La serie "Borradores de Economía" es una publicación de la Subgerencia de Estudios Económicos del Banco de la República. Los Trabajos son de carácter provisional, las opiniones y posibles errores son responsabilidad exclusiva de los autores y sus contenidos no comprometen al Banco de la República ni a su Junta Directiva.

OUTPUT GAP ESTIMATION, ESTIMATION UNCERTAINTY AND ITS EFFECT ON POLICY RULES

Por:

Juan Manuel Julio
Javier Gómez

1999 **No. 125**

Para comentarios favor dirigirse a los autores:
Teléfono: 3430529 – 3430564 Fax: 2865936

Output Gap Estimation, Estimation Uncertainty and its Effect on Policy Rules

Juan Manuel Julio and Javier Gómez*

May 1999

Abstract

The authors propose a short run model for the monetary *transmission mechanism* in which the output gap is modelled as an *unobserved variable.* By estimating this model using maximum likelihood on a Kalman Filter, the authors find an estimate of the unobserved output gap as well as its *estimation uncertainty.* The *performance of monetary rules* is studied both with certainty on the output gap values as well as with *estimation uncertainty.*

Although the estimated gap is more reasonable than some other estimates proposed for Colombia, it is estimated with a considerable amount of uncertainty. In fact, the gap is not significantly different from zero in all but five quarters. This result amounts to say that we can not be sure about the sign or value of the gap except when the economy faces an unusual rate of growth. Moreover, we found that potential output does not differ statistically from a linear trend, thus, the gap may be understood as deviations from a linear trend, being the money surprises the source of this deviations. This result may be due to the sample length.

In addition, we estimated the optimal linear policy rule with and without uncertainty and used it as a benchmark to evaluate the Taylor rule and the historical data. By introducing output gap estimation uncertainty the variance of the target variables increases, and so the reaction of the authority is smaller. Finally, Colombian historical results resemble those of an economy under a Taylor rule with uncertainty.

JEL Classification: G00; E32; E58.

*jjulioro@banrep.gov.co Both authors work in the Research Department of the Banco de la República, the central bank of Colombia. The content of this paper does not compromise the Banco de la República nor it Board of Governors.

1 Introduction

In this paper we propose a short run model for the monetary transmission mechanism in which the output gap is an unobserved variable. By estimating this model using maximum likelihood on a Kalman Filter, we find an estimate of the unobserved output gap as well as its estimation uncertainty. The performance of monetary rules is studied both with certainty on the output gap values and with estimation uncertainty.

We split the relationship between money and inflation into the short and the long run. The long run transmission mechanism from money to prices as well as the transition to international levels of inflation was already dealt with in Gómez and Julio (1999) while the short run relationship is the subject matter of this paper.

Our short run model consists of an aggregate demand equation and an expectations augmented Phillips curve. In the first equation the output gap depends on its own lags and the monetary surprise while in the second the short run inflation movements depend lagged inflation and output gap. Unanticipated money determines the output gap on impact, and the output gap determines inflation with a two year lag.

There are several ways to filter out the short or log run components of a time series. Lucas (1998), for example, extracts the long run component of money and inflation with a two tailed exponential filter, while Hodrick and Prescott (1980) extract the long run component with a smoothing minimization problem. For this paper we measure the short run inflation as the deviation from the core measured as the Hodrick Prescott filtered inflation. We abstract from long run "core" inflation since its behavior may better be explained by a long run model as in Gómez and Julio (1999). On the other hand, the deviations of inflation from the core are explained in our model by the short run mechanics of unanticipated money and the output gap. Where the monetary surprises are defined as in Barro (1977), i.e. the residual of an autoregressive process on the money growth.

Once the model is set up in State Space form, it is straightforward to obtain the likelihood function and the estimated parameters. Using the estimated parameters, the Kalman filter provides us with filtered and smoothed estimates of the unknown output gap as well as the estimation uncertainty. The difference between these two being the sample update effect.

Our estimated gap is more reasonable than some other estimates proposed for Colombia. In particular, our estimate captures well the slowdown of the eighties along with the subsequent recovery in the early nineties. It also depicts well the deflationary pressures in the nineties. Associated with the estimated gap we found a considerable amount of uncertainty in its estimation. In fact, the gap is not significantly different from zero in all but five quarters. This result amounts to say that we can not be sure about the sign or value of the gap except when the economy faces an unusual rate of growth. Hence, the gap could not be a good leading indicator of inflation or inflationary pressures.

Another interesting finding is that potential output does not differ statistically from a linear trend, thus, the gap may be understood as deviations from a linear trend, being the money surprises the source of these deviations. This result may be due to the sample length.

We estimated the optimal linear policy rule with and without uncertainty on the past and present values of the gap and used it as a benchmark to evaluate the Taylor rule and the historical data. By introducing output gap estimation uncertainty the variance of the target variables increases, and hence the reaction of the authority is smaller. Finally, Colombian historical results resemble those of an economy under a Taylor rule with uncertainty.

The plan of the paper is as follows. In the second part we explain the short run transmission mechanism of monetary policy. Following Smets (1998), in the third part we estimate the output gap as a variable that is unobserved. Following Rudebusch and Svensson (1998), in the fourth part we use the short run model to evaluate the performance of the Taylor rule and the actual monetary policy. Finally we present some conclusions.

2 The Short Run Monetary Transmission Mechanism

2.1 The Short Run Model

The model consists of an expectations-augmented aggregate demand, and an expectational Phillips curve.

The aggregate demand equation is intended to capture the relationship between the economic activity and a measure of the stance of monetary policy measured as the unanticipated money growth. If we denote z to be the output gap in percentage points and m the unanticipated component of money growth, the aggregate demand equation is:

$$z_t = \varphi_1 z_{t-1} + \varphi_2 z_{t-2} + \lambda m_t + \varepsilon_t^z \qquad (1)$$

The Phillips curve relates the real side of the economy, the gap z, with inflation π:

$$\pi_t = \alpha_1\pi_1 + \alpha_2\pi_2 + \alpha_3\pi_3 + \alpha_4\pi_4 + \beta z_{t-8} + \varepsilon_t^\pi \qquad (2)$$

To complete the model we need a law of motion of unobserved potential output:

$$y_{t+1}^p = \mu + y_t^p + \varepsilon_t^y \qquad (3)$$

and the definition of the output gap:

$$y_t = y_t^p + z_t \tag{4}$$

2.2 Features of the Model

2.2.1 Monetary Surprises

Following a long tradition in monetary studies, as in Barro (1977), and (1978), Grossman (1981), and Kormendi and Maguire (1984), we decompose money growth in anticipated and unanticipated:

$$\Delta \log M_t = c + \sum_{i=1}^{\infty} \beta_i \Delta \log M_{t-i} + m_t \tag{5}$$

In (5) M is the logarithm of the money, the adjusted monetary base in the empirical exercise, $c + \sum_{i=1}^{\infty} \beta_i \Delta \log M_{t-i}$ is anticipated money growth, and the error term, m_t, is unanticipated money growth or the surprise in money growth.

2.2.2 Expectations Augmented Aggregate Demand

While the anticipated component of money growth does not cause movements in output, the unanticipated growth does determine real activity. That is, output is neutral to anticipated money growth and not neutral to unanticipated money growth ($\lambda \neq 0$).

2.2.3 Expectations Augmented Phillips Curve

Because lagged inflation helps explain current inflation, the Phillips curve is expectational. If the coefficients of the four inflation lags sum to one, there is full inflation persistence and the Phillips curve is vertical.

2.2.4 A Lag in the Effect of Monetary Policy

While the unanticipated money determines the output gap on impact, the output gap affects the short run inflation rate after two years. Thus, there is a two year lag in the effect of monetary policy on output. In Gómez and Julio (1999) we argue that money does not have a discernible impact on prices in the short run but causes a 1 to 1 response on prices in the long run, thus, there is a lag in the effect of monetary policy on prices that for the case of Colombia we estimate in 11 quarters. As the specification of this short run model shows, the response of the short run component of inflation to money also lags several quarters.

