[Very preliminary and incomplete version for comments]

CENTRAL BANKERS' FEAR OF FLOATING: THE PERUVIAN EVIDENCE

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ABSTRACT

We contend that the exchange rate regime debate the theoretical arguments of flexibility against credibility lack of empirical support. In particular, flexible exchange rate regimes are not quite so. Central banks of dollarized economies have developed what Calvo (1999) calls a *fear of floating*. Economies with large liability dollarization have little room to allow highly volatile exchange rates. Therefore, central banks not follow a sole objective of price stability but its preferences include an implicit exchange rate objective. Peru is an economy with these characteristics: highly dollarized and with a flexible exchange rate system since 1990. Using Favero & Rovelli (1999) methodology we estimate the preferences of the Peruvian Central Bank and found that the evidence supports the hypothesis of an implicit exchange rate band.

JEL Codes: C52, E52

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1 Motivation

Not surprisingly the debate over the exchange rate regime has come again after the sequence of crises in the emerging markets in 1998-99. Emerging economies have been forced to sustain massive pressure for devaluation. Within Latin America, Brazil wait up to the very last to abandon the crawling peg regime and Colombia and Chile moved to a fully flexible exchange rate system. Despite the financial turmoil, Argentina convertibility system has endured and there are no winds of change. There seems to be a common view that among the Latin American economies, those with more flexible exchange rate regimes (Mexico, Chile and Peru) have performed better under the circumstances compared to those with more fixed regimes (Argentina and Brazil). This statement should obviously be qualified if we inspect more closely each economy.

In particular, we should take a closer look at how do flexible exchange rate regimes behave in practice. This is important, as much of the debate has concentrated on the benefits of having theoretical flexible arrangements that are quite different of what we see in practice. For instance, most -if not all- economies with flexible regimes have a substantial amount of international reserves.[1] Of course, one can argue that countries need them to attend their external obligations but most countries have much more than that.

But our interest is more concentrated in those economies that currently have a flexible exchange rate system but are highly dollarized. In particular, we are interested in those with a high degree of *liability dollarization* as Calvo (1999) put it. Among these economies Peru is a leading case. Even though one might argue that central bankers would tend to keep an eye on the exchange rate due to the possible effect those sudden depreciations have on inflation and credit conditions. Notwithstanding, the Peruvian monetary authorities defend their current monetary policy as having a unique and clear objective: price stability (BCRP, 199?).

One of the lessons of the exchange rate debate suggests that the middle ground is not precisely the safer ground and economies should move to one of the extremes.[2] Rather than discussing this we will rather explore the consequences of Central Bank decisions regarding monetary policy in a small, open and dollarized economy as Peru. One of this considerations is the claim that the Central Bank asymmetric behavior (being only a buyer, not a seller) have set the wrong incentives to the banking system to become even more dollarized in a context in which creditors have very few instruments to hedge against exchange rate risk. This weakens the financial system as the payments system is exposed to another set of risks.

Since Krugman (1979) we know that a fixed exchange rate system is an implicit one-sided bets against the Central Bank. If countries do not have enough reserves, they will eventually lose the bet. The second-generation exchange rate crisis literature goes further and

[1]The Latin American G-7 reserves average was 9.75 months of imports in 1998. This is using a simple average and 6.7 with a weighted average.
[2]Of course, there are some that suggests that this claim is not sustained. Frenkel (1999).

concludes that if people think that countries will not have enough reserves in the near future, central banks will lose again.[3] If flexible exchange rate systems are not flexible at all due to a "hyperactive" central bank (Calvo, 1999) they sure face this type of risk at the first signs of a relaxation of the fiscal stance.

A second consideration is the claim that the output response of an external shock should be lower within a flexible regime as the Central Bank has the possibility of let the exchange rate depreciate and adjust the nominal expenditure. How different is Chilean unemployment problem compared to Argentina? How much employment is gained due to the fact of a flexible system?

The paper goes as follows. In the second section we explore some monetary facts about Peru. In section 2 we present some facts that describe how monetary policy is conducted in Peru. In section 3 we present some preliminary evidence of the implicit exchange rate band that the Peruvian Central Bank follows. We focus in the last three years of high volatility. In the fourth section we present the methodology of Favero and Rovelli (1999) to unveil the preferences of the Central Bank using alternative definitions of uncertainty. Our closing remarks finish the paper.

2 Some Facts to Understand the Peruvian Monetary Policy

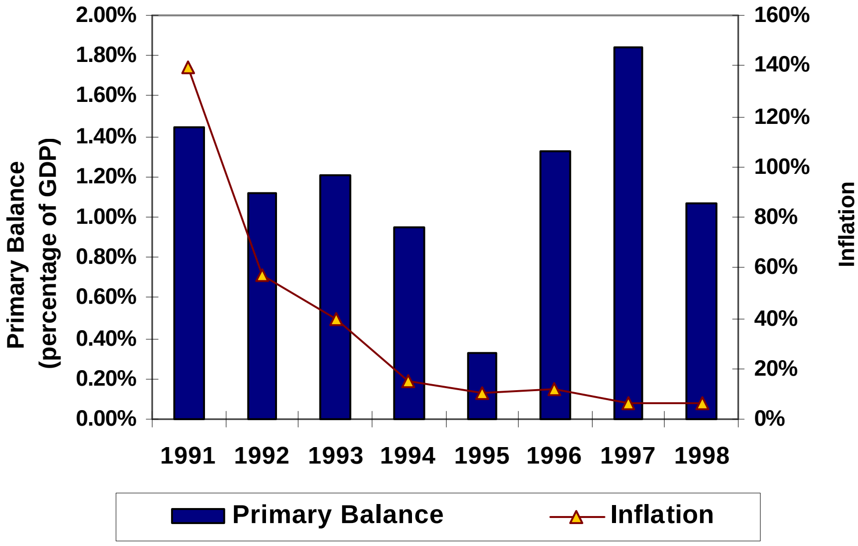
Peru has came from a hyperinflation of 7,000% per annum in the late 1980s to an impressive 3% per annum in 1999 (see Table 1). The 1990 stabilization program included a complete liberalization of the exchange rate regime, the financial system, a reduction of tariffs and a new Central Bank charter that cut the possibility of government financing. The choice of the exchange rate regime was quite difficult as the new government needs to build credibility to stop the hyperinflation but the previous administration had already tried almost every possible exchange rate arrangement. Moreover, the decision need to take into account that by then most of the deposits where in dollar-denominated accounts and the level of intermediation in soles (domestic currency) was its historic lowest levels.

