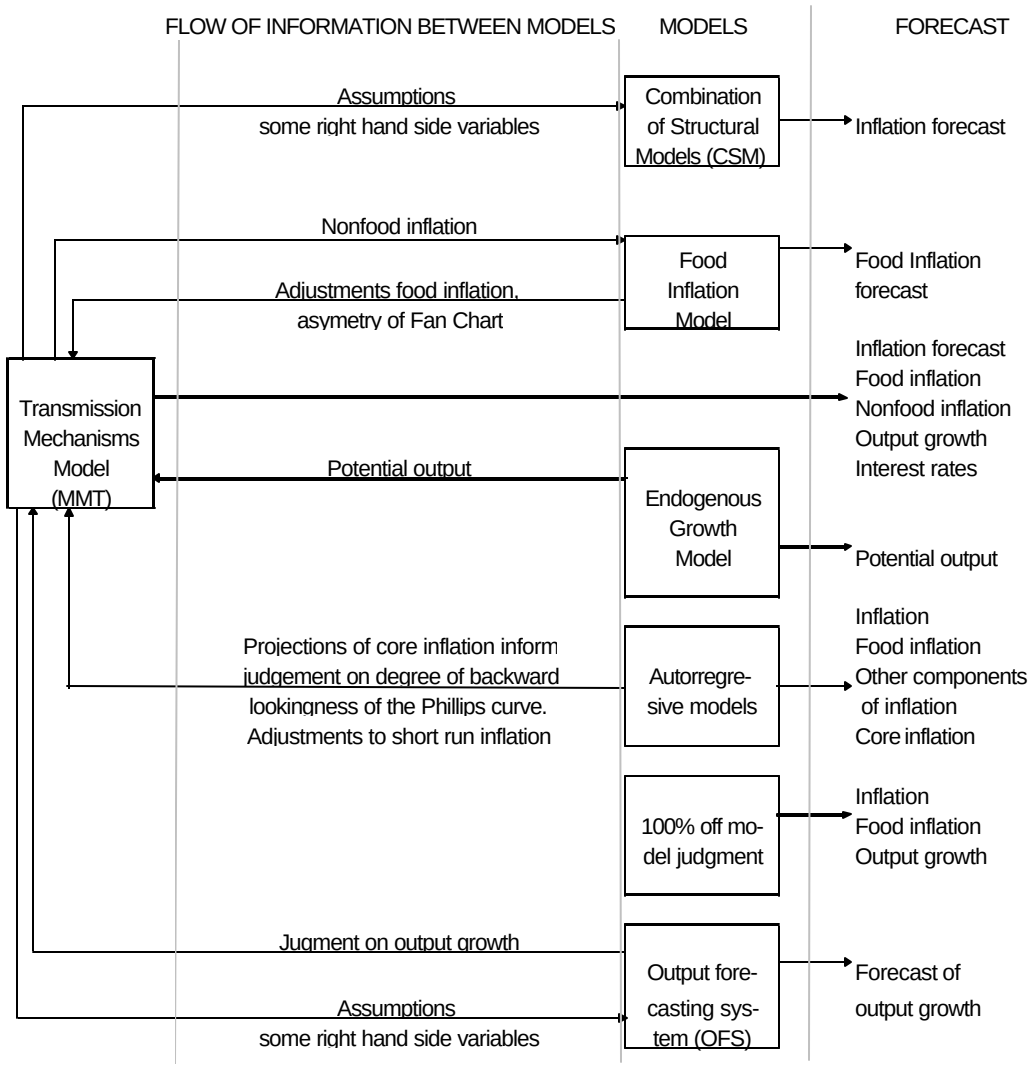


Figure 2: The Inflation Forecasting System of the Banco de la República

5 The Model of Transmission Mechanisms

The MMT[5] is used for policy analysis and also for forecasting; since September 2001 it constitutes the staffs's official forecasts and feeds the central view of the inflation report's fan chart.

5.1 Characteristics

The price-wage system is statically homogeneous, dynamically homogeneous, and forward looking. In the wage price system the nominal-real trade off is nonlinear.

The policy rule is inflation forecast based.

In the model currently the measure of potential output is exogenous, it is based on the production approach to potential output and comes from the neoclassical growth model (also presented in this document).

The nominal exchange rate is determined in policy simulations by UIP, and when forecasting it is assumed exogenous.

There are supply shocks in the agricultural sector, a cobweb-like dynamics of the relative price of food is switched on by droughts. Core inflation is neutral to supply shocks.

5.2 Equations in the model

The following equations are estimated:

Phillips curve

Aggregate demand

Transmission between interest rates

Imported price inflation

Long run of prices, wages and the price of imports

The following equations are calibrated:

Staggered wages

Policy rule

UIP

There are also about 10 definitions and liking equations.

Inflation in Colombia is determined mainly by the extent of slack in economic activity (the output gap) and supply shocks in the agricultural sector. These are the two main characteristics of the Colombian economy the MMT incorporates. The model can stand alone without food inflation, in this case it produces a forecast for core inflation (measured as nonfood inflation). A separate block for food inflation habilitates the model to forecast the overall

[5]The current version of the model was originated in Gómez and Julio (2000), and draws from Gómez (2000) on wage indexation, Avella (2001) on the supply shocks in agriculture, and other research that have tackled on other issues.

CPI. There are two reasons for modelling the food sector separately. On the one hand, as we explain below, there is not much monetary policy can do to offset the kind of supply shocks that occur in Colombia. The reason is that they appear suddenly, are difficult to predict, and change inflation in the very short run. On the other hand, the board of the bank may not move interest rates in response to supply shocks since this policy would add variability to the real economy. Although the inflation target is defined in the overall CPI, if a supply shock results in the central bank not meeting the target, the board would explain that that happened as a result of a supply shock, that the event is transitory and that core inflation is in line with the target[6].

In the MMT monetary policy is neutral and superneutral in the long run, but has important effects on the economy in the short run.

5.3 The Transmission Channels

The aggregate demand channel: Assume an exogenous intervention decreases the real interest rate below the long run equilibrium (Figure 3, Region A). By the aggregate demand equation the relatively low level of the real interest rate increases output above potential (Region B). By the Phillips curve, the negative output gap increases inflation above target (Region C). By the policy rule, the deviation of inflation from target increases the real interest rate above the long-run equilibrium. The interest rate is kept above the long-run equilibrium until inflation converges to target. At this point output is equal to potential and the output gap is zero.

Direct exchange rate channel: an increase in interest rates leads to an immediate appreciation. The appreciation causes a decrease in inflation with a one-quarter lag. The effect of the direct exchange rate channel on inflation is small.

Indirect exchange rate channel: an increase in the interest rate leads to an immediate appreciation. The appreciation causes a decrease in output with a lag of one quarter. The decrease in output leads with a lag one quarter lag to a small decrease in inflation.

Expectations channel: a decrease in inflation expectations for the next quarter leads to a decrease in current inflation. The effect on inflation depends on the weight of inflation expectations in the Phillips curve.

Cost push channel: in the long run prices tend to costs and nominal wages tend to the value of average output.

[6]This was the explanation given by the Board in the July 1988 Report to Congress.

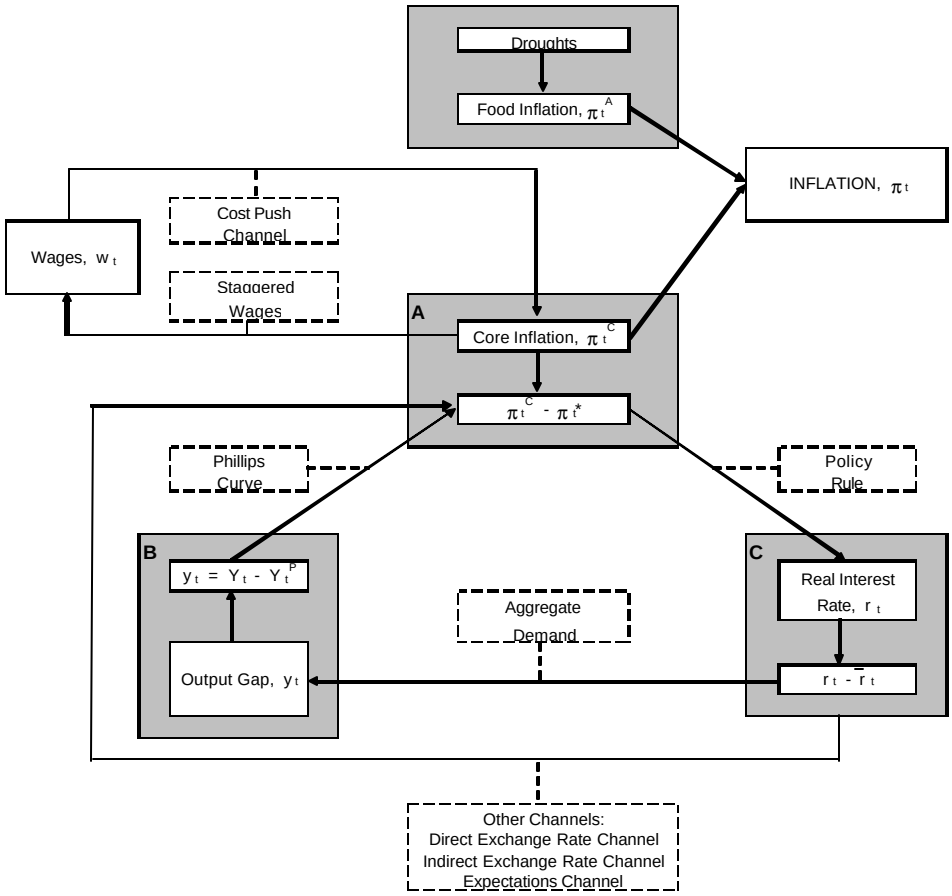


Figure 3: Flow chart of the "Modelos de Mecanismos de Transmisión" (MMT)

5.4 The Shocks

5.4.1 Supply shocks, droughts, and food inflation

In 1991 the weather phenomenon El Niño drove food price inflation up beyond 30%. 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, weather changes may continue to be an important source of short-term shocks to inflation.

Figure 4 shows the impact of droughts on food inflation. Panel 1 shows the amount of rainfall measured in cubic millimeter. Panel 2 the seasonal pattern of the amount of rainfall; depicted in logs. The amount of rainfall may double from the first quarter of the year two the second one. Panel 3 shows the seasonally adjusted amount of rainfall. The amount of rainfall may not affect agricultural output when it rains well above the average but its does when it is below a critical level. Following Avella (2000), we have defined this critical level as -20%. Any amount of rainfall below this critical level is our definition of drought. Panels 5 and 6 show CPI inflation, food inflation and nonfood inflation. The behavior of food inflation shows the cobweb like profile triggered by a shift to the left in the supply of food products on the relative price of food. The cobweb effect is illustrated in Figure 5.

5.4.2 Shift in inflation targets

Simulating the effects of a permanent decrease in the inflation target 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 6). Although these targets were not compulsory, they were part of the overall macroeconomic programme and as such acted as the monetary policy anchor.

Beyond 2002, inflation targets are also decreasing to a long run target of 3%. This figure, announced in 22 November 2001, was believed to be small enough for inflation not to be a problem, but big enough to enable the Banco de la República to eventually undertake an expansionary monetary policy, ease changes in relative prices, and incorporate possible biases in the measurement of the CPI. The long run inflation target was defined on the overall CPI.