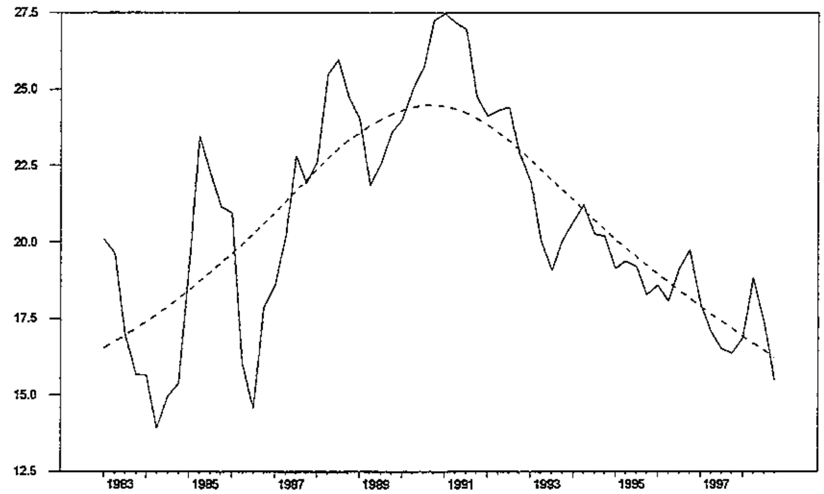

Figure 1: Observed and Long Run Inflation

2.2.5 A Transmission Mechanism that is Significant

We tried different specifications of the model, in particular introducing the real exchange rate in the aggregate demand equation, but unfortunately there was not significant improvement. Further research could help improve the model specification.

2.2.6 A Specification of the Evolution of Potential Output

In (3), if the variance of the change in potential output is not zero, $\sigma_y = 0$, potential output is not stationary and follows a random walk with drift. If $\sigma_y = 0$, output is stationary, it is a deterministic trend.

3 The Data

Our measure of inflation is the four quarter difference of the logarithm of the consumer price index: $\pi = 100 * (p_t - p_{t-4})$ expressed as deviation from the Hodrick Prescott Filter with $\lambda = 1600$. Figure 1 shows observed inflation and the core while Figure 2 shows the short run component of inflation, the deviation of inflation from the core.

Figure 3 illustrates unanticipated money growth where the measure of money is the adjusted monetary base. The figure reveals the large swings of monetary policy in the nineties: the expansion of 1991-1992, the contraction of 1995-1996, and the contraction of 1998. Money growth in equation (5) is measured as the first logarithmic difference. Money surprises in Figure 3

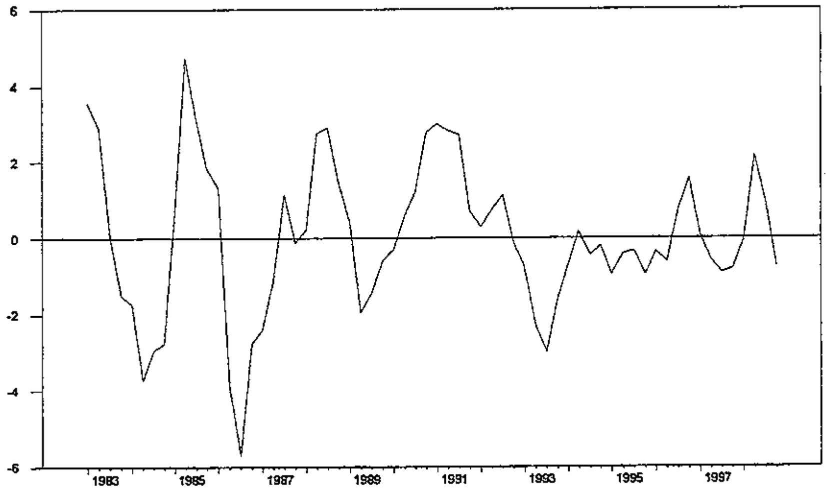

Figure 2: Deviation of Inflation from Core

are measured as $\Delta \tilde{m}_t = 100 * (\sum_{j=1982:1}^{t} m_j - \sum_{j=1982:1}^{t-4} m_j)$.

4 The Estimated Output Gap

We write the model 1 to 4 in state space representation where the state equation is given by

$$X_t = FX_{t-1} + Gu_t + \eta_t$$

and the observation equation is

$$Y_t = HX_t + Du_t + P\varepsilon_t$$

where

$$X_t = \begin{bmatrix} z_t \\ z_{t-1} \\ z_{t-2} \\ z_{t-3} \\ z_{t-4} \\ z_{t-5} \\ z_{t-6} \\ z_{t-7} \\ z_{t-8} \end{bmatrix}, F = \begin{bmatrix} \sum_{j=1}^{2} \varphi_j f_j \\ f_1 \\ f_2 \\ f_3 \\ f_4 \\ f_5 \\ f_6 \\ f_7 \\ f_8 \end{bmatrix}, G = \begin{bmatrix} h_5\lambda \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, u_t = \begin{bmatrix} \pi_{t-1} \\ \pi_{t-2} \\ \pi_{t-3} \\ \pi_{t-4} \\ m_t \end{bmatrix}$$

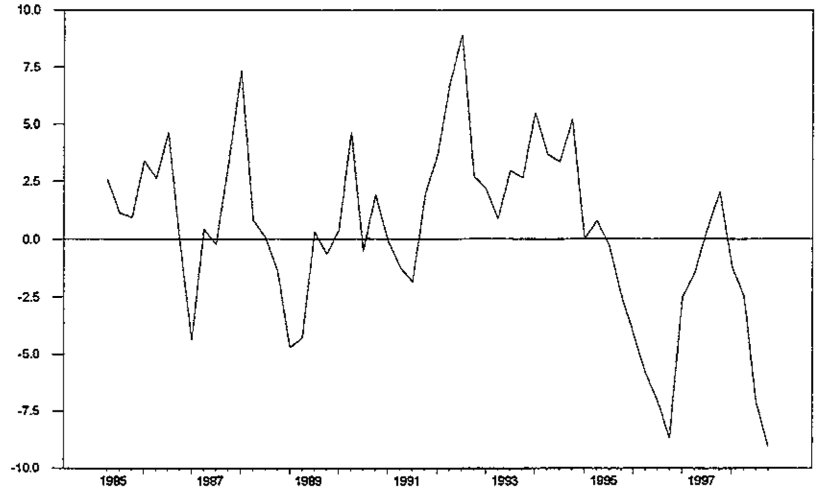

Figure 3: Unanticipated Money Growth

$$Y_t = \begin{bmatrix} y_t - y_{t-1} \\ \pi_y \end{bmatrix}, H = \begin{bmatrix} e_1 - e_2 \\ e_0 \end{bmatrix}, D = \begin{bmatrix} h_0 \\ \sum_{j=0}^{4} \alpha_j f_j \end{bmatrix}, P = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \varepsilon_t = \begin{bmatrix} \varepsilon_t^y \\ \varepsilon_t^\pi \end{bmatrix}$$

and f_j is a 1x9 vector whose $(1,j)$ element is 1 and the other elements are zero, and h_j is a 1x5 vector with a 1 in position $(1,j)$ and zero elsewhere, and h_0 1x5 vector of zeros.

For estimation all unknown parameters were arranged in a row vector of the form,

$$\Theta = \begin{bmatrix} \varphi_1 & \varphi_2 & \beta & \alpha_1 & \alpha_2 & \alpha_3 & \alpha_4 & \lambda & \sigma_y^2 & \sigma_p^2 & \sigma_z^2 \end{bmatrix}$$

Given initial values of the parameters, the state variables at time cero, and forecast variances at time cero, the Kalman filter provides the observation equation residuals from which we calculate the likelihood function.