The economic advisors of President Fujimori even considered the possibility of an official dollarization as a forward escape of the currency substitution. However, the balance leaned toward a flexible exchange rate due to the fact that the international reserves were negative and Peru has no access to international markets after several years of a *de facto* moratorium. There was no room to defend a fixed exchange rate or to consider a currency board.

The flexible exchange rate system worked well in the first years of a significant inflow of foreign capital. The Central Bank policy was very simple: accumulate reserves through sterilized interventions (see Table 1). However, is hard to pinpoint what worked as the nominal anchor of the economy. In our view, the fiscal stance that improved systematically throughout the 1990s was the true nominal anchor of the Peruvian economy (see Graph 1).

[3] Marion (1999) is a recent survey of this literature.

Graph 1: Fiscal superavit & Inflation



In the last five years the Central Bank has changed its monetary policy. In particular, there is a clear and declared sole objective of maintaining price stability.[4] In practical terms the Central Bank follows a rule very close to the one followed now by Banco de Mexico.[5] The price stability objective is achieved through a quantity rule rather than the more typical interest rate rule (as in Brazil or Chile). In the CB monetary policy framework the intermediate objective is the growth rate of the monetary base. But there is an operational target given by the balances that the banking system maintains at the Central Bank in a daily basis.

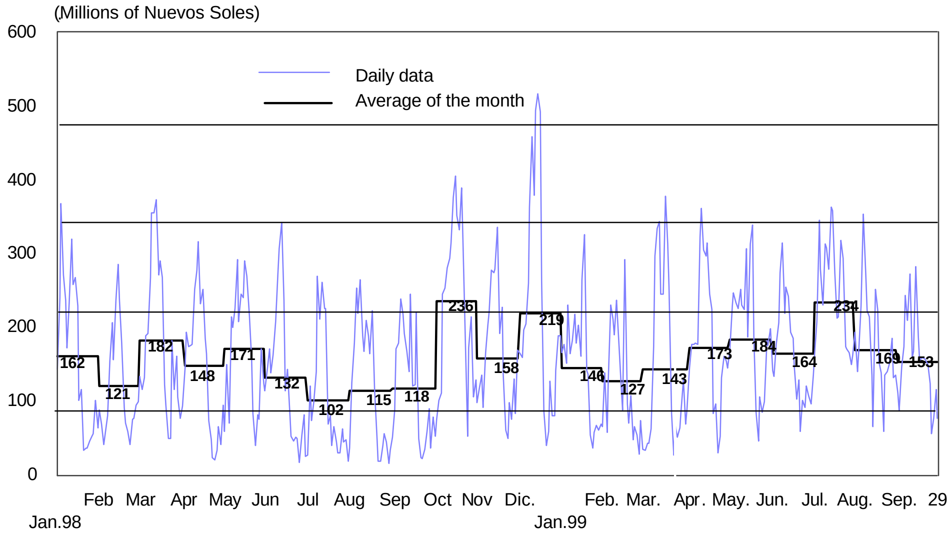
In theory, there are no more targets. In particular, the CB does not have an exchange rate or interest rate targets. There are no exchange rate bands or anything of the sort. Maybe this lack of an interest rate rule is why the CB officials are not fully convinced that they follow an inflation targeting. Our opinion is that they do follow it, but not an explicit or a strict one in the Svensson (1999) sense [add this reference]. Why they do not do this is another question. We will address this issue later.

We show the past behavior of this operational target (see Graph 2). Clearly this variable has a very volatile behavior. This is explained in part by the legal framework. The third week of the month is when firms pay taxes, so there is a substantial increase in the demand for money. But another important point is that the problem of looking at the balances that

[4]See Banco Central de Reserva del Peru (1995) La Politica Monetaria ...
[5]See Carstens and Werner (1999), ...

banks keep at their accounts at the CB is that normal banking business gets mixed with particular problems of liquidity that a bank might face.

Graph 2. Banks' current account balances at the Central Bank



The CB has tried to conduct its monetary policy without committing its actions to predetermined rules. In contrast to Banco de Mexico predetermined rules of intervention if the exchange rate fluctuates too much, the Central Bank of Peru has no rules but discretion. The question that we pose is if in effect the market -and in particular the banks- had already learned that behind this discretion there is an implicit rule of intervention. And if is that so, how much does actually affect the presence of an implicit exchange rate band to the preferences of the central bank.[6]

3 The Reasons Behind the Fear of Floating

Before explaining the methodology applied to estimate the Central Bank preferences we illustrate the idea of fear of floating. One should ask why central banks around the region - if not the world- that follow flexible exchange rate regimes maintain a substantial amount of forex reserves. A quick answer to this is the fact that international liquidity is crucial to build effective credibility for central banks.[7]

A first and the most striking feature of the flexible exchange rate system is the lack of flexibility. If we compare how flexible have been the flexible exchange rate systems of Latin America (Chile, Colombia, Mexico and Peru) we will be surprised by learning that Peru is the one with less variability even compared to Chile or Colombia when they had exchange rate bands (see graph 4); or to other open economies with flexible exchange rates.

[insert graph 4]

We compare all these economies from January 1997 to March 1999 using daily exchange rate data. We compute several measures of volatility for each case expecting more volatility in Peru and Mexico that do not have exchange rate bands. One can also expect very little days in which the exchange rate does not move. Our findings are in Table 2. Clearly, the Peruvian floating system is not as flexible as one might think. The question is if it should be more flexible or not. The Chilean monetary authorities after narrowing the exchange rate band have decided to widen the band and keep doing that to introduce a more flexible exchange rate regime.