The long run inflation target appears in Figure 6. The figure also shows the $4\%-6\%$ *range for* the *point* target for the end of 2003. The range for the target for the end of 2003 was decided at the end of 2001 and the decision for the point target for the end of 2003 will be taken at the end of 2002.

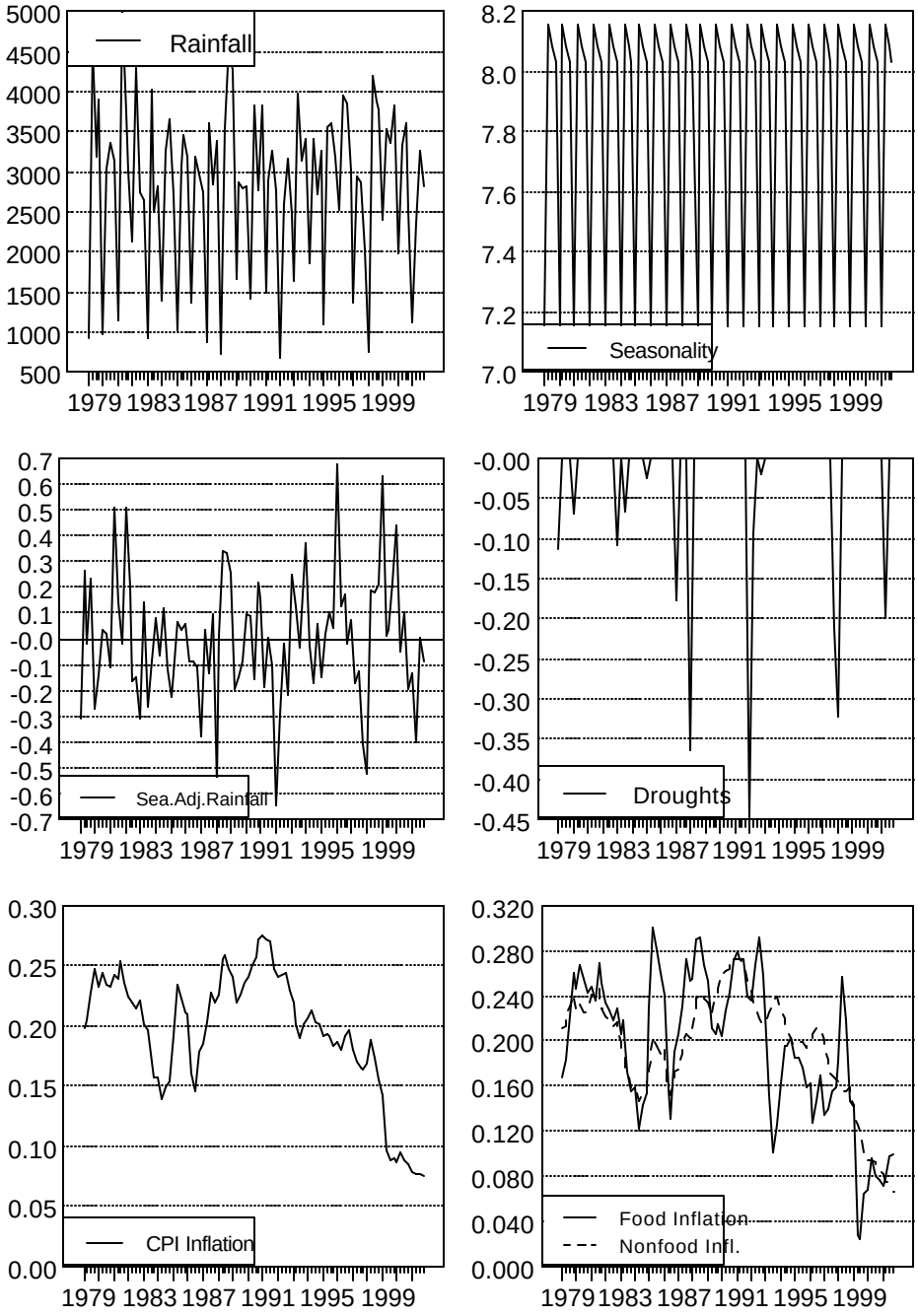
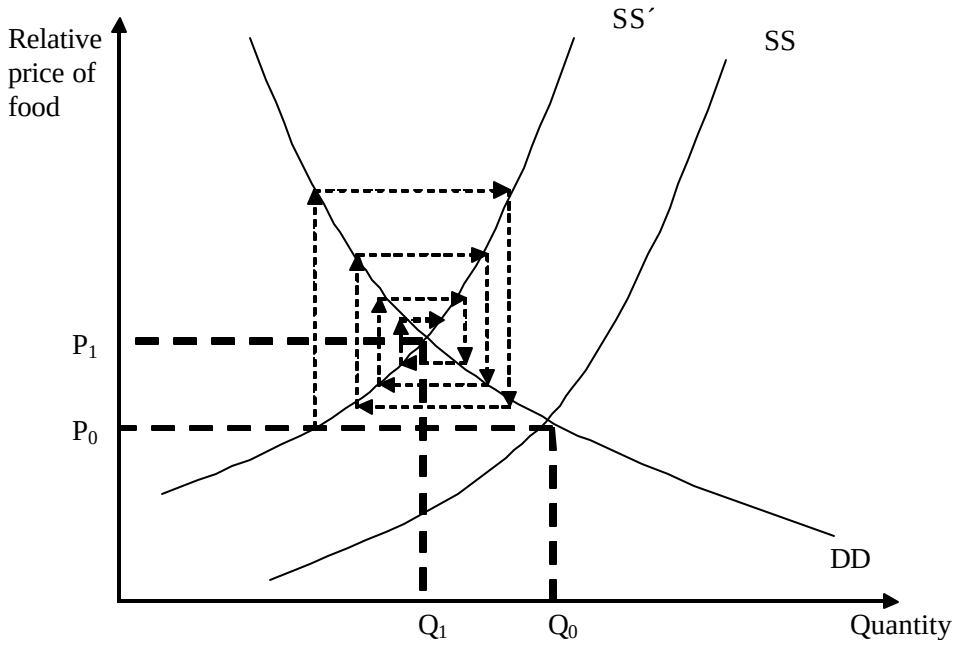


Figure 4: Supply shocks, droughts, and food inflation

Figure ¿?



"The Cobweb effect": Starting from equilibrium at (Q_0,P_0) a supply shock moves the supply schedule from SS to SS´. Excess demand is generated at P_0, and prices rise. Excess supply is generated, and prices fall back again. This "cobweb effect" continues until new equilibrium is reached at (Q_1,P_1).

Figure 5: Supply shocks in agriculture

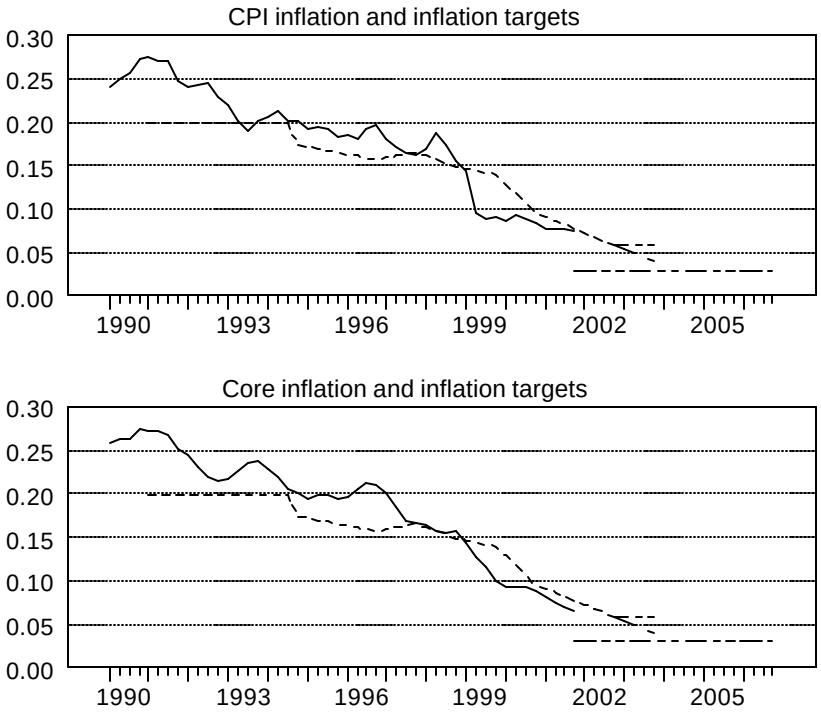


Figure 6: Gradual decrease in inflation targets

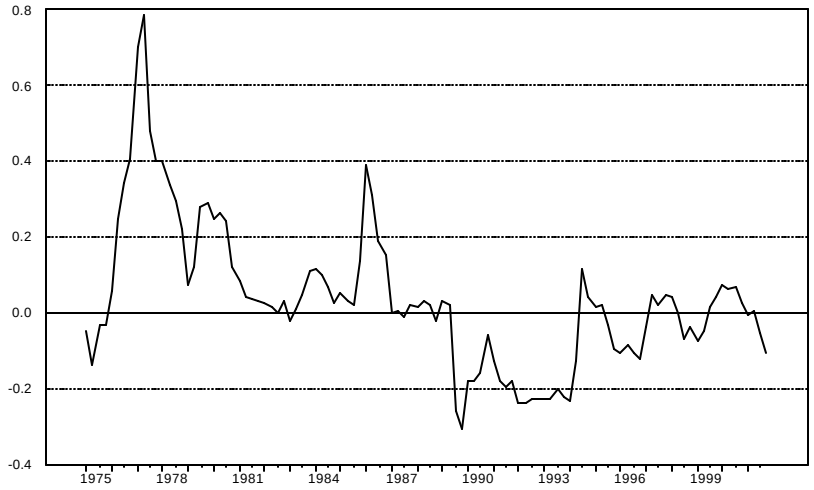


Figure 7: Shocks to the terms of trade

5.4.3 Terms of trade

Since coffee and oil and derivatives amounts to 11.4% and 32.5% of exports in 2001 respectively, the fluctuations in the international market price is an important source of variability to the Colombian economy. Movements in the terms of trade are quantitatively large, in the logarithmic scale in Figure 7, a change of 0.1 means a 10% change.

5.4.4 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 (Figure 8).

5.4.5 Changes in interest rates

At times the interest rate itself may become a source of exogenous variability to the economy (Figure 9). Below we also model the effect of a temporary monetary policy impulse. This shock can also help us discuss the effects of both temporary and permanent shifts in the monetary stance.