Maximization of the likelihood function is carried out by standard numerical procedures. The value of the Hessian matrix, H, was provided in each step, and from the last step Hessian we obtain the estimated Fisher

	Coefficient	Standard Error	T Statistic
φ_1	0.513	0.142	3.607
φ_2	0.359	0.138	3.603
β	0.343	0.160	2.144
α_1	0.821	0.118	6.948
α_2	-0.414	0.150	-2.762
α_3	0.259	0.152	1.700
α_4	-0.476	0.111	-4.302
λ	0.224	0.075	2.983
σ_y^2	0.278	0.170	1.639
σ_p^2	1.020	0.225	4.541
σ_z^2	0.944	0.265	3.565

Table 1: Estimated Coefficients

information matrix and the asymptotic variance covariance matrix of the estimated coefficients. See Harvey (1989), Watson and Engle (1983), and Burmeister & Wall (1982) for further details.

Using the estimated parameters, we forecast the state variables and its variances, which correspond to the one sided or filtered output gap. Final estimated gaps correspond to the smoothed version which uses at each step all the sample information available in the estimation.

4.1 Results

Table 1 presents the estimated coefficients. The table reveals a significant contemporaneous effect of unanticipated money on the output gap $\lambda \neq 0$, a significant lagged effect of the output gap on inflation $\beta \neq 0$, a relatively high output persistence $\varphi_1 + \varphi_2 \equiv \varphi(1) = 0.873$, and low inflation inertia $\alpha(1) = 0.189$.

Figure 4 shows the estimated (smoothed) output gap along with the two standard deviation confidence band. This estimated gap depicts some interesting features not shown by other estimates. During the second half of the eighties it remains above zero while during the first half of the nineties it remains below zero except for the 1994-1995 period. Afterwards the gap goes below zero and then goes above during 1997 after which the gap goes far below zero.

However, there is considerable uncertainty in the estimation of the output

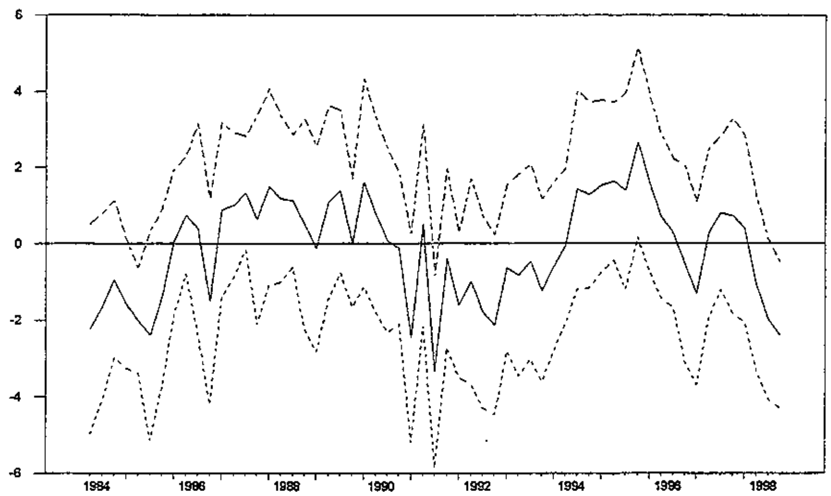

Figure 4: Estimated Output Gap and Two Standard Deviation Cofidence Band

gap. In fact, it is not statistically different form cero in all but five quarters in the sample. It means that for a point of time in which the gap is not different from zero, it is equally likely that it corresponds to inflationary or deflationary pressures. Moreover, the gap is significantly different from zero only when the economy faces an unusually high or low rate of growth. In fact, since the band is about four percentage points wide, the gap is significantly different from when it is above two percentage points or below minus two percentage points.

Since for most of the periods the estimated gaps are inside the minus two plus two interval, this result imply that the gap could not be a good tool as a leading indicator of inflationary pressures in most circumstances. However, it could shed valuable information whenever its value is outside the non significance interval.

Table 1 shows that the variance of potential output, σ_y^2, is not statistically different from zero. The Lagrange multiplier test for the null $\sigma_y^2 = 0$ takes a value of 1.309, with a p-vale of 0.252. Hence we cannot reject the hypothesis that potential output is a deterministic trend (see equation (3)) and that the output gap is the deviation of output from this trend. As the gap is simply the deviation of output from a linear trend, the growth of the gap equals the growth of output except for a constant. Table 2 presents the growth of output (or the growth of the gap) as a function of lagged output and the monetary surprise for different monetary aggregates. The table shows that, for all definitions of money, unanticipated money growth is significant in the

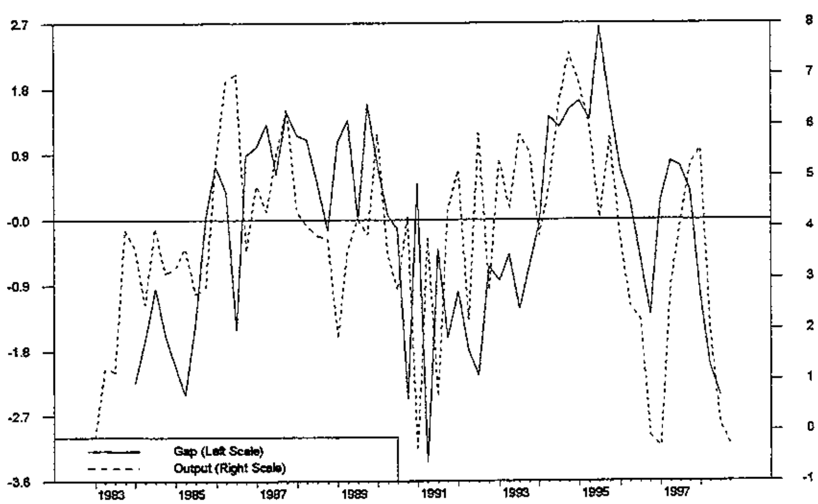

Figure 5: Unanticipated Money Growth and the Change in the Output Gap

output equation.

Further, for all the definitions of money except for broad money, our cumulative measure of unanticipated money, $\tilde{m}_t = \sum_{j=1982:1}^{t} m_j$ is cointegrated with output and a linear trend. The hypothesis of weak exogeneity of money and endogeneity of output cannot be rejected, thus, we can conclude that indeed, money causes the fluctuations of output around trend. This result is in sharp contrast with the critical view expressed, for instance, in Freeman and Kyndland (1998), where the causation between money and output goes in the opposite direction. Further, the contrast is sharp also because our measure of money is outside money or the monetary base.

5 Inflation Targeting

We follow Rudebush and Svensson (1998) in the distinction between instrument rules and targeting rules. An instrument rule dictates the behavior of the monetary instrument as a function of the available information, for instance, as a function of the state of the economy, the vector X_t. Central banks would hardly constraint themselves to follow instrument rules. Instrument rules, however, may provide a benchmark for the policy actually followed. An inflation targeting strategy minimizes deviations of inflation from target (strict inflation targeting), and also deviations of other objectives from target (flexible inflation targeting). As we show below, a targeting rule combined with a model of the workings of the economy is an implicit instrument rule. Below we compare two instrument rules implicit in the

Dependent variable GDP growth Period 1984:2 1998:4	Adjusted Monetary Base	Monetary Base	M1	M3 plus bonds
Constant	0.015	0.015	0.014	0.015
	(5.509)	(5.747)	(5.146)	(5.912)
Seasonal (t+2)	-0.039	-0.039	-0.036	-0.040
	(-4.968)	(-5.213)	(-4.615)	(-5.414)
Seasonal (t+1)	0.018	0.015	0.023	0.014
	(-1.465)	(1.277)	(1.876)	(1.240)
Seasonal (t)	0.014	0.013	0.017	0.014
	(1.358)	(1.263)	(1.603)	(1.390)
GDP growth (t-1)	-0.274	-0.274	-0.221	-0.294
	(-2.206)	(-2.242)	(-1.741)	(-2.489)
GDP growth (t-2)	-0.336	-0.361	-0.291	-0.352
	(-2.748)	(-3.005)	(-2.390)	(-2.997)
Money Surprise	0.278	0.103	0.277	0.289
	(2.624)	(2.307)	(2.756)	(2.815)
	(2.624)	(2.307)	(2.756)	(2.815)
R^2	0.809	0.806	0.811	0.814
D.W.	2.430	2.363	2.285	2.303
S.E.	0.016	0.016	0.016	0.015

Table 2: Unanticipated Money Growth and Output

following (flexible) inflation targeting problem that minimizes a weighted average of the unconditional variance of the goal variables. The problem is to minimize the expected loss:

$$E[L_t] = \gamma Var[\pi_t] + (1-\gamma)Var[z_t] + \nu Var[m_t]$$

subject to (6) and (7).