After all this evidence a logical question is just: why? Why the Central Bank in Peru is so reluctant to allow the exchange to freely float? The reasons behind this fear of floating lie in the characteristics of the economy. The first one is the degree of dollarization of our economy. Despite the success taming the inflation rate from hyperinflationary levels to the current 3% per annum, the degree of asset and liability dollarization remained more or less

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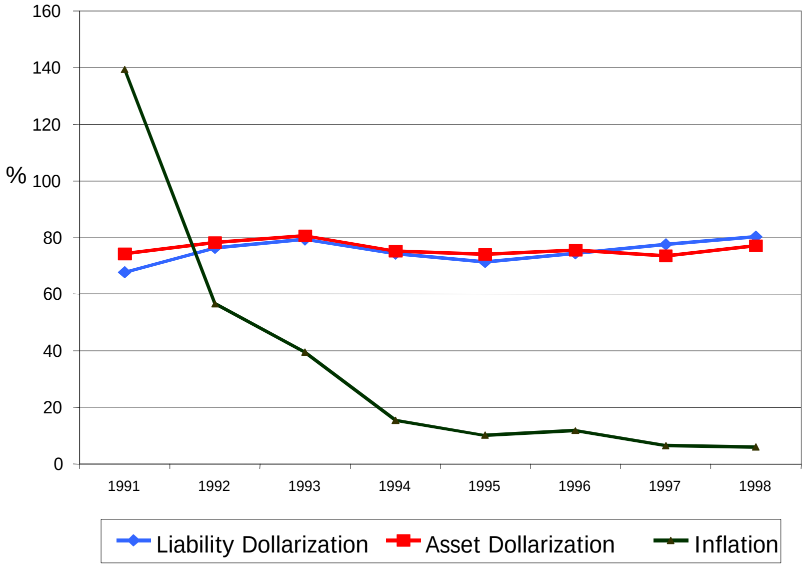
[6]A related question is what happens with the banks preferences when the CB has an implicit exchange rate band and an implicit commitment to avoid large depreciations.

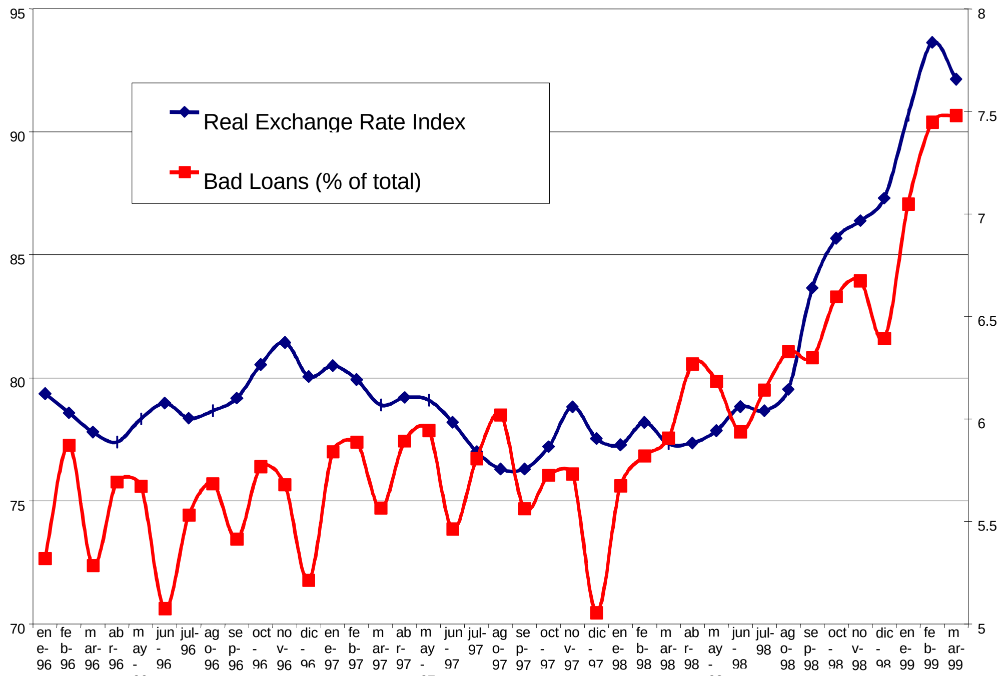
[7]See Calvo and Leiderman (1994) or Kaminsky and Reinhart (1996) using the ratio M2 to forex reserves as one of the best indicators of financial fragility.

hovering around the 70%-80% levels in the last ten years. (see graph 5). The high level of foreign currency denominated liabilities within a country in which there are scant opportunities to hedge against the risk of sudden depreciations of the exchange rate become a repayment risk. The twin crisis phenomenon is right there. If we look at the Peruvian case we will see a clear relationship between the real exchange rate behavior and the bad debts ratio of the financial system (see graph 6).

Graph 5. Asset and Liability Dollarization in Peru



Graph 6: Real Exchange Rate Index v. Bad Debts Ratio



This devastating effect on the financial fragility is exacerbated through the contractionary effect of the devaluation in the context of a highly indebted private sector that is not fully hedged against exchange rate risks. This second round effects have been important in practice as there are no signs of recovery of this temporary shock.

A second characteristic is the possible impact of any depreciation in the rate of inflation. The Peruvian monetary authorities like to show off to international bankers and investors that they have overcame a huge threshold reducing inflation to the current levels. However, much of this was due to the fact that Peru received a substantial flow of funds from abroad that put a lot of downward pressure on the nominal exchange rate. The pass-through coefficient for Peru is

If the main objective is price stability but the pass-through is high enough, any external problem will eventually imply a sudden depreciation and a new round of contractionary effects on domestic activity. However, one element that should be considered is the presence of a time-varying pass-through coefficient that actually depends on the sign and size of the output gap, exactly as in Israel.[8]

This will work -in a way- in favor for the monetary authorities that will not face inflationary pressures if the depreciation has contractionary effects. The banks, however, will face a double hazard. The exchange rate and the recession both will hit the performance of their loans. Either the Central Banks decides to act after the fact (sudden depreciation) with liquidity provision to those banks in need, or higher interest rates on reserves held at the Central Bank. Remember that in that type of situation banks will recover their liquidity faster than firms and households will recover their likelihood to receive a new loan. The best debtor turns out to be the Central Bank.

4 Unveiling the Preferences of the Central Bank

The central element of an *inflation-targeting* framework is the commitment from the monetary authority to keep the inflation rate within a specified range or value.[9] In order to fulfill the target the Central Bank might use a variety of instruments.