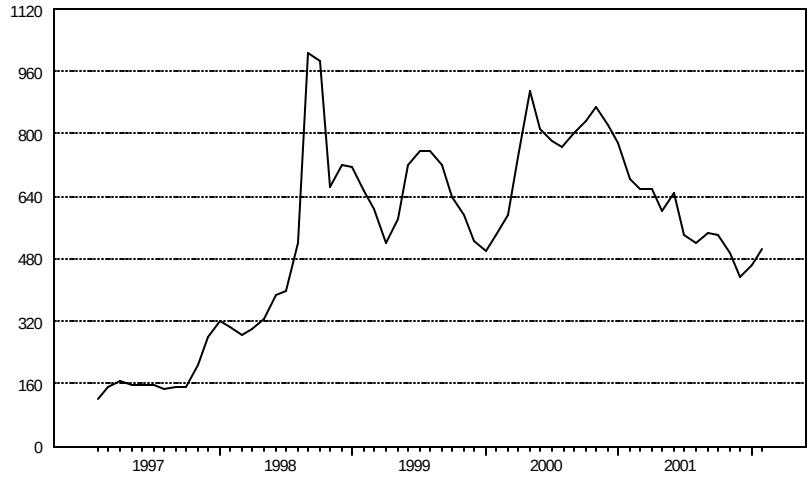


Figure 8: Spread of Colombian bonds

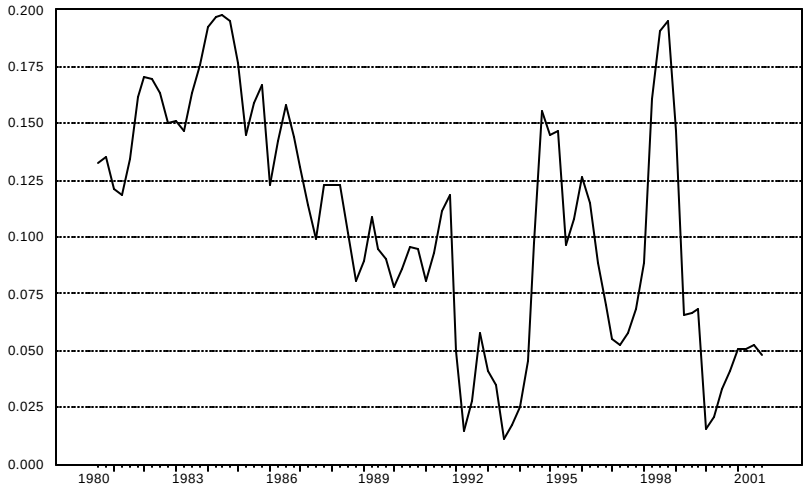


Figure 9: Real interest rates

5.5 The Phillips Curve

5.5.1 Estimation

The restricted estimation is obtained by substracting π_{t-1} from both sides of Eq. (**??**):

$$\pi_t^C = (1 - 0.640 - 0.031)\pi_{t+1|t}^C + \underset{(25.338)}{0.640}\,\pi_{t-1}^C + \underset{(3.361)}{0.031}\pi_{t-1}^M + \underset{(3.008)}{0.048}F(y_{t-1}) + \underset{(1.409)}{0.008}z_{t-4}^P$$

$$- \underset{(-10.322)}{0.005}\,d_t^1 + \underset{(2.607)}{0.007}d_t^2 - \underset{(-4.734)}{0.032}\,d_t^3 + \varepsilon_t^\pi \qquad (1)$$

Estimation method: GMM-IV.

Sample period: 1982:2-2001:4.

$R^2 = 0.983$

Standard error of estimate 0.0067.

The Ljung-Box Q test does not show any evidence of autocorrelation up to order 32.

Jarque Bera statistic p-value: 0.349.

As the coefficient on z_{t-1}^π in Eq. (**??**) is not significant, it was calibrated to -0.005.

Instruments to approximate inflation expectatoins with future observed inflation: π_{t-2}^C, π_{t-3}^C π_{t-4}^C, y_t, and the gap in capacity untilization, gaps zero to four.

The coefficient on inflation expectations, although estimated in 0.329 was calibrated to 0.150, the remaiing weight was given to past core inflation.

5.5.2 Definitions

$\pi_t^C = \log P_t^C - \log P_{t-4}^C$, P_t^C is core inflation where P_t^C is the monthly geometric average of the nonfood component of the CPI.

y_t is the output gap.

$\pi_t^M = P_t^M - P_{t-4}^M$, is inflation of the price of imports, where P_t^M is the imported component of the PPI.

$z_t^P = P_t^C - c_1 - U_t$ is the long run of the Phillips curve.

$U_t = W_t + N_t - Y_t$ is the log of the unit labor cost.

W_t the log of the nominal wage.

N_t the log of the labor force.

Y_t is GDP.

$c_1 = 6.971$.

d_t^1 is a dumy for 1997:1-2001:4. Unknown.

d_5^2 is adummy for 1992:3-1993:3. Market reforms in foreing trade sector.

d_t^3 is a dumy for 1986:2-1986:3. IMF adjustment program.

5.5.3 Results

The Phillips curve is expectational, superneutral, neutral, and nonlinear.

It is expectational in the sense that it includes inflation expectations, approximated with observed future inflation. The forward looking part of the Phillips curve weights about 15.0% of the weight of all the coefficients on the nominal variables. The high weight of the backward looking component implies that decreasing inflation is costly. Chadha, Masson, and Meredith (1992) illustrate that the cost of disinflation is decreasing in the coefficient of future inflation and that it approaches zero when the coefficient on future inflation is one half.

The Phillips curve is superneutral because the sum of the coefficients on inflation in the Phillips curve is one. This property is also known as dynamic homogeneity and makes the long-run trade off between output and inflation disappear, that is, in the long run the Phillips curve is vertical. There is a trade off between economic activity and inflation but this trade off takes place in the short run. Any attempt to stimulate output is not lasting in the long run; it only results in higher inflation. Due to the property of dynamic homogeneity, in the absence of shocks, inflation tends to perpetuate at a given level unless it is obliged to change by an output gap that is different from zero, a supply shock, or a movement in the exchange rate. Colombian inflation increased to a higher average by 1973 after twenty five years it could probably settle at a lower level. The history of some Latin-American countries is a real example of how monetary policy in the long run can not stimulate economic activity.

The Phillips curve is neutral because it includes a log run error correction adjustment. Static homogeneity makes the model neutral in the price level, this means that the economy converges to the same solution of the real variables whenever there is a change in the price level.

It is nonlinear because inflation is a nonlinear function of the output gap. Nonlinearity in the Phillips curve has interesting policy implications: The higher the recession, the higher the number of percentage points of output that must be foregone to decrease inflation by one percent and the higher the cost of disinflation. An increase in inflation implies a gain in output that is smaller than the cost of returning inflation back to the initial level. A gradual disinflation over a long period of time has a cost that is smaller than the cost of a sudden disinflation[7].

Nonlinearity has been introduced to the Phillips curve in a number of ways[8]. In this model we make the Phillips curve nonlinear by letting inflation

[7]See Clark and Laxton (1997), Isard, Laxton and Eliasson (1999), Isard and Laxton (1996), Laxton, Rose and Tambakis (1998), Laxton, Rose and Tetlow (1993), Phillips (1998) for the policy implications of convexity of the Phillips curve.

[8]See Dupasquier and Ricketts (1998) for a revision of the litterature on different non-

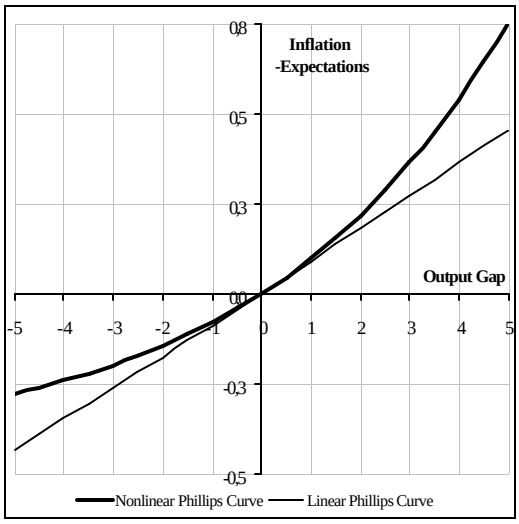


Figure 10: The Nonlinear Effect of the Output Gap on Inflation

depend on a nonlinear function of the output gap[9]:

The nonlinear function of the output gap is:

$$F(y_t) = \frac{1}{1-\sigma}\left((1+y_t)^{1-\sigma} - 1\right)$$

where $\sigma = 0$ for linearity and $\sigma < 0$ for convexity. The model is hence operational with linearity and with different degrees of convexity. In the simulations we use $\sigma = -16.227$ a parameter that was estimated by NLLS.

Figure 10 shows the effect on inflation (minus inflation expectations) of different levels of the output gap[10][11].

5.6 Nominal Wages

Nominal wages are determined according to an overlapping contracts model (Taylor, 1980, 1993). We have assumed all wage contracts last four quarters and staggering is uniform:

$$X_t = \lambda_0 V_t + \lambda_1 V_{t+1|t} + \lambda_2 V_{t+2|t} + \lambda_3 V_{t+3|t} + 0.05F(y_{t-1}) + 0.02z^W_{t-4} + c_2$$

linearities in the Phillips curve.

[9]The absence of asymptotes in this function is a considerable simplification.

[10]The degree of convexity in both figures is $\sigma = 16.227$. The axes in both functions have been multiplied by 100. As the model is nonlinear, in the program, a 10% disinflation should be understood as a decrease in inflation of -0.1.

[11]We tried to include the domestric price of oil in the Phillips curve measured as the change in the domestic price of oil relative to the change in the CPI, but the results where not statisticaly significant.

$$W_t = \lambda_0 X_t + \lambda_1 X_{t-1} + \lambda_2 X_{t-2} + \lambda_3 X_{t-3}) \tag{2}$$

Due to the quality of wage data, we have preferred a calibration.

5.6.1 Definitions

X_t is the log of the contract wage.

$V_t = P_t^C + Y_t - L_t$ is the log of the value of average output.

y_t is the output gap.

$z_t^W = W_t - c_2 - V_t$ is the long run of wages.

$\lambda_i = 0.25$.

$c_2 = -7.677$.

5.7 Food Inflation

5.7.1 Estimation

Food inflation is determined by the rainfall deficit according to the equation:

$$\pi_t^F = \underset{(5.975)}{0.418}\pi_{t-1}^C + \underset{(8.290)}{0.581}\pi_{t-4}^F$$

$$-\underset{(3.807)}{0.120}\varphi_{t-1} - \underset{(-2.103)}{0.072}\,\varphi_{t-2} + \underset{(4.525)}{0.155}\varphi_{t-5} + \underset{(4.231)}{0.157}\varphi_{t-6} + z_{t-4}^F + \varepsilon_t^R \tag{3}$$

Estimation method: restricted least squares.

Sample: 1990:1 2000:4

$R^2 = 0.935$

Standard error of Estimate 0.019

Significance of Lung Box Q: 0.471.

5.7.2 Definitions

$\pi_t^F = P_t^F - P_{t-4}^F$ is food inflation, where P_t^F is the log of the price of food.

e_t is the log of the amount of rain.

ϵ_t seasonally adjusted deviation of the amount of rainfall from the long run average.

φ_t is the measure of droughts.

$z_t^F = P_t^F - c_4 - P_t^C$ is the long run of the price of food.

$c_4 = 0.150$.

5.7.3 Results and Estimation Issues

Droughts are measured as the seasonally adjusted amount of rain that is 20% below the average. Algebraically,

$$\varphi_t = \epsilon_t + 0.2 \text{ if } \epsilon_t < -0.2 \text{ and}$$
$$\varphi_t = 0 \text{ if } \epsilon_t > -0.2$$

where

$$\epsilon_t = e_t - (c + \delta_1 d_{1t} + \delta_2 d_{2t} + \delta_3 d_{3t})$$

According to Avella (2001), the rainfall variable enters with a negative sign at short lags because of the effect of the weather on food supply and with a positive sign by the fifth quarter because, as in the cobweb effect, farmers respond to high relative prices with an increase in supply.

Food inflation is quite volatile. This can be seen in the high standard error of the food inflation equation. The MMT projection of food inflation is always complemented with input from a model of food inflation by type of product and also with judgment by experts in agriculture.