The state and observation equations are:

$$X_t = AX_{t-1} + Bm_t + v_t \tag{6}$$

$$Y_t = C_x X_t + C_m m_t \tag{7}$$

where

$$X_t = \begin{bmatrix} \pi_t \\ \pi_{t-1} \\ \pi_{t-2} \\ \pi_{t-3} \\ z_t \\ z_{t-1} \\ z_{t-2} \\ z_{t-3} \\ z_{t-4} \\ z_{t-5} \\ z_{t-6} \\ z_{t-7} \end{bmatrix}, A = \begin{bmatrix} \sum_{j=1}^{4} \alpha_j e_j \\ e_1 \\ e_2 \\ e_3 \\ \sum_{j=5}^{6} \varphi_j e_j \\ e_5 \\ e_6 \\ e_7 \\ e_8 \\ e_9 \\ e_{10} \\ e_{11} \end{bmatrix}, B = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ \lambda \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, v_t = \begin{bmatrix} \varepsilon_t \\ 0 \\ 0 \\ 0 \\ \eta_t \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

and

$$Y_t = \begin{bmatrix} \pi_t \\ z_t \\ m_t \end{bmatrix}, C_x = \begin{bmatrix} e_1 \\ e_5 \\ e_0 \end{bmatrix}, C_m = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

here e_j is a 1x12 vector with a 1 in position $(1, j)$ and zeros elsewhere, and e_0 is a 1x12 vector of zeros.

5.1 Efficient Instrument Rules

An instrument rule expresses the monetary instrument m as a function of the state variables in the economy:

$$m_t = gX_t \tag{8}$$

The efficient feedback coefficients or elements of g may be obtained minimizing the weighted sum of the unconditional variance of the goal variables:

$$E[L_t] = E[Y'KY] = trace(\textstyle\sum yy)$$

where K is a diagonal matrix with elements γ, $1-\gamma$, and ν, $\sum_{yy} = C \sum_{xx} C'$, $vec(\sum_{xx}) = [I - (M \otimes M)]^{-1} vec(\sum_{vv})$, and $M = A + Bg$.

We will consider the following two instrument rules.

5.1.1 The Optimal Linear Feedback Rule

Following Sargent (1987), the optimal linear feedback rule is the solution to the problem:

$$\min_{\{m_t\}_{t=0}^{\infty}} \quad E_t \sum_{t=0}^{\infty} \delta^t Y_t' k Y_t$$

subject to (6) and (7).

The Bellman equation is:

$$X_t' V X_t = \min_{m} \left\{ Y_t' k Y_t + \delta X_{t+1}' V X_{t+1} \right\} \tag{9}$$

Replacing (6) and (7) into (9), deriving with respect to m_t, and solving for m_t, we write the optimal feedback rule:

$$m_t = -(R + \delta B' V B)^{-1} (U + \delta B' V A) X_t \tag{10}$$

the optimal feedback rule is a linear function, g, of the state vector X_t where

$$g = -(R + \delta B' V B)^{-1} (U + \delta B' V A) \tag{11}$$

Inserting the optimal rule into the right hand side of equation (9) it is possible to find the Ricatti equation

$$V = Q + Uf + f'U' + f'Rf + M'VM \tag{12}$$

where $Q = C_x k C_x$, $U = C_x k C_m$, $R = C_m' k C_m$.

With an initial value of V, the optimal feedback parameters can be found by iterating the Ricatti equation (12), and the optimal feedback rule (11).

For $\gamma = 0.5$, and $\nu = 0.25$, the optimal feedback rule is:

$$m_t = -0.194\pi_t + 0.010\pi_{t-1} - 0.014\pi_{t-2} + 0.076\pi_{t-3}$$

$$-0.737 z_t - 0.307 z_{t-1} + 0.076 z_{t-2} + 0.098 z_{t-3}$$

$$+0.079 z_{t-4} + 0.029 z_{t-5} - 0.020 z_{t-6} - 0.054 z_{t-7}$$

Of particular interest are the coefficients on contemporaneous inflation and output gap, -0.194 and -0.737, they will serve as a basis for the comparison of the Taylor rule and the historical data.

5.1.2 The Taylor Rule

In the Taylor rule the monetary instrument depends on inflation and the output gap. In (8) the g vector takes the form:

$$g = \begin{bmatrix} g_\pi & 0 & 0 & 0 & g_z & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

where g_π and g_z are the efficient inflation and output gap coefficients.

The efficient Taylor rule coefficients estimated minimizing the loss function are $g_\pi = -0.194$ and $g_z = -0.803$. These coefficients are quite similar to the corresponding elements of the optimal linear rule, also, the zero constraint on the remaining elements of vector g does not imply extreme changes to the optimal feedback parameters.

The efficient Taylor rule coefficients appear in Figure 6. The efficient coefficients are negative because monetary policy is a setting for the monetary base instead of a setting for the interest rate as if often understood in a Taylor rule. The negative sign means that in response to a positive shock to inflation or output, money should decrease. The figure shows that for a given weight on the variance of unanticipated money (for a given ν), as the weight of inflation in the loss function increases (the bigger the γ), the higher the response of monetary policy to inflation (the larger the absolute value of g_π), and the lower the response of monetary policy to the output gap (the lower the absolute value of g_z). Figure 6 also shows that the higher the weight of the variance of unanticipated money in the loss function (the higher the ν), the lower the response of monetary policy to both inflation and the output gap (the lower in absolute value g_π and g_z).

5.1.3 Comparison of the Variance of the Target Variables

Figure 7 compares the variance of inflation and the output gap in the optimal rule, the Taylor rule and the historical data. The comparison is made both for the certainty and uncertainty cases. The variance of the goal variables is the lowest in the optimal rule. As expected, for both rules the variance of the goal variables is also higher under uncertainty. The variance of the historical data is quite close to the variance of the goal variables under the Taylor rule under uncertainty. Had the authorities pursued a Taylor rule strategy under uncertainty, the weight of the inflation argument in the loss function would be close to 0.7, the weight of the output gap 0.3, and the one on money 0.25.