We have presented evidence on the possibility (even necessity) of the Central Bank to keep an eye on the nominal exchange rate. The remaining question is how this second objective interferes or is compatible with the supposedly sole objective of price stability. Furthermore, one should ask if this other objective is instrumental to the price stability objective.[10] In our case we would like to calculate if the Central Bank decisions are the

[8]See Leiderman and Badas-Or (1999).
[9] Ver Svensson (1998) para una revisión de la literatura teórica de *inflation targeting*. Asimismo, Bernanke et. al. (1999) presentan la experiencia de los países desarrollados que adoptaron este régimen monetario.
[10]Favero and Rovelli (1999) ask a very similar question including an output gap as a secondary objective for the Central Bank.

outcome of a trade-off between inflation stabilization and the flexibility of the exchange rate.

However, a large share of the literature has focused on the estimation of the policy reaction functions rather on trying to identify the preferences of the Central Bank. We follow Favero and Rovelli (1999) in a GMM estimation of the first order conditions of the intertemporal problem that the Central Bank faces. They combine this estimation with a prior estimation of a small structural model of the economy. In this way they are able to identify the preferences of the CB. In contrast with Favero and Rovelli (1999) we present the estimation for an open and small economy that follows a special kind of inflation targeting, where there is no interest rate rule but a quantity rule.

The Structural Model of the Economy

The aggregate supply and demand in this economy are specified by the following equations:

$$x_t = \beta_0 + \beta_1 x_{t-1} + \beta_2 M_{t-3} + \beta_3 M_{t-4} + \beta_4 CU_{t-1} \quad (1.)$$
$$\pi_t = \alpha_0 + \alpha_1 \pi_{t-1} + \alpha_2 \pi_{t-3} + \alpha_3 TC_{t-2} + \alpha_4 PAS_{t-2} + \alpha_5 M_{t-2} \quad (2.)$$
$$TC_t = \gamma_0 + \gamma_1 TC_{t-1} + \gamma_2 M_{t-2} + \gamma_3 DUMMYR \quad (3.)$$

The first equation is for the output gap (x_t), which depends on the monetary instrument (M_t) and the price of copper, one of the most important commodities that Peru exports, to reflect the fact that most of the output volatility comes from changes in the terms of trade. The second equation is for the inflation rate (π_t) which depends on lags of itself and the behavior of the exchange rate (TC_t), the short run external debt of private banks and the monetary instrument. Finally, currency depreciation is a function of lags of itself, the monetary instrument and a dummy to reflect the observed downward trend.[11] The estimation results are shown in Table 5.

The Central Bank Preferences

In order to identify the central bank preferences we need to specify a loss function that will be intertemporal minimized choosing the monetary instrument (M_t). The intertemporal problem of the central bank is as follows:

$$E_t \sum_{j=0}^{\infty} \delta^j L_{t+j} \quad (4.)$$

where, E_t is the conditional expectation given the information set available at time t; δ is the intertemporal discount rate of the central bank; and the loss function L is given by:

[11]The above specification was obtained by MCO equation by equation. The system was then estimated by SUR to include the correlations among the three shocks.

$$L = \frac{1}{2}\left[\pi_t^2 + \lambda x_t^2 + \rho TC_t^2\right] \quad (5.)$$

As we stated above, all variables are expressed as differences with respect to the target levels. The parameters λ and ρ measures the degree of flexibility of the inflation targeting regime with respect to the competing objectives. If λ=0 the Central Bank pay no attention to the output gap behavior. If ρ=0 we are in the case in which the Central Bank has no interest on the exchange rate volatility. The “inflation nutter” case is when λ=ρ=0. Our hypothesis is that ρ>0.

The Central Bank minimizes the intertemporal loss function subject to the structure of the economy described by equations (1-3). The first order condition of the problem is:

$$\frac{\partial L}{\partial M_t} = \partial^2 E_t(\pi_{t+2})\frac{\partial \pi_{t+2}}{\partial M_t} + \partial^2 \rho E_t(TC_{t+2})\frac{\partial TC_{t+2}}{\partial M_t} + \partial^3 E_t(\pi_{t+3})\frac{\partial \pi_{t+3}}{\partial M_t} + \\ + \partial^3 \lambda E_t(x_{t+3})\frac{\partial x_{t+3}}{\partial M_t} + \partial^3 \rho E_t(TC_{t+3})\frac{\partial TC_{t+3}}{\partial M_t} \quad (6.)$$

Using the specified structure of the economy we could rewrite (6) as:

$$\frac{\partial L}{\partial M_t} = \partial^2 E_t(\pi_{t+2})\alpha_5 + \partial^2 \rho E_t(TC_{t+2})\gamma_2 + \partial^3 E_t(\pi_{t+3})\alpha_1\alpha_5 + \partial^3 \lambda E_t(x_{t+3})\beta_2 \\ + \partial^3 \rho E_t(TC_{t+3})\gamma_1\gamma_2 \quad (7.)$$

Given the fact that this expression is an orthogonality condition, we can use GMM to estimate the parameters that describe the preferences of the central bank from the following equation:

$$E_t(\pi_{t+2}) = -\frac{\rho\gamma_2}{\alpha_5}E_t(TC_{t+2}) - \partial\alpha_1 E_t(\pi_{t+3}) - \frac{\partial\lambda\beta_2}{\alpha_5}E_t(x_{t+3}) - \frac{\partial\rho\gamma_1\gamma_2}{\alpha_5}E_t(TC_{t+3}) \quad (8.)$$

Renaming $\pi_{t+2} = \pi_{t+2} - \pi^*$, to distinguish the current inflation rate from the target value, we have our implicit monetary target:

$$E_t(\pi_{t+2}) = \pi^* - \frac{\rho\gamma_2}{\alpha_5}E_t(TC_{t+2}) - \partial\alpha_1 E_t(\pi_{t+3}) - \frac{\partial\lambda\beta_2}{\alpha_5}E_t(x_{t+3}) - \frac{\partial\rho\gamma_1\gamma_2}{\alpha_5}E_t(TC_{t+3}) \quad (9.)$$

Due to the fact that coefficients α, β, and γ have been already been estimated in the previous step, we include their values in equation (9). By the same token we assume δ=0.975. This gives us equation (10):

$$E_t(\pi_{t+2}) = 0.008 - 0.220\frac{\partial\gamma_1\gamma_2}{\alpha_5}E_t(TC_{t+3}) + 0.011*DUMMY \tag{10.}$$

The GMM results are shown in table 6.