5.8 CPI inflation

CPI inflation is a convex combination of core inflation and food inflation:

$$\pi_t = (1 - 0.295)\pi_t^C - 0.295\pi_t^F \tag{4}$$

5.9 Aggregate Demand

The estimated aggregate demand equation is:

$$y_t = \underset{(5.793)}{0.604} y_{t-1} + \underset{(2.933)}{0.314} y_{t-2} - \underset{(-3.005)}{0.105} (r_{t-1} - \bar{r}_t) + \underset{(0.908)}{0.012} z_{t-1}^Q + \underset{(0.545)}{0.054} z_t^{USA} + \underset{(2.388)}{0.044} \tau_t + \varepsilon_{t+1}^y \tag{5}$$

Estimation method: Restricted LS.
Sample period: 1990:1 2001:1.
Standard error of estimate 0.014.
$R^2 = 0.804$.
P-value Lung Box Q: 0.576.

5.9.1 Definitions

y_t is the output gap.
$r_t = i_t - \pi_t^C$ is the real interest rate.
i_t is the 90 days Certificates of Term Deposits (CDT).
z_t^{USA} is the US output gap estimated with the HP filter.

τ_t is the deviation of terms of trade from the HP filter, $\tau_t = \log \tau_t^{NHP} - \log \tau_t^{HP}$, $\tau_t^{NHP} = P_t^X / P_t^M$, where P_t^X is the PPI. for exports and P_t^M is the PPI for imports.

5.9.2 Estimation Issues

The aggregate demand equation is one of the most important equations in the model because different calibrations of its parameters within their confidence intervals significantly change the shape of the impulse response functions. We have estimated the equation since 1980 in order to obtain a degree of output gap persistence that is consistent with business cycles that last for about 8 years and also consistent with the current small recovery of output growth.

It is important to note that the real interest rate is defined on core inflation, otherwise supply shocks would have second round effects on economic activity through the definition of the real interest rate. This may be considered as a simplification that is indirectly considering the fact that aggregate demand should depend on a long run interest rate.

5.10 The Policy Rule

The policy rule is:

$$i_t = \phi i_{t-1} + (1-\phi)(\bar{r}_t + \pi_t^C - c_5) + 0.5(\pi_{t+k|t}^C - \pi_{t+k}^*) \tag{6}$$

5.10.1 Definitions

i_t is the nominal interest rate on 90 days certificates of deposits (CDT).

$\bar{r}_t$ is the long run real interest rate.

π_t^C is core inflation.

π_t^* is the inflation target.

$\pi_{t+k|t}^C$ is the forecast of core inflation k periods ahead conditional upon information up to time t.

ϕ is a smoothing parameter.

$c_5 = 0.02$ is the difference in the long run between the policy rate and the deposit rate.

5.10.2 Some results

The targeting horizon k is 8 quarters. With the aim of increasing the control of inflation and the credibility of the central bank while inflation is decreasing, an attempt was undertaken to decrease the targeting horizon to 4 quarters. As shown by Svensson (2001), and Rudebusch and Svensson (1998), a relatively short policy horizon increases the volatility of GDP

and other real variables. It also demands a more active policy and higher volatility of the policy rate.

As a policy prescription, a volatile path of the policy rate demands a deep study of the assumptions underlying the recommendation and thorough knowledge of the sensitivity of the policy prescription to different assumptions about the output gap, the long run interest rate and also other sources of uncertainty. We then decided to maintain the targeting horizon in eight quarters.

A study was developed on what type of measures of inflation should enter Eq. (6) (Banco de la República 2001a, 2001b). The conclusion of these studies is that π_t^C should enter the second and third terms of Eq. (6). The reason is explained below in the analysis of the impulse response to a supply shock.

5.11 The Transmission Between Interest Rates

5.11.1 Estimation

$$\Delta i_t = \underset{(-2.495)}{-0.295}\, i_{t-4} + \underset{(2.495)}{0.295} i_{t-4}^P$$

$$+\underset{(2.713)}{0.256}\Delta i_{t-1} + \underset{(0.144)}{0.474}\Delta i_t^P + \underset{(2.655)}{0.250}\Delta i_{t-4}^P + \varepsilon_t^i \qquad (7)$$

Estimation method: Restricted LS.
Sample: 1992:1 2001:2, quarterly.
$R^2 = 0.926$.
Standard Error of Estimate 0.0229.
Significance of Lung Box Q: 0.206.

5.11.2 Definitions

i_t is the 90 days interest rate on certificates of term deposits (CDT Bancos y Corporaciones).

i_t^P is the policy rate, the inter bank interest rate (TIB) at an annual rate.

Δ is the fourth difference operator.

5.11.3 Estimation Issues

The estimation was subject to the restriction that the coefficients on i_{t-4} and i_{t-4}^P were equal to each other with different sign. This restriction passed with a $\chi^2_{(1,30)} = 0.335$, p-value 0.567. With the restriction imposed the coefficients on the first differences of the variables add up to one. The coefficients on Δi_{t-1}, Δi_t^P and Δi_{t-4}^P were hence calibrated to 0.25, 0.5 and 0.25[12].

[12]The estimates of this equation could change in the event the central bank changes its policies about the communication of the future path of interest rates or if the inflation

Quarter	Deposit Rate	Quarter	Deposit Rate
0	0.500		
1	0.875	7	1.009
2	0.969	8	1.107
3	0.992	9	1.042
4	1.146	10	1.012
5	1.073	11	1.002
6	1.028	12	1.074

Table 1: Response of the Deposit Rate to a One Percentage Point Increase in the Interbank Rate

5.11.4 Results

Table 1 shows the response of the deposit rate to a one percentage point increase in the interbank rate. On impact the deposit rate increases to half the increase in the interbank rate. In one quarter the deposit rate increases to 87.5% of the change in the interbank rate. The complete long run change of one percent in the deposit rate is achieved almost completely two quarters after the shock[13].

5.12 Uncovered Interest Rate Parity

The nominal exchange rate vis a vis the US is determined by the uncovered interest parity condition (UIP):

$$E_t = E_{t+1|t} - 0.25(i_t - i_t^{US} - \varphi_t) \tag{8}$$

E_t^{US} is the nominal exchange rate vis a vis the US.
i_t is the 90 days deposit interest rate.
i_t^{US} is the US 90 days interest rate on certificates of deposit.
φ_t is the country risk premium.

5.13 The Pass-Through

The partial adjustment model for the inflation in the price of imports is:

$$\pi_t^M = 0.850\pi_t^M + 0.150e_t - 0.001z_{t-4}^M \tag{9}$$

targeting strategy is better undertood by the public.

[13]The oscilations of the impulse response function after the third quarter are a result of using four quarter differences. They do not arise when forecasting with real data.

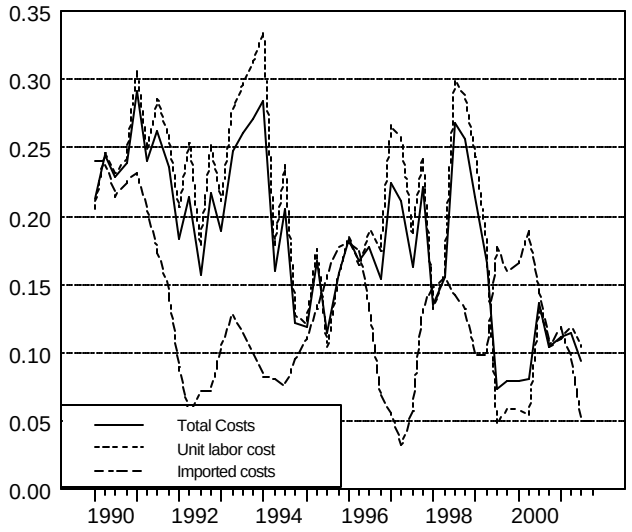


Figure 11: Cost push channel

where

π_t^M inflation of imports.

$z_t^M = P_t^C - c_3 - P_t^M$ is the long run of the price of imports where P_t^M is the imported goods component of the PPI.

$e_t = E_t - E_{t-4}$ is the rate of exchange rate depreciation, where E_t is the nominal exchange rate.

$c_3 = -1.800$.

5.14 The Long Run

In the long run prices converge to costs, nominal wages to the value of average output and the price of imports to the domestic price level. As explained above, a well defined long run makes the model neutral, that is, the long run solution of the real variables is independent of the price level.

In the Phillips curve, positive values of the cointegrating error arise when costs have risen above prices; as they enter the Phillips curve with negative sign, they represent inflationary pressure. Figure **??** shows the growth of total costs estimated as a weighted average of unit labor costs and the price of imports. The estimated weights are 0.8 for the unit labor cost and 0.2 for the price of imports.

5.14.1 The long run of the wage equation

In the long run nominal wages should converge to the value of average output:

$$W_t = c_2 + V_t + z_t^W \tag{10}$$

where $V_t = P_t^C + Y_t - N_t$ is the log of the value of average output.
$c_2 = -7.677$.
The long run of the nominal wage equation is defined as

$$z_t^W = W_t - c_2 - V_t \tag{11}$$

5.14.2 The long run of the price of imports

In the long run the price of imports converges to the domestic price level:

$$P_t^M = c_3 - P_t^C \tag{12}$$

where
$c_3 = -1.800$.
The long run of the imported price inflation may be written:

$$z_t^M = P_t^M - c_3 + P_t^C \tag{13}$$

5.14.3 The long run of the Phillips curve

The cost push inflation channel states that in the long run prices are equal to costs:

$$P_t^C = c_1 + 0.888U_t + 0.112P_t^M + z_t^P \tag{14}$$

Using Eq. (15), define the long run of the Phillips curve as

$$z_t^P = P_t^C - c_1 - U_t - P_t^M \tag{15}$$

Using Eqs. (11), (13), and (15) the long run of the Phillips curve may be written,

$$z_t^P = -c_1 - (1-\alpha)c_2 - \alpha c_3 - (1-\alpha)z_t^W - \alpha z_t^M \tag{16}$$

where
$U_t = W_t + N_t - Y_t$ is unit labor cost
W_t is the log of nominal wages[14]
N_t is the log of the labor force
Y_t is the log of output
P_t^C is the log of the nonfood component of the CPI.
$c_1 = 6.971$ is a constant.

[14]We use wage figures processed by DNP on raw data from the Encuesta Anual Manufacturera produced by DANE. This series is available until 2000Q2, hence we have updated it with data for wages in the industrial sector.

5.14.4 Cointegration analysis

The variables prices and price of imports in Eq. (12) are cointegrated. The null of a long run relationship between them one to one as in Eq. (12) passes with a p-value of 0.87.

The variables nominal wages and the value of average output product in are also cointegrated. The null hipothesis of a one to one relationship as in Eq. (10) is not rejected with a p-value of 0.99.

The variables prices, unit labor cost and price of imports in Eq. (14) are cointegrated. The coefficient $\alpha = 0.112$ was obtained with ordinary least squares in levels.

5.15 Calibration and Adjustments

The calibration includes a Phillips curve that may be more backward looking than the estimated one. As the weights of future and past inflation in the Phillips curve are difficult to estimate, they may be calibrated so that the future evolution of nonfood inflation is in line with judgement and with auto-regressive projections of different measures of core inflation.

Adjustments in the MMT mainly have to do with the price of food. Judgements for these adjustments come from a satellite model for food inflation by type of product and from judgement from field experts.

As an example, in January 2002 the adjustments were: a $+0.1$ adjustment during 2002Q1-2002Q4 and a -0.1 adjustment during 2003Q1-2003Q4 to the equation for food inflation π_t^F to account for livestock cycle.