5.1.4 Impulse Response Functions

Figures 8 to 13 show the response of money, inflation, and the output gap to a one percentage point innovation in inflation (Figures 8 to 10) and the output gap (Figures 11 to 13). As shown in Figure 8 in response to a one

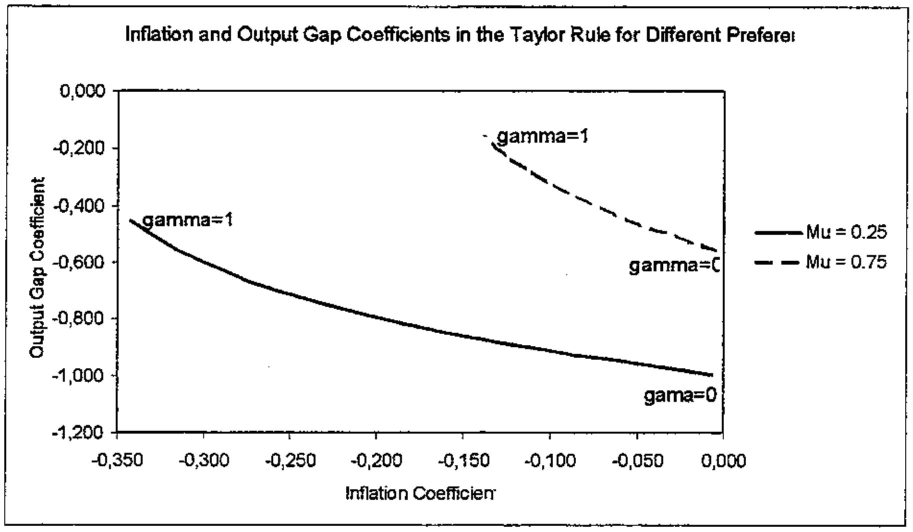

Figure 6: Inflation and Output Gap Coefficients in theTaylor Rule for Different Preferences

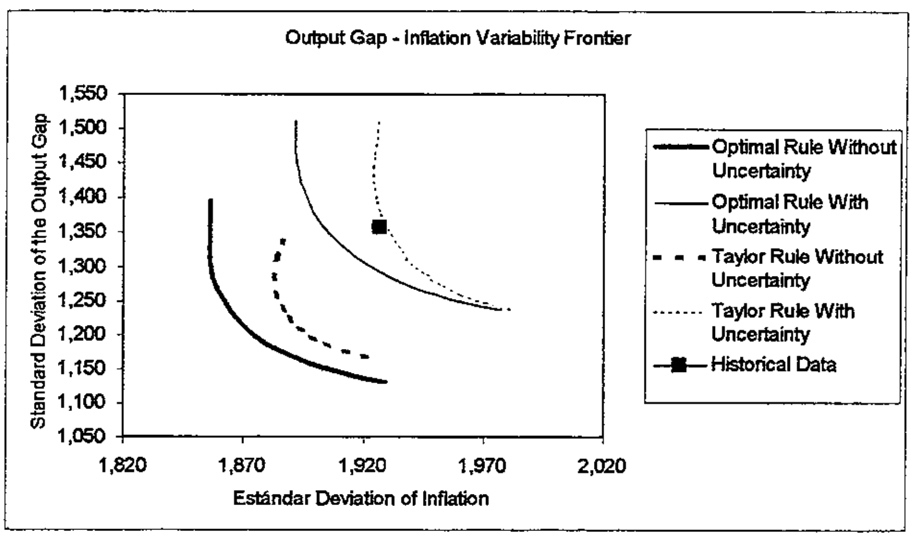

Figure 7: Output Gap - Inflation Variability Frontier

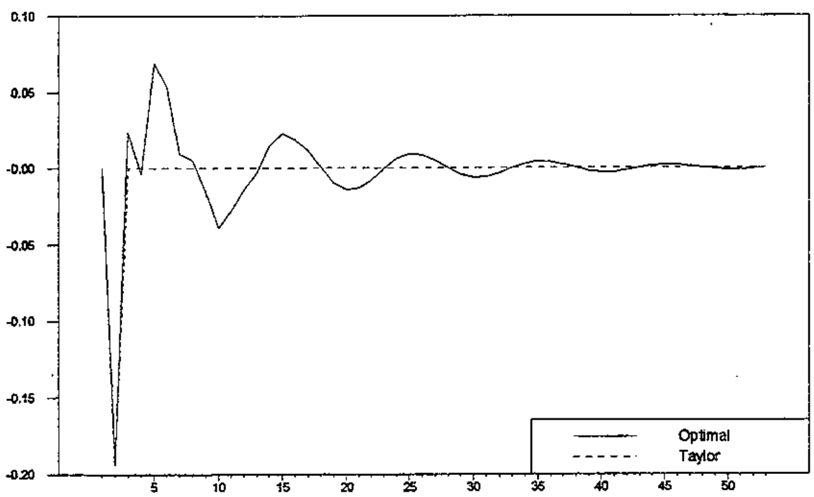

Figure 8: Response of Money to an Inflation Shock

percentage point increase in inflation money decreases. The contraction in money generates a contraction in the output gap (Figure 9). As the persistence of the output gap is relatively high ($\varphi(1) = 0.873$), the gap does not return to zero rapidly but it decreases by 0.127 every two quarters. Figure 10 shows the response of inflation to the inflation shock. The Figure shows the small persistence of inflation. ($\alpha(1) = 0.189$).

The response of monetary policy to a positive innovation in the output gap is also a contraction (Figure 11). The contraction of monetary policy makes the initial one percentage point innovation in output to shorten because output responds to monetary policy on impact. Thus, the response of money makes output increase by $1.0 - \lambda m_t < 1.0$ (Figure 12). Figure 13 shows that inflation responds to the output gap with a two year lag.

The behavior of monetary policy under the optimal and the Taylor rules is remarkably similar, the differences being explained by the rather different response of money to lagged output in the optimal rule.

6 Conclusions

We proposed a short run transmission mechanism of monetary policy with expectations channel for the case of Colombia. The unanticipated component of money growth determines output and the output gap on impact, and output and the output gap determine deviations of inflation from the core with an eight quarter lag.