For the 1992:01-1994:06 period, we should add the target inflation (π*) and the coefficient of the dummy variable. We get a 1.92% monthly inflation or 25.7% annualized. This is a plausible number as the actual rates of inflation for 1992, 1993 and 1994 were 58.7%, 35.5% and 13.7%, respectively.

For the 1995-98 period, the target monthly inflation that we can get from the estimation is 0.8% (10% annual). Even though that rate is greater than the target inflation used to construct π (7%), the results are not that bad.

However, the important result is a different one. Our estimates of $\rho = 0.22$ and $\lambda \approx 0$ tell us that the Central Bank do react to changes in the exchange rate but does not to the output gap. The Central Bank has only two objectives: price stability and exchange rate stability.

Monetary Policy Rule

Once we estimate the structural model parameters and the central bank preferences we can recover the monetary policy rule. To do that we combine equation (10) and (2). The last one models the inflation rate process within the structural model. Rearranging terms we get:

$$\begin{aligned} M_t = &-\frac{\alpha_0}{\alpha_5} - \frac{\alpha_1}{\alpha_5}*E_t(\pi_{t+1}) - \frac{\alpha_2}{\alpha_5}*\pi_{t-1} - \frac{\alpha_3}{\alpha_5}*TC_t - \frac{\alpha_4}{\alpha_5}*PAS_t + \frac{\partial\gamma_1\gamma_2\rho}{\alpha_5}E_t(TC_{t+3}) \\ &+ \frac{\theta}{\alpha_5}Dummy \end{aligned} \tag{11.}$$

The absence of any lags of the monetary instrument reflects that the central bank does not take into account the possibility of some persistence on the effects of its actions. That seems odd. We will get to this point again. As before, we use GMM to estimate the policy rule. The equation estimated was:

$$\begin{aligned} M_t = &\, c_1 + c_2*E_t(\pi_{t+1}) + c_3*\pi_{t-1} + c_4*TC_t + c_5*PAS_t + c_6*E_t(TC_{t+3}) \\ &+ c_7*\text{Seasonal Dummies} \end{aligned} \tag{12.}$$

The results obtained are as expected. All coefficients of the policy rule are negative, showing that the Central Bank uses its monetary policy as a stabilizer.

The last step of Favero and Rovelli (1999) methodology is to check if the monetary authority has followed the estimated policy rule. We need to test the hypothesis that the coefficients obtained in the last estimation (c_i) are statistically similar to those obtained in equation (11) that include the parameter values that govern the structure of the economy and those related with the preferences of the Central Bank. Formally we need to reject the following restrictions:

$$c_1 = -\frac{\alpha_0}{\alpha_5}; c_2 = -\frac{\alpha_1}{\alpha_5}; c_3 = -\frac{\alpha_2}{\alpha_5}; c_4 = -\frac{\alpha_3}{\alpha_5}; c_5 = -\frac{\alpha_4}{\alpha_5}; c_6 = \frac{\partial\gamma_1\gamma_2\rho}{\alpha_5}; c_7 = \frac{\theta}{\alpha_5}$$

The Wald test of these restrictions is rejected (see Table 7). These results indicate that the policy rule specified in equation (11) does not represent appropriately the behavior of the Central Bank. This could be due to two factors. The first one is misspecification of the structure of the economy or the preferences of the Central Bank. The second possibility is that the Central Bank follows a gradualist approach of the policy rule. Behind this explanation might lie a Brainard (1967) type of uncertainty about the impulse-response of the instrument or an adjustment cost within the loss function of the Central Bank as in Goodfriend (1987 and 1991).

Uncertainty on the Effects of Monetary Policy (Brainard-style)

Brainard (1967) considered that the actions of the monetary authority are influenced by uncertainty coming from two different sources: (i) exogenous shocks that hit the economy; (ii) the lack of knowledge of the real effect of the policy decisions. In this section we introduce this second type of uncertainty in the monetary policy rule decisions. In this case the monetary authority knows that the response to the monetary policy decisions could differ substantially from the expected value. Following Brainard (1967), we include some noise to the parameters that determine the monetary policy transmission process, as follows:

$$\alpha_5 = a_5 + \varepsilon_1$$
$$\gamma_2 = c_2 + \varepsilon_2$$
$$\alpha_1\alpha_5 = a_1 a_5 + \varepsilon_3$$
$$\gamma_1\gamma_2 = c_1 c_2 + \varepsilon_4$$

where each of this disturbances εi, are i.i.d. normal distributed with zero mean and constant variance. In this way, we are explicitly assuming that the parameters are influenced by the same source of uncertainty. The Euler equation (6) now becomes:

$$\frac{\partial L}{\partial M_t} = \partial^2 E_t(\pi_{t+2})(a_5 + \varepsilon_1) + \partial^2 \rho E_t(TC_{t+2})(c_2 + \varepsilon_2) + \partial^3 E_t(\pi_{t+3})(a_1 a_5 + \varepsilon_3) + \partial^3 \rho E_t(TC_{t+3})(c_1 c_2 + \varepsilon_2) \qquad (13.)$$

As we found that λ is zero we are not including the term $E_t(X_{t+3})$. After some manipulation we can obtain a policy rule that incorporates this sort of uncertainty.

$$M_t = -\frac{\partial\rho}{(1+\rho+\partial)} * M_{t-2} - \frac{a_5}{\sigma^2(1+\rho+\partial)} * E_t(\pi_{t+2}) - \frac{\rho c_2}{\sigma^2(1+\rho+\partial)} * TC_{t+2} - \frac{\partial a_1 a_5}{\sigma^2(1+\rho+\partial)} * E_t(\pi_{t+3}) - \frac{\partial \rho c_1 c_2}{\sigma^2(1+\rho+\partial)} * TC_{t+3} \qquad (14.)$$

We estimate by GMM the previous equation (see Table # 8). The main difference between this rule and the one specified by equation (12) is that the first one considers a two-period lag of the monetary instrument (M_{t-2}). In this way we introduce a degree of smoothness into the rule to account for the lack of a clear-cut answer on the effects of monetary policy.

The results show that all variables are statistically significant and the Central Bank rule depends on the future behavior of inflation and the volatility of the exchange rate. If any of those fluctuates more than expected the central bank reacts restricting its monetary stance.