A 0.1 value for the drought in 2001Q1 instead of the -0.19 observed because, although that drought did affect crops, it did not seem to affect potato crops.

A -0.1 expected drought in 2003Q1. The expected value was obtained as a one third probability of a drought comparable in size to one of the biggest during the nineties.

The exogenous forecast for the nominal exchange rate was given by a projection of the balance of payments.

5.16 Response to the main shocks

5.16.1 A Supply Shock in the Agricultural Sector

Disturbances to relative food prices make inflation volatile (upper pales of Figure 12). Food items are a small share of GDP but a fairly large share of the CPI. In the model, monetary policy does not respond to these kind of supply shock disturbances. The experiment consists of a -0.35 drought like the one observed in 1998Q1. The impact of the drought on food inflation is an increase of 5% two quarters after the shock and a decrease of 8% six

quarters after the shock. In these same quarters CPI inflation increases relative to the baseline by 1.5% and then decreases by −2.2%. The effect of the drought is an increase in food inflation and CPI inflation while core inflation, real interest rates and output are left unchanged.

The model has been designed neutral to supply shocks in agriculture because when there is one of these shocks, there is not much a central bank can do.

The dotted lines in Figure 12 show an economy where the central bank does not respond to supply shocks. The only effect of the shock is on CPI and food inflation. The solid lines depict the path of the economy when the central bank responds to supply shocks according the following aggressive policy rule:

$$i_t = (\bar{r}_t + \pi_t - c_5) + 0.75(\pi_{t+4|t} - \pi^*_{t+k}) \tag{17}$$

This rule has a quick response to the overall CPI.

The central bank intends to offset the expected *decrease* in CPI inflation four quarters ahead by decreasing the real interest rate and increasing core inflation. Extra variance is added to the output gap. Despite the strong feedback of the central bank to supply shocks, CPI inflation four or eight quarters ahead is unaltered.

5.16.2 A 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 eighth quarter. From the fourth quarter onwards, the aggregate demand channel kicks in to accelerate the disinflation process. Inflation decreases 75 basis points by 14 quarters and 95 basis points by 19 quarters (Figure 13).

The sacrifice ratio, or the cumulative loss of output per unit of annual inflation reduced, is in this version of the model 0.788. The shock to the target seems to be a good method to quantify the sacrifice ratio, since the effect of output on inflation is cleaned for the effect on infltion of other tranmission channels.

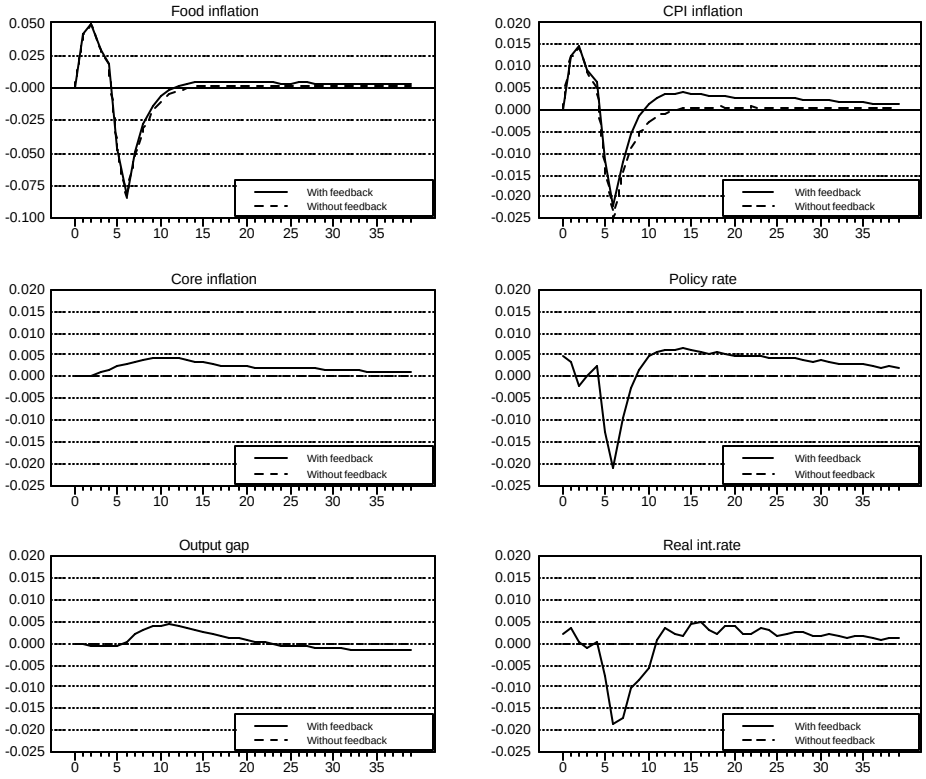


Figure 12: A supply shock with and without feedbak in monetary policy

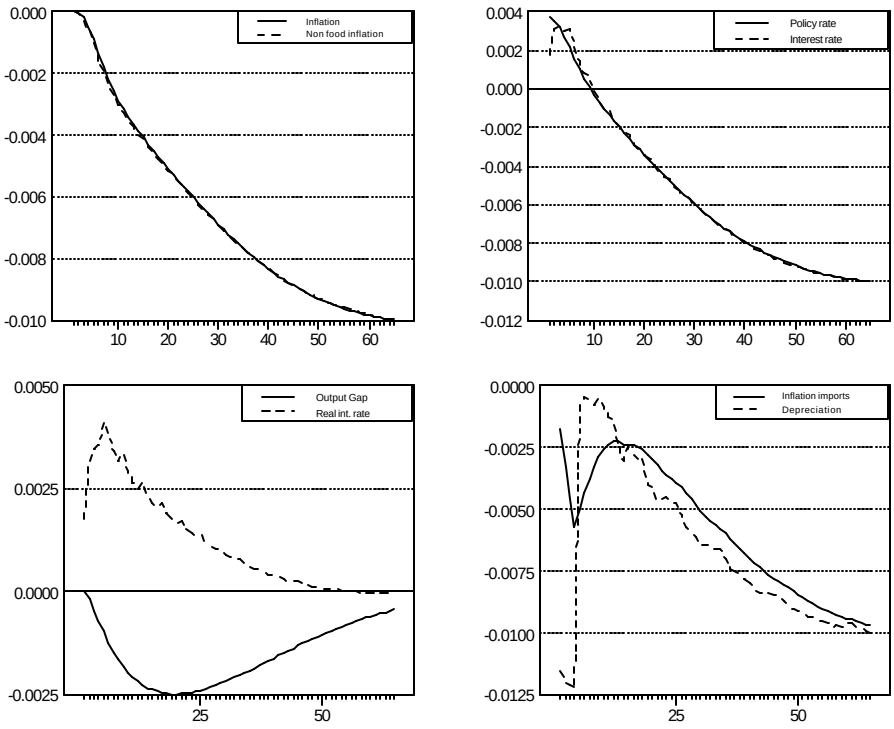


Figure 13: A permanent shift in the inflation target

5.16.3 A Shock to the Price Level Target

This shock is designed for a purpose that is theoretical. To show that in the long run monetary policy has only nominal effects and does not have any effect on the real economy. The interest rate rule (6) is replaced with a rule that pursues a target for the price level:

$$i_t = \phi i_{t-1} + (1-\phi)(\bar{r}_t + \pi_t^C - c_5) + 0.5(P_{t+k|t}^C - P_{t+k}^{C\,*}) \tag{18}$$

The target for the price level is changed one percentage point. The path of the nominal variables, prices, wages, nominal exchange rate, price of imports also decrease one percentage point in the long run. Real variables like the output gap and real wages converge in the long run to zero, that is, converge to the long run equilibrium. The behovior of real and nominal variables in this shock demonstrates that in the long run monetary policy does not have any effect on real variables; the model is neutral[15].

5.16.4 The Effect of Monetary Policy

Figure 15 presents the behavior of the economy under a percentage point shock to the nominal interest rate that is sustained for four quarters. During the period of the shock, the policy rate is fixed, but after the fourth quarter it is allowed to follow the policy rule (Eq. 6). The increase in the policy rate changes the deposit rate quite quickly (Table 1). Acting through the direct exchange rate channel, inflation decreases immediately and by a relatively small amount. After a lag, inflation falls further following an opening of the output gap. Once the policy rule is switched on, the interest rate decreases and this returns inflation back to target.

5.16.5 A Shock to the 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 16).

[15] Needless to say, the model does not operate with a price level target but, by mimicking the behavior of the central bank, it pursues an inflation target.