We estimated the output gap as a variable that is unobserved and found

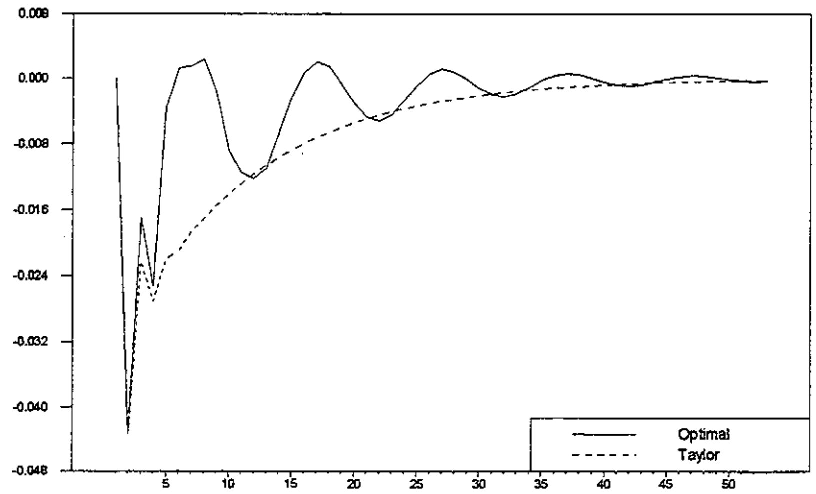

Figure 9: Response of Output to an Inflation Shock

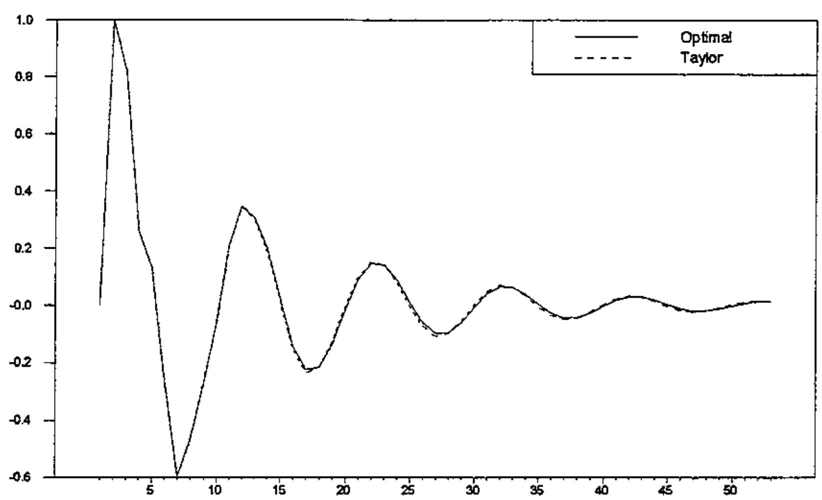

Figure 10: Response of Inflation to an Inflation Shock

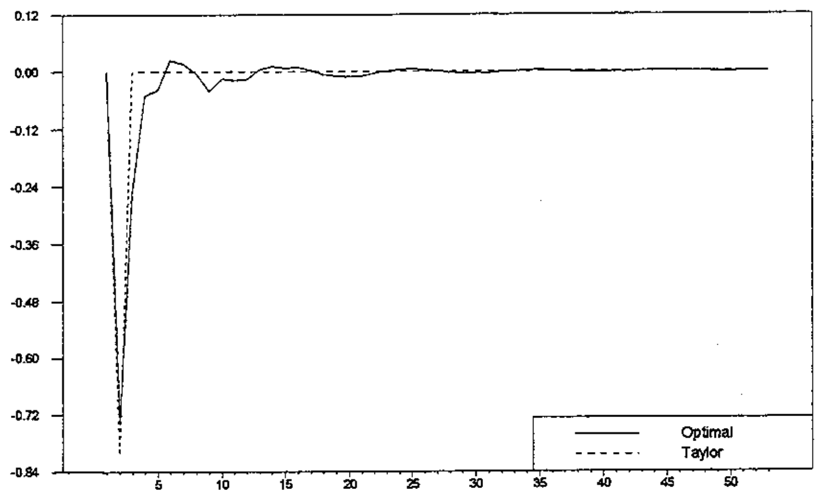

Figure 11: Response of Money to an Output Shock

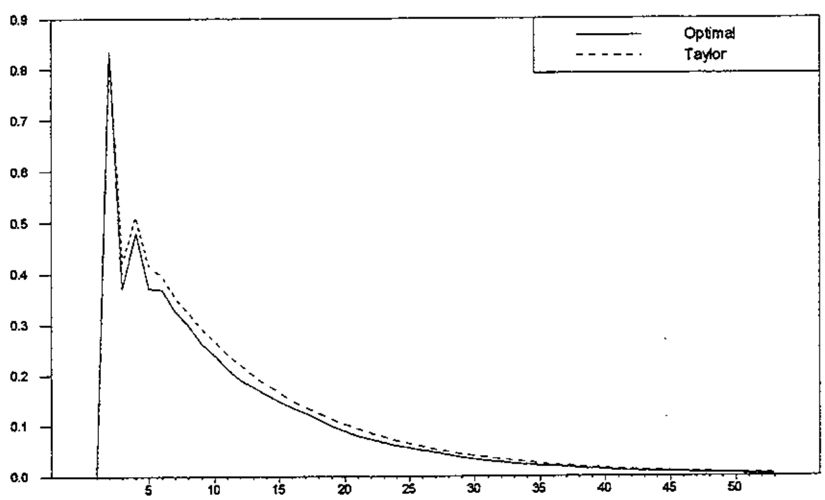

Figure 12: Response of Output to an Output Shock

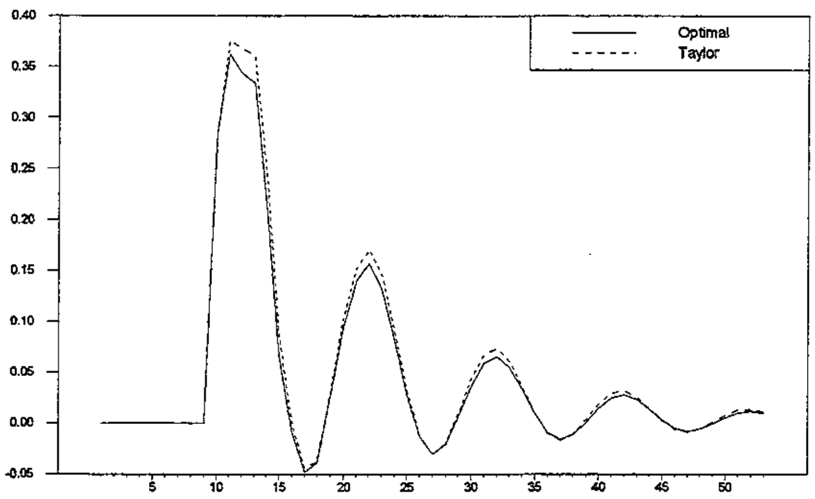

Figure 13: Response of Inflation to an Output Shock

that although there is considerable uncertainty in the measurement of the output gap, it is significantly different from zero for a few quarters in the sample. This result throw some doubt of the usefullnes of the output gap as a measure of inflationary pressures or as a leding indicator of inflation.

As the variance of the first difference of potential output is not statistically different from zero, we do not reject the hypothesis that potential output follows a linear trend, thus, the output gap is the deviation of output from trend. We end up with a Keynesian view of the transmission mechanism of monetary policy in Colombia where unanticipated money growth determines the gap, and the gap determines deviation of inflation from core. However, this result may be due to the sample length.

The short run mechanism of monetary policy is as follows. Deviations of money from anticipated money explain, on impact, deviations of output from long run trend. Deviations of output from trend explain, with a two year lag, deviations of inflation from core.

Stating a loss function defined on the variance of inflation, output, and money, we found that the behavior of the goal variables under the Taylor rule is not too far from the behavior of the goal variables under the optimal rule. Compared to the optimal rule with certainty, the variance of the goal variables is higher for the Taylor rule, as well as for the case of uncertainty. The variance of the goal variables in the historical data is quite close to the uncertainty case when the instrument rule is the one of Taylor.

References

[1]Barro, Robert (1977). "Unanticipated Money Growth and Unemployment in the United States". *The American Economic Review* 67(1) March.

[2]Burmeister, Edwin, and Kent D. Wall (1982). "Kalman Filtering Estimation of unobserved rational expectations with an application to the German hyperinflation. *Journal of Econometrics.* Vol. 20 No. 2. November.

[3]Freeman, Scott, and Finn Kydland "Monetary Aggregates and Output". Paper presented at the 1998 LACEA conference in Buenos Aires.

[4]Gómez, Javier, and Juan Manuel Julio (1999). "Monetary Policy and Inflation: The Long Run and the Lag". Mimeo Banco de la República.

[5]Grossman, Jacob (1981). "The "Rationality" of Money Supply Expectations and the Short-Run Response of Interest Rates to Monetary Surprises". *Journal of Money, Credit, and Banking.* Vol. 13, No. 4. November.

[6]Harvey, Andrew (1989). *Forecasting, Structural Time Series Models, and the Kalman Filter.* Cambridge University Press. Cambridge, U.K.

[7]Hodrick, R. J., and Edward Prescott (1980). "Postwar U.S. Business Cycles: An Empirical Investigation". Discussion Paper 451. Carnegie-Mellon University. Pittsburgh.

[8]Lucas, Robert (1973). "Some International Evidence on Output-Inflation Tradeoffs". *The Amercian Economic Review.* Vol. 63 No. 3. June.

[9]Rudebush, Glenn D, and Lars E. O. Svensson (1998). Policy Rules for Inflation Targeting". NBER Conference on Monetary Policy Rules, January.

[10]Sargent, Thomas (1987). *Dynamic Macroeconomic Theory.* Harvard University Press. Cambridge MA.

[11]Smets, Frank (1998). "Output Gap Uncertainty: Does It Matter for the Taylor Rule?". BIS Working Papers No. 60, November. Bank for International Settlements, Basle, Switzerland.

[12]Wasserfallen, Walter (1988) "Trends, Random Walk, and the Expectations-Augmented Phillips Curve Evidence From Six countries". *Journal of Money, Credit and Banking,* Vol. 20, No. 3. August.

[13]Watson, Mark, and Engle, Robert (1983). "Alternative Algorithms for the Estimation of Dynamic Factor, Mimoc and Varying Coefficient Regression Models". *Journal of Econometrics.* Vol. 23 No. 3 December.