This new specification of the monetary policy rule on the money base (equation (14)) shows a much better fit than the previous rule (equation (12). This justifies the presence of a partial adjustment term (see Graph 8 comparing both). Notwithstanding these results, we require that the restrictions on the coefficients are satisfied and to check if the results are not explained by another story different from Brainard's.

We test the following issues:[12]

The coefficient restriction on M_{t-2}

Using a Wald test to determine if the coefficient linked to M_{t-2} is equal to the one obtain replacing the parameter values of the Central Bank preferences obtained in the previous section. We construct the coefficient: $-\frac{\partial\rho}{(1+\rho+\partial)} = -\frac{0.975*0.22}{(1+0.22+0.975)} = -0.097$ and compute a Wald test on equation (14). The results show that the null hypothesis cannot be rejected, satisfying the restriction.

The constant term should be zero.

The Wald test results are clear on this one. The null hypothesis of C(1)=0 is rejected.

[12] Los resultados pueden apreciarse en el Anexo No.7

Coefficients' Variances

This is the most important test and consists on checking if the variance of the coefficients of equation (14) are the same as the ones obtained in the estimation of the structural model. As we can see in the (Appendix 7), the variances obtained for each coefficient of equation (14) are greater than those obtained in the structural system. Therefore, we can conclude that the monetary policy rule derived is not subject to this type of uncertainty at least in the period analyzed.

Gradualism as a Sign of Uncertainty (Goodfriend, 1987)

In the previous section we estimated a policy rule that incorporates a gradualist behavior based on the idea that there is some uncertainty on the actual effects of monetary policy. This new specification was slightly better than the one that does not include any persistence on the policy rule. However, the results obtained have not allowed us to show that including Brainard-style uncertainty into the model accounts for this gradualism in the monetary policy rule.

An alternative way of modeling this gradualist behavior is to include an adjustment cost into the loss function of the Central Bank. Favero and Rovelli (1999) find evidence suggesting that the Federal Reserve do have a gradualist approach. The new loss function is:

$$L = \frac{1}{2}\left[\pi_t^2 + \rho TC_t^2 + \mu (M_t - M_{t-2})^2\right] \qquad (15.)$$

As we did not find evidence supporting the presence of an output gap, it was excluded from this specification.

The following step is to estimate the monetary policy rule keeping the structure of the economy fixed. The first order condition of the optimization problem of the Central Bank is as follows:

$$\frac{\partial L}{\partial M_t} = \partial^2 a_5 E_t(\pi_{t+2}) + \partial^2 \rho c_2 E_t(TC_{t+2}) + \partial^3 a_1 a_5 E_t(\pi_{t+3}) + \partial^3 \rho c_1 c_2 E_t(TC_{t+3}) + M_t(\mu + \partial^2 \mu) - \mu M_{t-2} - \partial^2 \mu M_{t+2} = 0 \qquad (16.)$$

After some manipulation we can obtain the following policy rule that includes an adjustment factor of itself (μ):

$$M_t = \frac{1}{1+\partial^2} M_{t-2} + \frac{\partial^2}{1+\partial^2} M_{t+2} - \frac{\partial^2 a_5}{\mu(1+\partial^2)} * E_t(\pi_{t+2}) - \frac{\partial^2 \rho c_2}{\mu(1+\partial^2)} * E_t(TC_{t+2}) - \frac{\partial^3 a_1 a_5}{\mu(1+\partial^2)} * E_t(\pi_{t+3}) - \frac{\partial^3 \rho c_1 c_2}{\mu(1+\partial^2)} * E_t(TC_{t+3}) \qquad (17.)$$

The estimation procedure was GMM. The results are in Table No.9. Using the estimated coefficients we obtain a value of μ=0.0216. Not only this number is within Favero and Rovelli (1999) estimates but also the model fit is much better (see graph 8). They obtain a μ=0.032.

6 Final Remarks

<incomplete>

Even though Peru has not followed a strict inflation targeting, the Peruvian experience should motivate the question of how feasible is to adopt this monetary policy framework within an economy characterized by being highly dollarized, with a high pass-through coefficient and dependent of foreign funds.

One thing is IT under a fairly easy external environment and a completely different one when there is a situation of international liquidity crunch. The exchange rate complicate the objective of low inflation unless a recession is underway. Look at the food prices in 1999 (compare with other components of the CPI basket).

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Table 1
Peru: Selected Indicators

	Inflation	**International Reserves**	**GDP Growth Rate**	**Asset Dollarization**	**Liability Dollarization**
Year	(%)	MM US$	(%)	(%)	(%)
1990	7,649.6	531	-3.7	46.9	53.0
1991	139.2	1,304	2.9	59.9	60.9
1992	56.7	2,001	-1.7	64.5	70.3
1993	39.5	2,742	6.4	69.1	76.3
1994	15.4	5,718	13.1	64.1	73.7
1995	10.2	6,641	7.3	62.7	71.1
1996	11.8	8,540	2.4	67.1	74.2
1997	6.5	10,169	6.9	65.1	77.3
1998	6.0	9,183	0.3	69.1	80.0
1999	4.5	8,600	3.0	69.8	80.0

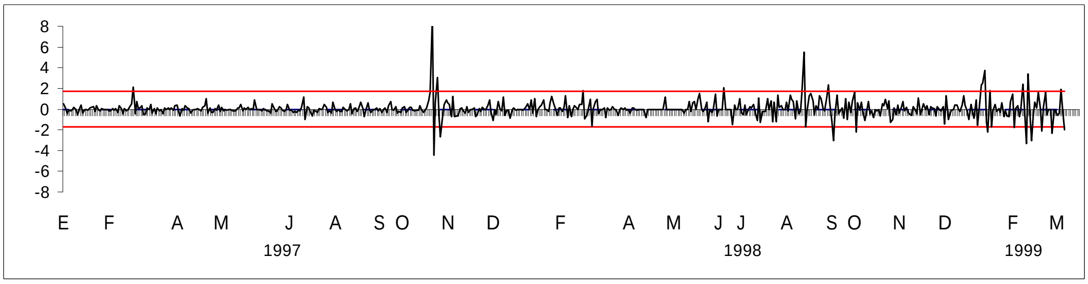
Source: Central Bank of Peru, Memoria
The 1999 figures are forecasts.