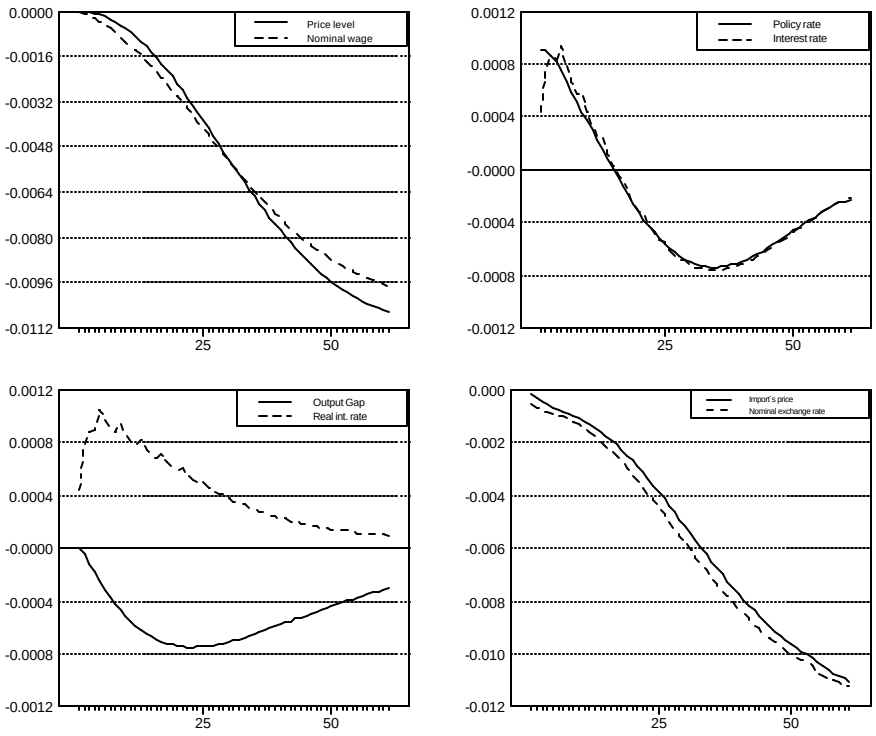


Figure 14: A shock to a price level target

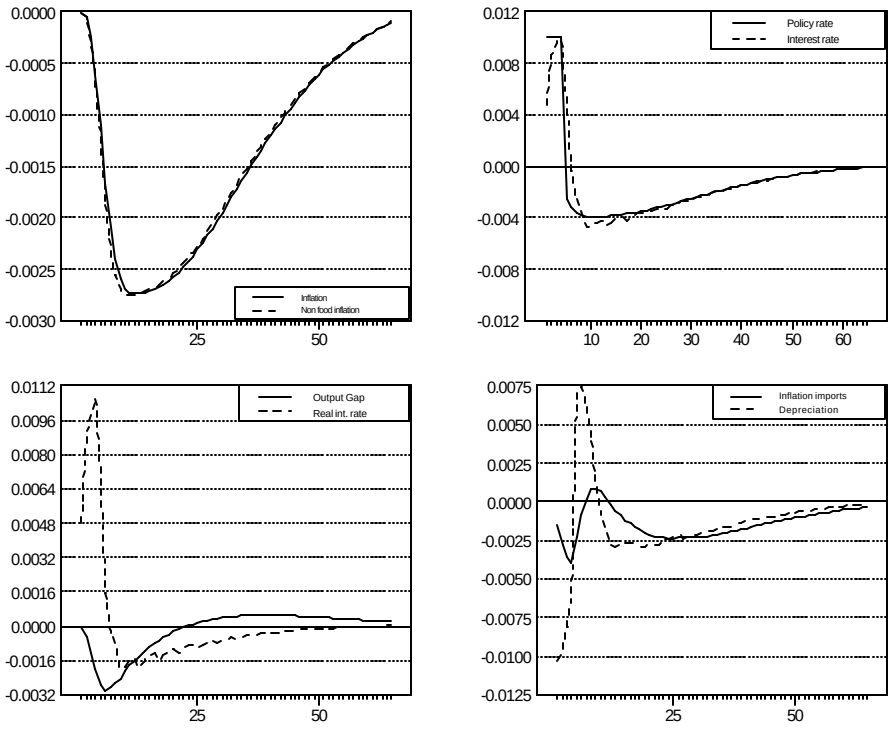


Figure 15: A transitory shock to the policy rate

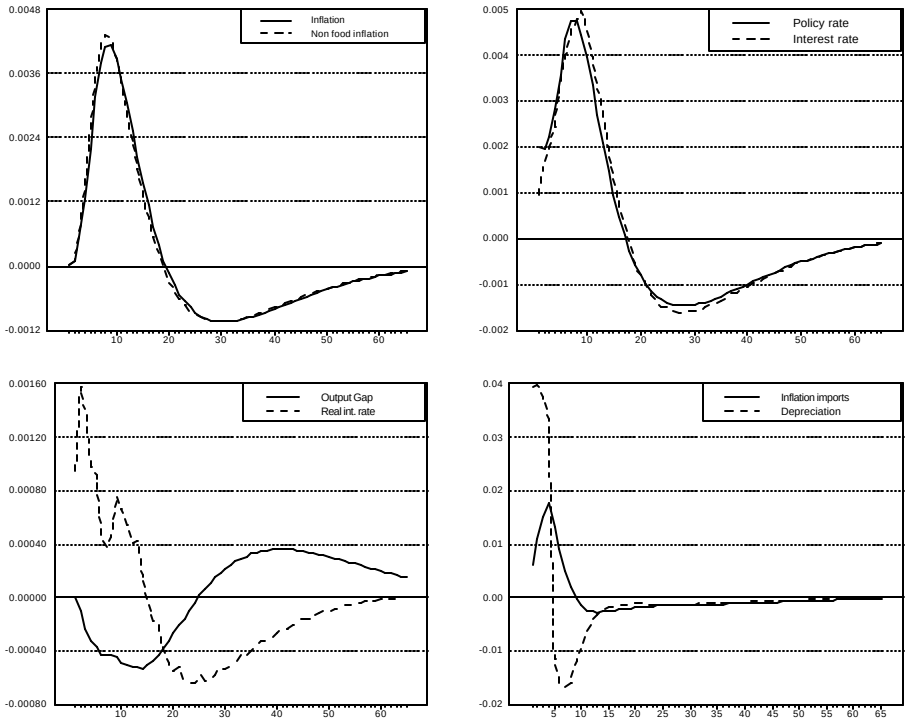


Figure 16: A shock to the country risk premium

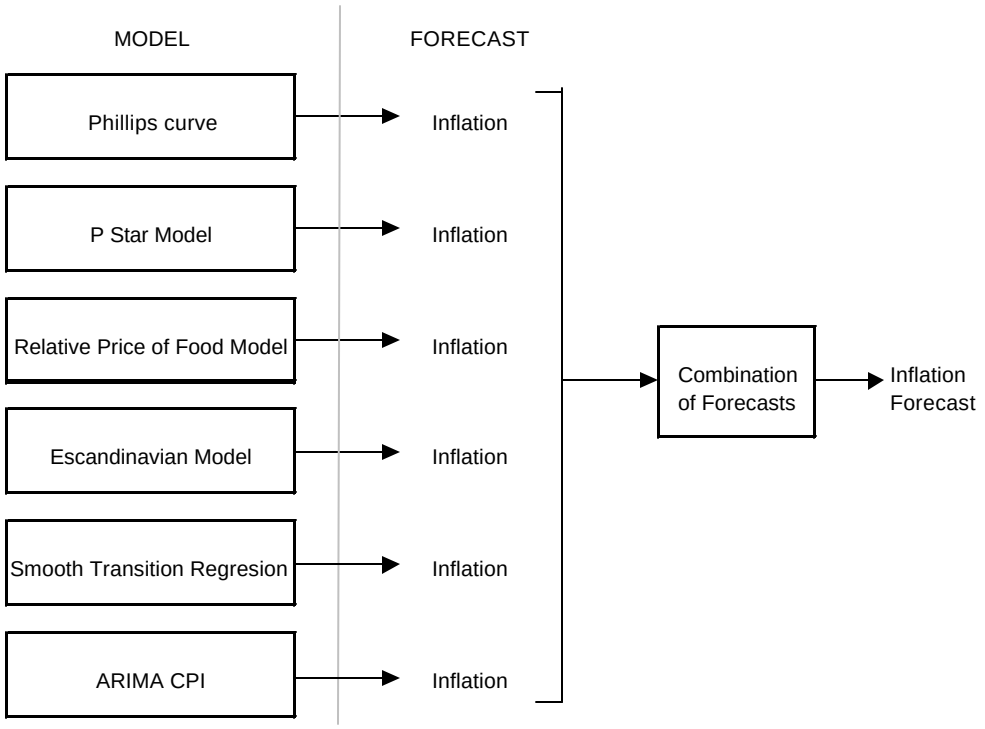


Figure 17: Combination of Forecasts

6 The Combination of Structural Models (CSM)

Figure 17 describes the single equation structural models used in forecasting inflation. Considered in isolation, each of these models focuses on a few among the many elements that may impact on inflation. In order to have an idea of the combined effect of all these inflationary sources the Banco de la República produces a combination of forecasts (Melo and Castaño (1998)). The combination of forecasts uses the forecasts of each of these structural models and may also include the forecast of other auto-regressive models. The combination of forecasts is a statistical methodology that weights the forecast of each model to produce a single forecast. The weights depend on the quality of every model's forecast.

The models used in the combination of forecasts may enter of leave the combination depending on the results of statistical tests and the quality of their forecasts.

6.1 The Phillips Curve Model

This model, developed for Colombia by López and Misas (1998) is based on the triangular Phillips curve model. It is an augmented Phillips curve since it incorporates inflation expectations. The estimation of this model incorporates a variable that measures the probability of change in the inflation regime. This probability switches according to a Markov chain.

6.1.1 Estimation

$$\begin{aligned}\pi_t &= \underset{(5.568)}{0.437}\pi_{t-4} + \underset{(4.174)}{0.304}\pi_{t-6} + \underset{(2.833)}{0.151}y_{t-1} + \underset{(2.446)}{0.157}\pi^M_{t-2} \\ &\quad + \underset{(4.123)}{0.019}P_{1t} - \underset{(-6.134)}{0.075}\,D_{1t} + \underset{(4.869)}{0.028}d_{1t} + \underset{(3.676)}{0.016}d_{2t} - \underset{(-2.920)}{0.012}\,d_{3t}\end{aligned} \tag{19}$$

Estimation method OLS
Sample: 1980Q1−2001Q2
$R^2 = 0.813$
Standard error 0.011

6.1.2 Definitions

π_t is the first difference of the log of the end of period CPI.

y_t is the output gap estimated by the production approach to potential output.

π^M_t is the first difference of the logarithm of the PPI for imports.

P_{1t} is the probability of being in a state of high inflation according to Hamilton's switching model.

D_{1t} a pulse dummy for 1986Q2.

d_{it} seasonal dummies.

6.2 P* Model

The seminal paper on the P star model was proposed by Hallman et. al. This model is based on the quantity theory of money. The Banco de la República currently runs two versions of this model: the original one and a modified version (Misas, López and Melo (1999)). The original version assumes that velocity is stationary. In this case the price level depends on the velocity gap (M1 velocity) and the output gap (measured with the HP filter). However, as the stationarity tests are not conclusive[16], a modified version of the P star model was constructed. This version assumes that velocity is integrated of order one. The modified version includes a long run for the demand for money, that is, a cointegrating error for money demand

[16]The study included stationarity tests for velocity measured with different monetary aggregates: monetary base, M1, M3.

and its determinants. In the modified case the price level is determined by the output gap (measured by the gap of the industrial production index) and the monetary gap (measured by the monetary base).

6.2.1 Estimation

$$\begin{aligned}\pi_t &= \underset{(4.241)}{0.328}\pi_{t-2} + \underset{(8.038)}{0.618}\pi_{t-4} + \underset{(0.860)}{0.044}y_{t-1} + \underset{(3.180)}{0.085}m_{t-1} \\ &\quad - \underset{(-4.838)}{0.059}\, D_{1t} + \underset{(3.998)}{0.035}D_{2t} + \underset{(3.959)}{0.048}D_{9t} - \underset{(-2.064)}{0.009}\, d_{2t} - \underset{(-3.887)}{0.031}\, d_{3t} - \underset{(-3.830)}{0.024}\, d_{4t}\end{aligned} \tag{20}$$

Estimation method OLS
Sample 1980Q1−2001Q2
$R^2 = 0.808$
Standard error 0.011

6.2.2 Definitions

m_t is the deviation of M1 from HP filter.
D_{2t} pulse dummy for 1985Q1-1985Q2.
D_{9t} pulse dummy for 1986Q4.

6.3 The Relative Price of Food Model

Inflation in Colombia is mainly determined by the output gap and supply shocks in the agricultural sector. These two are the main two elements that this model intends to capture. The projection of the relative price of food is exogenous to this model and it is constructed with another model that projects the overall price of food with the projection of a separate model for each type of product. The model is complemented in the right hand side with the growth of money, a variable that in Colombia, has traditionally been attended..

6.3.1 Estimation

$$\begin{aligned}\pi_t &= \underset{(9.461)}{0.604}\pi_{t-4} + \underset{(6.170)}{0.297}\pi_{t-6} + \underset{(4.581)}{0.397}\pi_t^R + \underset{(2.408)}{0.21}\, \pi_{t-5}^R + \underset{(-)}{0.099}M_{t-3}^1 \\ &\quad + \underset{(2.204)}{0.102}y_t - \underset{(-7.141)}{0.075}\, D_{1t} + \underset{(3.540)}{0.028}D_{2t} - \underset{(-2.67)}{0.020}D_{3t} - \underset{(-4.971)}{0.042}\, d_{3t}\end{aligned} \tag{21}$$

Estimation method: OLS
Sample 1980Q1-2001Q2
$R^2 = 0.856$
Standard error 0.010

6.3.2 Definitions

π_t^R is the first logarithmic difference of the price of food relative to the CPI.
M_t^1 first difference of the logarithm of M1.
D_{3t} pulse dummy for 1999Q1-1999Q2.

6.3.3 Estimation Issues

The estimation was restricted to homogeneity in the lags of inflation. The F-statistic of the homogeneity restriction is $F = 2.698$, p−value 0.105.