RESUMEN "BORRADORES DE ECONOMIA"

Número	Autor	Título	Fecha
001	José Darío Uribe E.	Inflación y crecimiento económico en Colombia	Sep/94
002	Roberto Junguito B.	La independencia de la Banca Central en América Latina	Sep/94
003	Alberto Carrasquilla B. Arturo Galindo A. Hilde Patrón	Costos en bienestar de la inflación: teoría y una estimación para Colombia	Sep/94
004	Armando Montenegro T. Carlos Esteban Posada P.	Criminalidad en Colombia	Oct/94
005	Hugo Oliveros C. Carlos Varela B.	Consideraciones sobre el nivel óptimo de reservas internacionales	Oct/94
006	Adolfo Meisel R.	Cómo determinar si el peso está sobrevaluado o subvaluado	Oct/94
007	Martha Misas A. Hugo Oliveros C.	La relación entre salarios y precios en Colombia: un análisis econométrico	Oct/94
008	Alberto Carrasquilla B.	Desarrollo reciente de las políticas monetaria y cambiaria en Colombia	Nov/94
009	Hernando Vargas H.	A qué juegan el gobierno y un banco central independiente?	Nov/94
010	José Darío Uribe E.	Inflación inercial, tasa de cambio y anclas	Nov/94
011	Martha Misas A. Hugo Oliveros C. José Darío Uribe E.	Especificación y estabilidad de la demanda por dinero en Colombia	Dic/94
012	Alejandro López M. Martha Misas A.	El PIB Nominal como meta de la política monetaria	Dic/94
013	Enrique López E. María Ripoll Freddy Cepeda L.	Crónica de los modelos de equilibrio general en Colombia	Dic/94
014	Arturo Galindo A.	Política económica e inflación : un análisis de la experiencia reciente 1988-1994	Dic/94
015	Hilde Patrón	El mercado internacional del café : una aplicación de la teoría de juegos	Ene/95
016	Martha Misas A. Carlos Esteban Posada P.	P-Estrella en Colombia : un punto de vista sobre la inflación	Ene/95
017	Zeinab Partow	Una investigación empírica sobre el impacto de la inflación en el Crecimiento Económico de Colombia, 1951-1992	Ene/95
018	Hernando Vargas H.	Sobre las consecuencias de las amenazas a la independencia del Banco Central	Ene/95
019	Jorge Ramos F. Norberto Rodríguez N.	Déficit fiscal y tasas de interés en Colombia	Ene/95
020	Carlos Esteban Posada	Crecimiento económico, capital humano, ahorro e instituciones	Feb/95
021	Carlos Humberto Ortiz	Rendimientos a escala y rentabilidad en la industria manufacturera colombiana: Análisis sectorial	Feb/95
022	Alberto Carrasquilla B.	Bandas cambiarias y modificaciones a la política de estabilización: lecciones de la experiencia colombiana	Feb/95
023	Zeinab Partow	La relación inflación-crecimiento: un resumen con algunas implicaciones para Colombia	Feb/95
024	Alejandro López M. Juana P. Téllez C.	Una historia de los años veinte para los noventa	Mar/95
025	José Darío Uribe E.	Flujos de capital en Colombia: 1978-1994	Mar/95
026	Carlos Esteban Posada P. Martha Misas A.	La tasa de interés en Colombia	Mar/95
027	Alejandro López M.	Las últimas décadas: un proceso lento e interrumpido de liberación financiera	Mar/95
028	Sandra Patricia Ospina	Los efectos de la regulación en el margen de intermediación de las tasas de interés en Colombia	Abr/95
029	Alberto Carrasquilla B.	Demanda por reservas bajo bandas cambiarias	Abr/95
030	Carlos Esteban Posada P.	El costo de la inflación (con racionalidad y previsión perfectas)	Abr/95
031	Roberto Junguito B. Ligia Melo B. Martha Misas A.	La descentralización fiscal y la política macroeconómica	May/95
032	Zeinab Partow	Una revisión de la literatura sobre los costos de la inflación	May/95
033	María Ripoll N. Martha Misas A. Enrique López E.	Una descripción del ciclo industrial en Colombia	May/95

Número	Autor	Título	Fecha
034	Alberto Carrasquilla B. Arturo Galindo A.	Consideraciones sobre el comportamiento de la tasa de cambio al interior de las bandas	May/95
035	Carlos Esteban Posada P.	Ahorro y Modelos Macroeconómicos	Jun/95
036	Rodrigo Suescún M.	Growth, welfare costs and aggregate fluctuations in economies with monetary taxation	Jul/95
037	Hernando Vargas H.	La relación entre el crédito y la inflación	Jul/95
038	Hernando Zuleta G.	Impuesto inflacionario y señoreaje	Jul/95
039	Patricia Morales C. Carlos Felipe Jaramillo J.	Estructura del índice de precios al consumidor: algunas implicaciones para el análisis de la inflación	Ago/95
040	Hugo Oliveros C.	Estacionalidad y pruebas de raíces unitarias: algunas consideraciones generales	Ago/95
041	Roberto Junguito B. Enrique López E. Martha Misas A. Eduardo Sarmiento	La edificación y la política macroeconómica	Nov/95
042	Alberto Carrasquilla B.	The changing role of the public sector: the colombian case	Nov/95
043	Juan Manuel Julio R.	Choques grandes / Choques pequeños: evidencia del Log IPC e inflación colombianos	Dic/95
044	Carlos Esteban Posada P.	Dinero, interés, inflación y fluctuaciones económicas en Colombia desde 1958	Dic/95
045	Jorge E. Ramos F. Daira P. Garrido T.	Gasto estatal y administración de justicia en Colombia	Ene/96
046	Roberto Junguito B. Hernando Vargas H.	Central bank independence and foreign exchange policies in Latin America	Feb/96
047	Carlos Esteban Posada P.	Ahorro y términos de intercambio de la economía dependiente	Mar/96
048	Juan Carlos Echeverry G.	Short run savings fluctuations and export shocks. Theory and evidence for Latin -America	Mar/96
049	Adolfo Meisel Roca	Autonomía de la Banca Central e Inflación: la experiencia colombiana, 1923-1995	Mar/96
050	Juan Carlos Echeverry G.	The rise and perpetuation of a moderate inflation, Colombia 1970-1991	Abril/96
051	Carlos Esteban Posada P.	Por qué ha crecido el gasto público?	Abril/96
052	Miguel Urrutia Montoya	Política económica e instituciones	Jul/96
053	Roberto Junguito B.	The management of coffee: bonanzas and crisis: political economy issues	Jul./96
054	Adolfo Meisel R.	Why no hyperinflation in Colombia? On the determinants of stable economic policies	Ago/96
055	Alberto Carrasquilla B.	Dimensiones fiscales de una inflación moderada: el caso colombiano	Ago/96
056	Zeinab Partow	Incertidumbre económica e inversión privada en Colombia	Ago/96
057	Alejandro López Carolina Gómez Norberto Rodríguez	La caída de la tasa de ahorro en Colombia durante los años noventa : evidencia a partir de una base de datos para el período 1950-1993	Ago/96
058	Alejandro López Martha Misas Hugo Oliveros	Understanding comsumption in Colombia	Sep\96
059	Rodrigo Suescún M. Martha Misas A.	Cambio tecnológico, ineficiencia de escala e ineficiencia X en la Banca Colombiana	Sep/96
060	Ignacio Lozano Ligia Melo	El déficit del sector público y la política fiscal en Colombia, 1985-1996	Oct/96
061	Juan Carlos Echeverry G.	The fall in Colombian savings during the 1990s. Theory and evidence	Oct/96
062	Luis Fernando Melo V.	Pronósticos condicionados para modelos VAR	Oct/96
063	Carlos Eduardo Vélez E.	La regulación de precios y la calidad de la educación privada en Colombia : posibilidades y limitaciones	Nov/96
064	Alberto Carrasquilla B. Andrés F. Arias	Tipo de cambio real en Colombia : □Qué pasó ?	Nov/96
065	Franz Alonso Hamann S.	Puede explicarse el precio externo del café con un modelo econométrico no lineal ?	Nov/96
066	Carlos Esteban Posada P.	La credibilidad de la política anti-inflacionaria	Nov/96
067	Andrés Carvajal Hernando Zuleta	Desarrollo del sistema financiero y crecimiento económico	Ene/97
068	Martha Misas A. Carlos Esteban Posada P.	Determinantes de la tasa de ahorro : una perspectiva internacional	Feb/97