Table 2
Flexibility of the Exchange Rate Systems

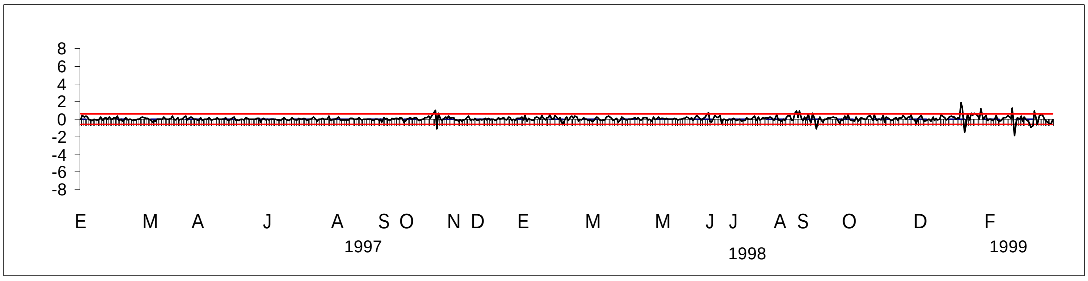
	Peru	Australia	New Zealand	Canada	Mexico	Chile	Colombia
1997							
Max. absolute change	1.10%	3.38%	2.25%	1.43%	8.90%	2.35%	3.26%
# of obs. with no change	33	41	33	31	9	12	57
Standard Deviation	0.18%	0.60%	0.54%	0.30%	0.77%	0.31%	0.49%
Average	0.02%	0.08%	0.08%	0.02%	0.01%	0.01%	0.10%
Coef. of Variability	963.29	771.85	709.69	1,701.11	5,808.19	2,277.32	496.68
Number of observations	260	260	260	260	260	260	260
1998							
Max. absolute change	1.08%	4.68%	3.90%	3.09%	5.49%	2.50%	8.06%
# of obs. with no change	24	23	21	17	70	5	28
Standard Deviation	0.24%	0.88%	0.97%	0.47%	0.76%	0.37%	0.93%
Average	0.06%	0.03%	0.04%	0.03%	0.09%	0.03%	0.07%
Coef. of Variability	429.27	3,128.66	2,235.75	1,532.82	893.84	1,278.02	1,272.05
Number of observations	261	261	261	261	261	261	261
1999							
Max. absolute change	1.88%	1.93%	1.61%	1.66%	3.73%	1.05%	2.06%
# of obs. with no change	4%	6	2	5	7	1	3
Standard Deviation	0.61%	0.66%	0.67%	0.52%	1.44%	0.41%	0.58%
Average	0.11%	-0.06%	-0.01%	-0.03%	-0.04%	0.06%	0.00%
Coef. of Variability	538.42	1,185.10	4,530.54	1,544.58	3,339.38	681.38	574,915.52
Number of observations	56	56	56	56	56	56	56
1997-1999							
Max. absolute change	1.88%	4.68%	3.90%	3.09%	8.90%	2.50%	8.06%
# of obs. with no change	61	70	56	53	86	18	88
Standard Deviation	0.28%	0.75%	0.77%	0.41%	0.86%	0.35%	0.73%
Average	0.04%	0.04%	0.05%	0.02%	0.04%	0.03%	0.08%
Coef. of Variability	619.91	1,752.36	1,478.59	2,194.84	2,114.40	1,390.27	941.49
Number of observations	577	577	577	577	577	577	577

Graph 5: Daily Volatility of the Nominal Exchange Rate

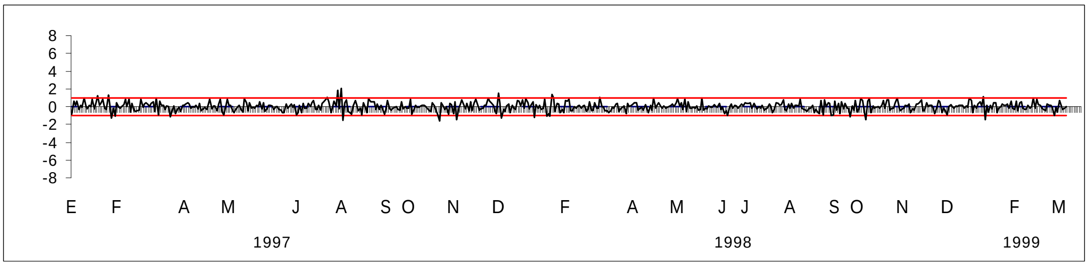
(A) Mexico (1997 - 1999)



(B) Peru (1997 – 1999)

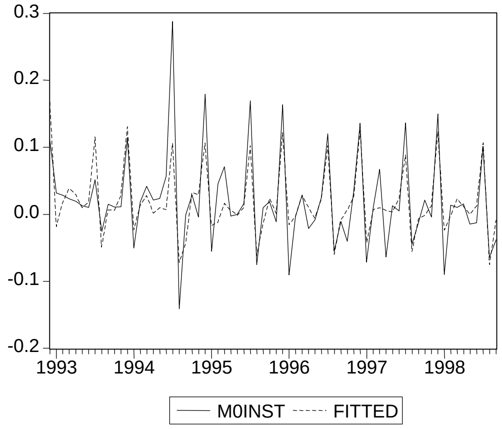


(C) England (1997 – 1999)

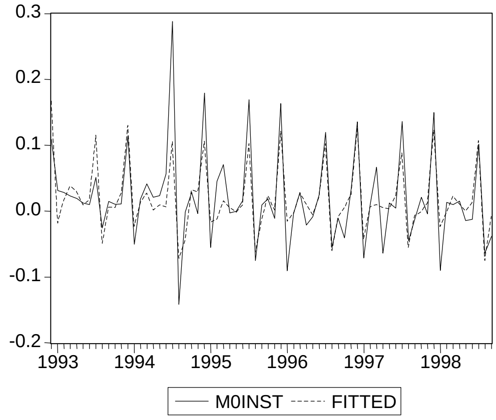


Graph 8: Alternative Monetary Policy Rules

Original Monetary Policy Rule



Monetary Policy Rule with
Brainard uncertainty



Monetary Policy Rule with Explicit
Adjustment Factor, Goodfriend (1987)