6.4 The Escandinavian Model

This model follows the Escandinavian tradition[17] where inflation in a small open economy is determined by cost push elements as the growth of wages and the exchange rate depreciation over and above the rate of inflation.

$$\begin{aligned}\pi_t &= \underset{(4.381)}{0.354}\pi_{t-1} + \underset{(-)}{0.646}\pi_{t-4} + \underset{(2.363)}{0.097}\chi_{t-2} + \underset{(3.735)}{0.128}\omega_t + \underset{(3.703)}{0.098}\omega_{t-3} \\ &\quad - \underset{(-5.695)}{0.073}\, D_{1t} + \underset{(2.798)}{0.025} D_{2t} - \underset{(-3.01)}{0.027}\, D_{3t}\end{aligned} \tag{22}$$

Estimation method: OLS
Sample: 1980Q1−2001Q2
$R^2 = 0.786$
Standard error 0.012

6.4.1 Definitions

χ_t first difference of the logarithm of the real exchange rate.
ω_t is the quarterly growth of wages in the industrial sector.

6.4.2 Estimation Issues

The homogeneity restriction has a statistic $F = 2.540$, p-value $= 0.115$.

7 The Neoclassical Growth Model

This model produces a path for potential output that is used as an exogenous input in the MMT.

The production function is Cobb-Douglass in the inputs of capital and labor:

$$\mathbf{Y}_t = \mathbf{A}_t \mathbf{K}_t^{\alpha} \mathbf{N}_t^{1-\alpha} \tag{23}$$

where

[17] Aee for instance Corbo (1985) and Corbo and Fischer (1995).

$\mathbf{Y}_t$ is real output in 1994 pesos.
$\mathbf{A}_t$ is the technology factor, an index number.
$\mathbf{K}_t$ is the stock of capital in 1994 pesos.
$\mathbf{N}_t$ is the labor force in number of people employed, source DNP.
The stock of capital was built with Harberger's inventory method:

$$\mathbf{K}_{t+1} = (1-\delta)\mathbf{K}_t + \mathbf{I}_t \tag{24}$$

$$\mathbf{K}_{1950} = 2.5\mathbf{Y}_{1950} \tag{25}$$

where

$\mathbf{I}_t$ is gross investment (public, private, and change in inventories[18]) in 1994 pesos.

δ is the rate of depreciation.

The production function (23) may be written

$$Y_t = \alpha_0 + \alpha_t t + \alpha K_t + (1-\alpha) N_t + \varepsilon_t^Y$$

where Y_t, K_t, and N_t are the logs of output, the capital stock and the labor force, and

$$A_t = \alpha_0 + \alpha_t t + \varepsilon_t^Y \tag{26}$$

is the technology factor.

7.1 Measuring technology and the productivity slowdown

The technology factor may be measured as in Eq. (26), or computed as

$$\mathbf{A}_t = \frac{\mathbf{Y}_t}{\mathbf{K}_t^{\alpha}\mathbf{N}_t^{1-\alpha}}$$

The technology index and the rate of technological change appear in Figure 18. In Colombia the productivity slowdown may have started by 1975. The nineties are characterized by a higher rate of technological change possibly explained by the opening of the economy and the use of information technology. The negative technological shock of the late nineties is most probably explained by the international recession and by the kind of political developments explained by Cárdenas (2001).

7.2 The sources of growth

Table 2 and Figure 19 show the sources of growth in Colombia in selected periods. The productivity slowdown appears as the main element explaining the slower growth since 1975.

[18] Figures for fixed private investment are not easy to construct for a useful period.

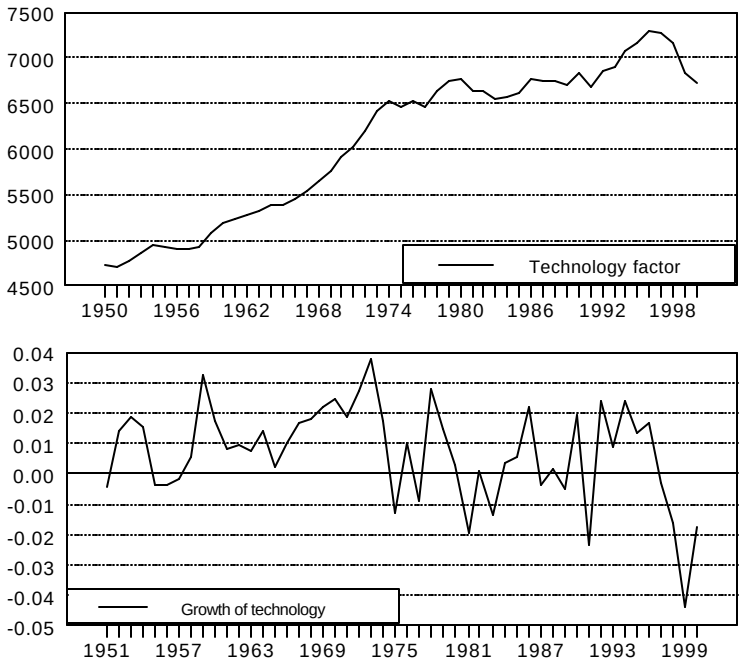


Figure 18: The Productivity Slowdown in Colombia

	GDP growth	Technological change	Growth of inputs	Growth of capital	Growth of labor
1950-1974	5.2	1.4	3.8	4.5	3.3
1975-2000	3.5	0.2	3.3	4.4	2.6
1975-1998	*3.8*	*0.4*	*3.4*	*4.5*	*2.7*
2001-2010	3.3	0.8	2.5	2.9	2.4

Table 2: The sources of growth 1950-2000 and projection 2001-2010

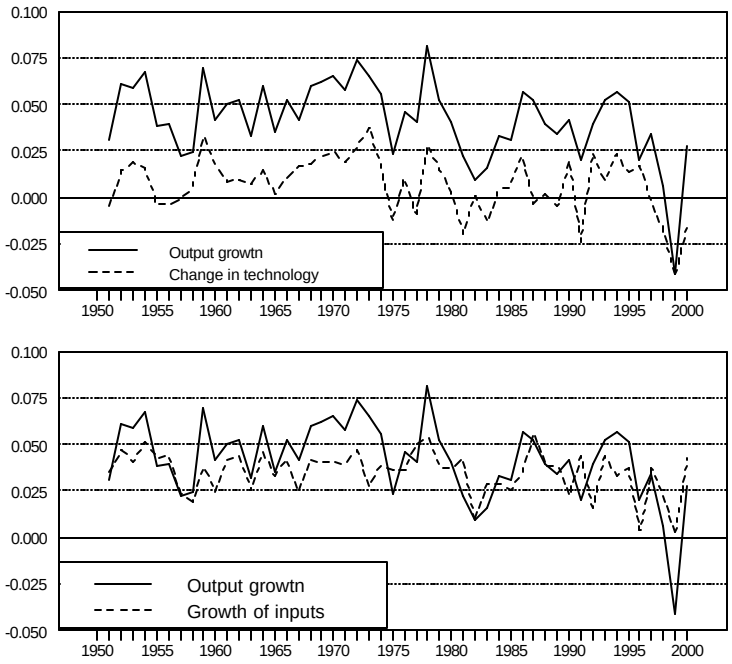


Figure 19: The sources of growth in Colombia 1950-2000

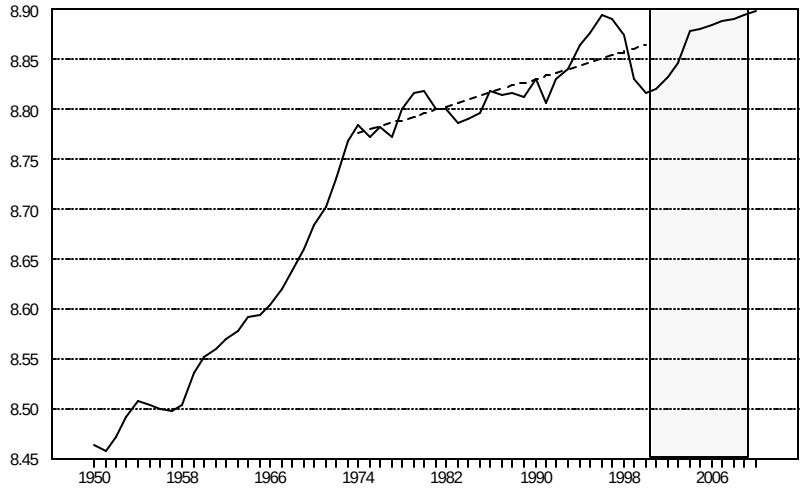


Figure 20: Projection of the technology factor

7.3 Prospects for growth in the long run

Figures (20), (21) and (22) show the projection of technology, the share of investment and the labor force.

In projecting the technology index, we assume it gradually converges to a long run trend that grows at an annual rate of 0.4%, as observed since 1975 (Figure 20).

The share of investment grows linearly until 2004 when it reaches the long run average of 18.3% (Figure 21).

In the projection of the labor force (Figure 22) the number of employees evolves according to

$$\mathbf{N}_t = (1 - u_t) p_t \overline{\mathbf{P}}_t \tag{27}$$

where

$\mathbf{N}_t$ is the labor force

u_t is the economy wide unemployment rate

$\underline{p_t}$ is the participation rate

$\overline{\mathbf{P}}_t$ is population.

In turn, $\overline{P}_{t+1} = (1 + n_t)\overline{P}_t$ where n_t is an exogenously given rate of population growth.

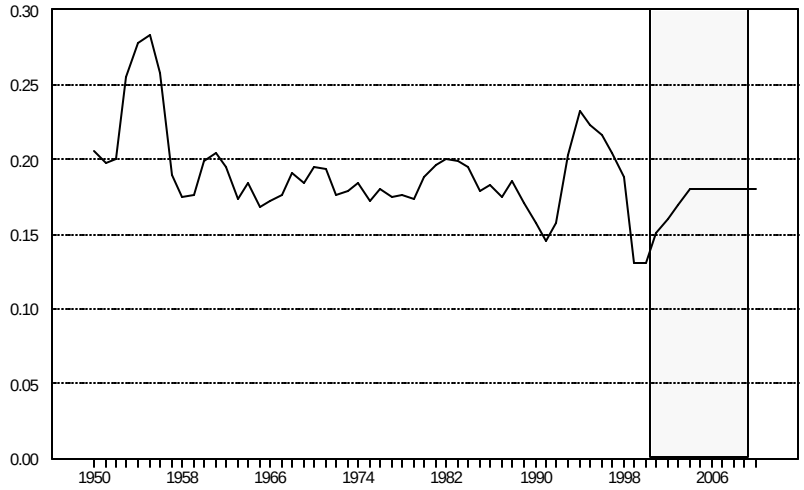


Figure 21: Projection of the share of investment

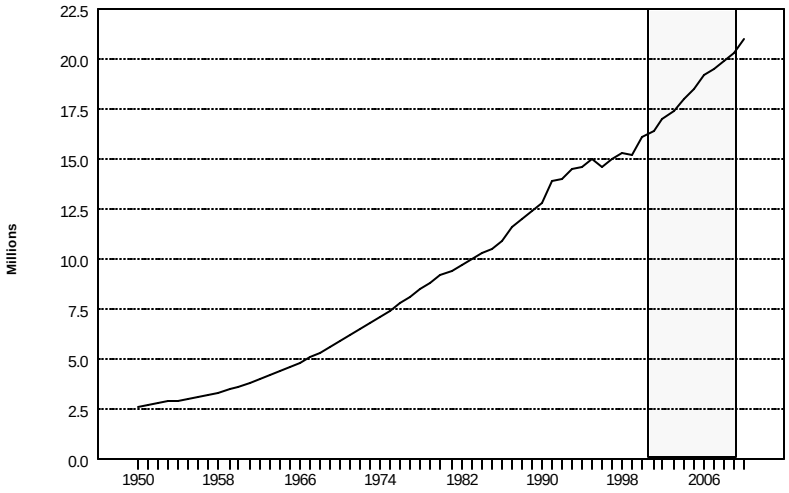


Figure 22: Projection of the labor force

7.4 The neoclassical growth model

The projection of output and the capital stock is obtained iterating the system[19]:

$$\mathbf{K}_{t+1} = (1-\delta)\mathbf{K}_t + \theta_t \mathbf{I}_t \tag{28}$$

$$\mathbf{Y}_t = \mathbf{A}_t \mathbf{K}_t^{\alpha} \mathbf{N}_t^{1-\alpha} \tag{29}$$

The results for the growth of output and its sources are presented in the last row of Table 2. Output growth is 3.4%, split into technology growth (0.8%) and the growth of inputs (2.5%). Output and capital grow at a rate that is higher than the one in the steady state because of the initial conditions.