Número	Autor	Título	Fecha
069	Salomón Kalmanovitz	Las instituciones, la ley y el desarrollo económico	Feb/97
070	Alberto Carrasquilla B.	An exchange rate band in times of turbulence : Colombia 1991-96	Mar/97
071	Hernando Zuleta G.	Una visión general del sistema financiero colombiano	Abr/97
072	Hernando Vargas H.	Apertura, encajes e intermediación financiera	May/97
073	Rodrigo Suescún M.	Commodity booms, dutch disease, and real business cycles in a small open economy : the case of coffee in Colombia.	Jun/97
074	Jaime Jaramillo U. Adolfo Meisel R. Miguel Urrutia M.	Continuities and discontinuities in the fiscal and monetary institutions of New Granada 1783-1850.	Jul/97
075	Martha Misas A. Hugo Oliveros C.	Cointegración, exogeneidad y crítica de Lucas : Funciones de demanda de dinero en Colombia : un ejercicio más.	Jul/97
076	Andrés Felipe Arias Hernando Zuleta	Tasa de cambio real e inversión. La experiencia de 1990-1996	Jul/97
077	Carlos Esteban Posada P.	Otro costo de una inflación perfectamente prevista	Jul/97
078	Juan Carlos Echeverry G. Marcela Eslava M.	Notas sobre la tasa de interés y la inflación en Colombia	Sep/97
079	Carlos Esteban Posada P.	Una presentación gráfica de la nueva teoría de la política anti-inflacionaria y el caso colombiano.	Oct/97
080	Carlos Eduardo Vélez E.	Eficiencia, equidad y reestructuración sectorial del gasto público social	Nov/97
081	Carlos Esteban Posada P.	Los mercados de instituciones y las instituciones endógenas	Nov/97
082	Alvaro Riascos V.	Sobre el costo en bienestar de la inflación en Colombia.	Dic/97
083	Luis Fernando Melo V. Alvaro Riascos V.	El Producto Potencial utilizando el filtro de Hodrick-Prescott con parámetro de suavización variable y ajustado por inflación : una aplicación para Colombia	Dic/97
084	Carlos Esteban Posada Andrés González	El mercado laboral urbano : empleo, desempleo y salario real en Colombia entre 1985 y 1996.	Dic/97
085	Andrés Felipe Arias Martha Misas A.	Monetary neutrality in the colombian real exchange rate.	Ene/98
086	Luis Fernando Melo V. Martha Misas A.	Análisis del comportamiento de la inflación trimestral en colombia bajo cambios de régimen : una evidencia a través del modelo "switching" de Hamilton.	Feb/98
087	Juan Carlos Echeverry Zeinab Partow	Why justice is unresponsive to crime : the case of cocaine in colombia.	Feb/98
088	Juan Carlos Echeverry G.	Summary of the minutes of the monetary board, 1971, 1988.	Mar/98
089	Franz A. Hamman Alvaro J. Riascos	Ciclos económicos en una economía pequeña y abierta –una aplicación para Colombia.	Abr/98
090	Juan Carlos Echeverry	Price setting in the Argentine and Colombian manufacturing industry.	Abr/98
091	Carlos Felipe Jaramillo	Improving the measurement of core inflation in Colombia using asymmetric trimmed means.	Abr/98
092	Javier Gómez	The banking spread and the resource cost of capital.	May/98
093	Luis F. Melo V. Franz A. Hamann S.	Inflación básica. Una estimación basada en modelos VAR estructurales.	Jun/98
094	Martha Misas Arango Enrique López Enciso	El Producto Potencial en Colombia: Una estimación bajo var estructural	Jun/98
095	GRECO (Grupo de Estudios del Crecimiento Económico Colombiano)	El desempeño macroeconómico colombiano - series estadísticas (1905-1997)	Jun/98
096	Luis Eduardo Arango Thomas	Temporary and Permanent Components of Colombia´s Output	Jun/98
097	Gonzalo Valencia B.	La Banca Central en Colombia	Jul/98
098	Hugo Oliveros C.	Modelos de duración: Una aplicación en el caso de la inflación y la tasa de interés.	Jul/98
099	Ignacio Lozano E.	Las transferencias intergubernamentales y el gasto local en Colombia.	Ago/98
100	Luis Eduardo Arango Thomas	Some univariate time series properties of output	Ago/98
101	Javier Gómez P.	La demanda por dinero en Colombia	Ago/98
102	Carlos Humberto Cardona Adriana Pontón Eduardo Sarmiento	Evidencia sobre las desinflaciones: Experiencia internacional	Sep/98
103	Arturo José Galindo	Estimating credibility in Colombia's exchange rate target zone	Sep/98
104	Salomón Kalmanovitz K. Mauricio Avella G.	Barreras del desarrollo financiero: las instituciones monetarias colombianas en la década de 1950	Sep/98

Número	Autor	Título	Fecha
105	Luis E. Arango T. Andrés González	Some evidence of smooth transition nonlinearity in Colombian inflation.	Sep/98
106	Carlos Esteban Posada P.	Dinero, inflación y actividad económica.	Oct/98
107	Enrique Ospina G.	Importaciones agropecuarias: a qué responden?	Oct/98
108	Adolfo Meisel Roca	Dutch Disease and Banana Exports in the Colombian Caribbean, 1910-1950	Nov/98
109	Elkin Castaño V. Luis Fernando Melo V.	Métodos de combinación de pronósticos: Una aplicación a la inflación Colombiana	Nov/98
110	Blanca Mónica Panqueva B.	La eficiencia en la asignación del gasto público local: servicios públicos en Manizales y Pereira	Dic./98
111	Felipe Suárez Parra	Modelo de ingreso permanente para la determinación de la cuenta corriente	Ene/99
112	Salomón Kalmanovitz	La política fiscal colombiana en un contexto histórico	Ene/99
113	Carlos Esteban Posada P.	La tasa de interés en una economía pequeña con movilidad imperfecta de capitales: el caso colombiano del siglo XX (1905-1997)	Feb/99
114	Salomón Kalmanovitz	Los equilibrios macroeconómicos y el banco central: el caso colombiano	Feb/99
115	Luis Eduardo Arango T. Mauricio Castillo	¿Son estilizadas las regularidades del ciclo económico? Una breve revisión de la literatura	Feb/99
116	Salomón Kalmanovitz Enrique López E. Carmen Astrid Romero B.	La producción agropecuaria colombiana 1915-1950	Mar/99
117	Enrique López E Martha Misas A.	Un examen empírico de la curva de Phillips en Colombia	Mar/99
118	Adolfo Meisel R.	La cliometría en Colombia: una revolución interrumpida, 1971-1999	Mar/99
119	Gustavo Suárez	Tecnología de transacciones endógena y los costos de la inflación	Mar/99
120	Hernán Rincón C.	Testing the short-and-long-run exchange rate effects on trade balance: the case of Colombia	Abr/99
121	GRECO (Grupo de Estudios del Crecimiento Económico Colombiano)	El desempeño macroeconómico colombiano - series estadísticas (1905-1997) (Segunda versión)	May/99
122	Armando Ibarra R.	Indice encadenado de la tasa de cambio real regional ponderado por el comercio de exportación	Jun/99
123	María Teresa Ramírez Hadi Salehi Esfahani	Infrastructure and economic growth	Jun/99
124	María Teresa Ramírez	The impact of transportation infrastructure on the Colombian economy	Jun/99
125	Juan Manuel Julio Javier Gómez	Output gap estimation, estimation uncertainty and its effect on policy rules	Jun/99