From Lucas (1988) the long run rate of output g may be written, $g = \frac{\mu}{(1-\alpha)} + \lambda$ where μ is the rate of technological change, $(1-\alpha)$ is the share of labor in national income and λ is the (assumed constant) rate of growth of the labor force. Output per worker (and output per capita for a constant participation rate p_t) grows at the rate $\frac{\mu}{(1-\alpha)}$, as α is a parameter, *increases in the rate of growth of output per capita are possible only with increases in the rate of technological change.* It is then misleading to place emphasis in the share of investment since it is only a level effect.

7.5 Potential output and the output gap

Potential output was obtained with the formula[20]

$$\mathbf{Y}_t^P = \overline{\mathbf{A}}_t \mathbf{K}_t^{\alpha} \overline{\mathbf{N}}_t^{(1-\alpha)} \tag{30}$$

where

$\overline{\mathbf{Y}}_t$ is potential output

$\overline{\mathbf{A}}_t$ is the Hodrick-Prescot filter of the technology index, smoothing parameter 100.

$\overline{\mathbf{N}}_t$ is the Hodrick-Prescot filter of the labor force, smoothing parameter 100.

The long run levels of technology and the labor force are shown in Figure 23.

The output gap is calculated as:

$$y_t = Y_t - Y_t^P$$

[19] An analytical solution of this model for $\delta = 0$ is found in Lucas (1988). We assume $\delta = 0.04$ and solve the system numerically.

[20] The capital stock and capacity utilization figures were not filtered because the recursive nature of the algorithm makes small errors accumulate and even out only in the long run.

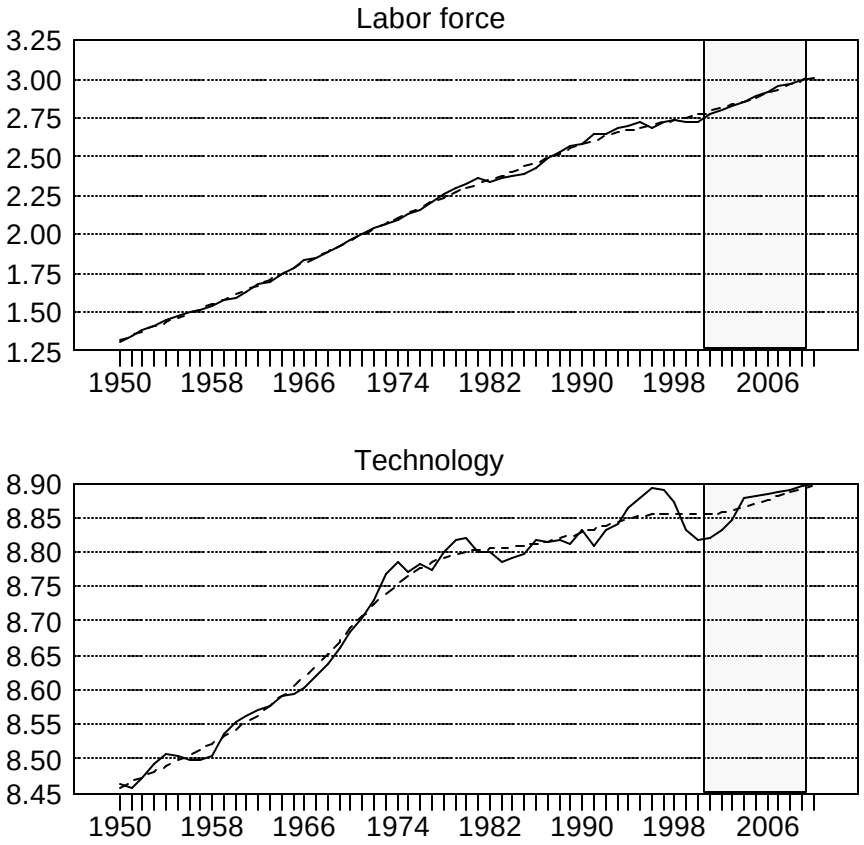


Figure 23: The long run of technology and the labor force

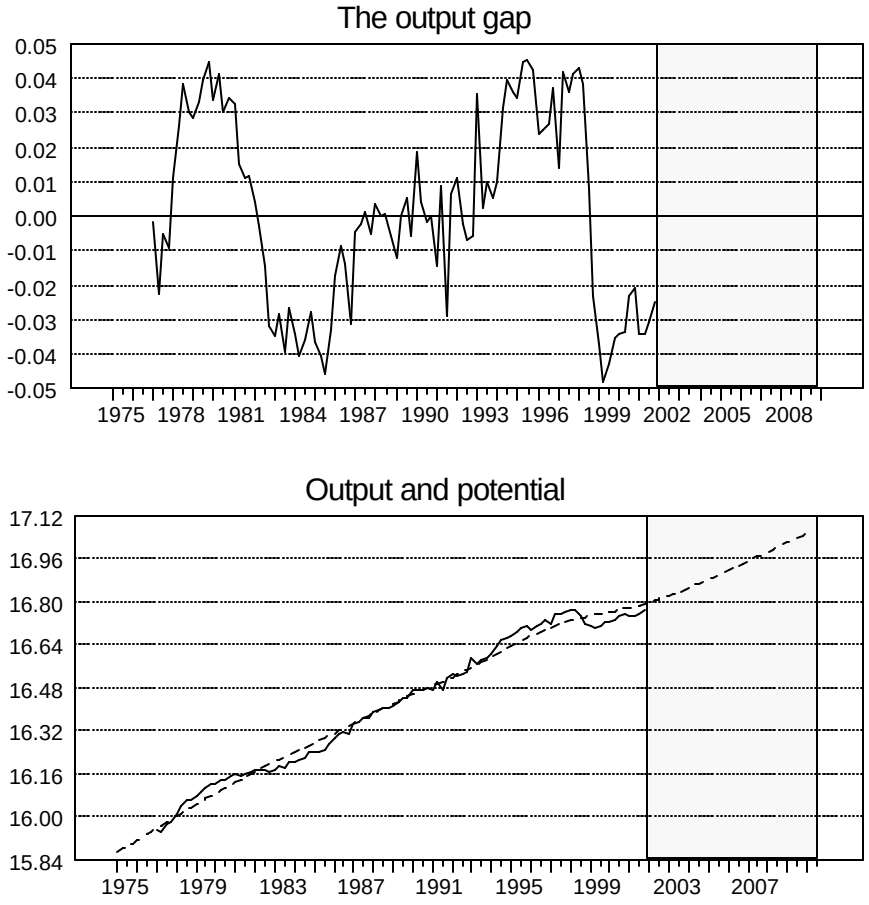


Figure 24: Potential output and the output gap

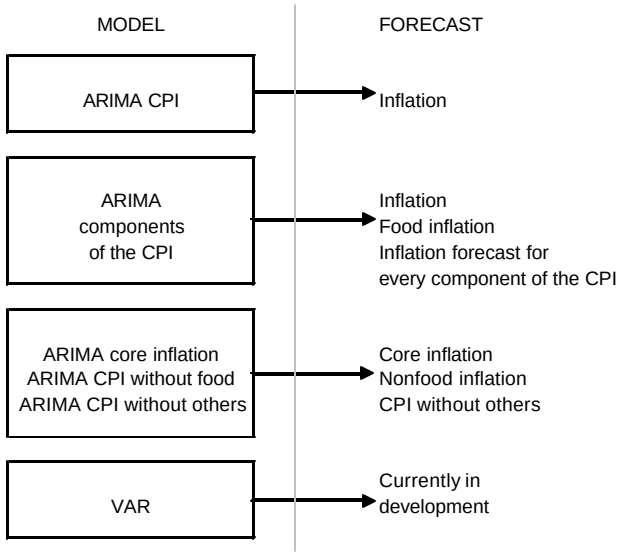


Figure 25: Autoregressive Models

where $Y_t^P = \log(\mathbf{Y}_t^P)$, $Y_t = \log(\mathbf{Y}_t)$. It is shown in Figure 24. Different levels of the output gap are obtained with different levels of the smoothing parameter in the Hodrick-Prescot filter.

8 Autorregresive Models

The auto-regressive models used in the Banco de la República are described in Figure 25. Given the accuracy of ARIMA projections in the short run, when running the MMT short run projections of the CPI or its components are at times used as data directly observed.

Autorregresive projections for core inflation help judge whether the extent of price rigidities in the MMT is appropriate. Discrepancies may be reconciled by calibrating the weights of the backward and forward looking components in the Phillips curve.

Aiming at improving its forecasting capabilities, the Banco de la República is currently developing some VAR models that may be used to forecast inflation.

9 Conclusions

Colombia started announcing inflation targets very early in the history of the countries that have adopted inflation targeting: 1991. However, the first inflation targets had more the character of a forecast within a program of macroeconomic consistency rather than a hard overriding objective of monetary policy.

Since the early 1990s the Constitution and the Law of the Banco de la República established the legal framework that is appropriate for price stability. The legal framework makes the central bank considerably independent. It also states that the objective of the central bank is price stability, that the central bank has to announce an inflation target once a year and that the central bank is required to submit a report to Congress twice a year.

Although the transition to inflation targeting has been gradual, the current management of monetary policy has all the features of inflation targeting: a floating exchange rate, central bank independence and accountability, and quarterly Inflation Report where monetary policy decisions are explained. The Banco de la República still monitors monetary aggregates and defines indicator corridors for the monetary base. The monetary approach can be a complement to the inflation targeting strategy while progress in the development of the Inflation Forecasting System is achieved.

In the last few years inflation decreased to one digit, a history of a quarter of a century of moderate inflation has ended, and since 1997 the inflation targets have been met. Currently established inflation targets are decreasing and a 3% long run target has been announced.

Giving support to economic analysis, macroeconomic models may help improve the evaluation of future trends in inflation, the effect on inflation of new developments in the economy and the effect on inflation of different policies. This paper has presented the current state of the Inflation Forecasting System of the Banco de la República, a set of macroeconomic and econometric models that is constantly in development. There are several topics in the research agenda and many improvements may be introduced to the current system, including its simplification. We hope this presentation of the inflation forecasting system as a whole may contribute to this improvement.

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