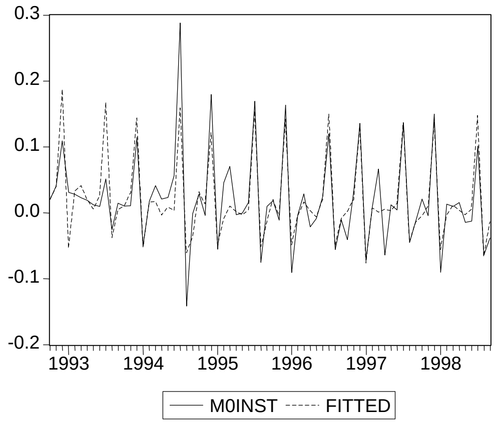


TABLE 5

STRUCTURE OF THE ECONOMY: SUR ESTIMATION

The three endogenous variables selected were output gap (x), inflation (π), and the exchange rate depreciation (TC). The estimated system was:

$$x_t = \beta_0 + \beta_1 x_{t-1} + \beta_2 M_{t-3} + \beta_3 M_{t-4} + \beta_4 Cu_{t-1}$$

$$\pi_t = \alpha_0 + \alpha_1 \pi_{t-1} + \alpha_2 \pi_{t-3} + \alpha_3 TC_{t-2} + \alpha_4 PAS_{t-2} + \alpha_5 M_{t-2}$$

$$TC_t = \gamma_0 + \gamma_1 TC_{t-1} + \gamma_2 M_{t-2} + \gamma_3 DUMMYR$$

The results were:

System: SUR
Estimation Method: Seemingly Unrelated Regression
Sample: 1992:04 1998:12
Included observations: 81
Total system (unbalanced) observations 240

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.000631	0.007391	0.085419	0.9320
C(2)	-0.474022	0.098060	-4.834015	0.0000
C(3)	0.212714	0.101248	2.100921	0.0368
C(4)	0.248762	0.102367	2.430090	0.0159
C(5)	0.137273	0.058240	2.357024	0.0193
C(11)	-0.000735	0.000751	-0.979174	0.3285
C(12)	0.347459	0.062909	5.523188	0.0000
C(13)	0.377672	0.063744	5.924828	0.0000
C(14)	0.118307	0.026050	4.541526	0.0000
C(15)	0.035784	0.014559	2.457848	0.0147
C(16)	0.016112	0.008259	1.950839	0.0523
C(21)	0.002187	0.001740	1.256808	0.2101
C(22)	0.408591	0.068159	5.994656	0.0000
C(23)	0.048444	0.023544	2.057610	0.0408
C(24)	0.088772	0.010461	8.486117	0.0000
Determinant residual covariance		1.38E-11		

Equation: PBIGAP = C(1) + C(2)*PBIGAP(-1) + C(3)*M0INST(-3) + C(4)*M0INST(-4)+ C(5)*CUINST(-1)
Observations: 79

R-squared	0.269744	Mean dependent var	0.006284
Adjusted R-squared	0.230271	S.D. dependent var	0.065697
S.E. of regression	0.057639	Sum squared resid	0.245845
Durbin-Watson stat	2.101844		

Equation: INFLGAP = C(11) + C(12)*INFLGAP(-1) + C(13)*INFLGAP(-3) + C(14)*TCGAP(-2) + C(15)*PASINST(-2) + C(16)*M0INST(-2)
Observations: 80

R-squared	0.832542	Mean dependent var	0.008175
Adjusted R-squared	0.821227	S.D. dependent var	0.011933
S.E. of regression	0.005046	Sum squared resid	0.001884
Durbin-Watson stat	1.803548		

Equation: TCGAP = C(21) + C(22)*TCGAP(-1) + C(23)*M0INST(-2) + C(24)*DUMMYR
Observations: 81

R-squared	0.656079	Mean dependent var	0.008958
Adjusted R-squared	0.642679	S.D. dependent var	0.023822
S.E. of regression	0.014240	Sum squared resid	0.015614
Durbin-Watson stat	1.954224		

DUMMYR is a dummy variable equal to 1 for observations between 1992:06 and 1992:11.

VARIANCE-COVARIANCE MATRIX OF THE COEFFICIENTS

We will later use this matrix to compute the variance associated with the following coefficients:

- Covariance of $\alpha_1\alpha_5$ or C(12)C(16) = -5.52 E-05
- Variance of γ_2 or C(23) = 0.000564

	C(1)	C(5)	C(11)	C(12)	C(13)	C(15)	**C(16)**	C(21)	C(22)	C(23)	C(24)
C(1)	5.46E-05	4.36E-05	-2.74E-07	4.40E-06	-3.35E-07	-1.10E-07	-1.05E-06	2.52E-07	-7.77E-07	9.49E-07	-3.72E-08
C(2)	-4.90E-06	-0.000705	1.14E-08	3.28E-05	-5.70E-05	-5.90E-06	6.22E-06	2.55E-07	-7.93E-06	-7.90E-06	-3.02E-07
C(3)	-0.000317	-0.000337	-7.76E-08	-0.000102	1.73E-05	2.16E-06	2.73E-05	3.88E-07	2.00E-05	-2.52E-05	6.71E-07
C(4)	-0.000313	0.000649	5.65E-08	-3.37E-05	-1.13E-05	8.31E-06	1.44E-05	3.44E-08	2.63E-05	-1.19E-05	5.13E-07
C(5)	4.36E-05	0.003392	1.61E-07	-3.56E-05	1.23E-05	5.99E-06	-3.00E-06	-2.46E-08	-6.65E-06	3.42E-06	1.24E-07
C(11)	-2.74E-07	1.61E-07	5.63E-07	-4.06E-07	-1.71E-05	-4.06E-06	-1.34E-06	-1.08E-07	1.46E-06	4.78E-07	5.05E-08
C(12)	4.40E-06	-3.56E-05	-4.06E-07	0.003958	-0.002855	-0.000229	-5.52E-05	-2.48E-07	1.81E-05	5.93E-07	3.82E-06
C(13)	-3.35E-07	1.23E-05	-1.71E-05	-0.002855	0.004063	0.000260	4.29E-05	1.29E-06	-0.000108	-3.10E-06	-1.25E-05
C(14)	-8.55E-07	2.74E-06	-5.03E-07	-0.000230	-0.000349	5.66E-05	-2.18E-05	5.10E-07	-7.18E-05	-3.40E-06	7.06E-06
C(15)	-1.10E-07	5.99E-06	-4.06E-06	-0.000229	0.000260	0.000212	4.02E-06	5.70E-08	-4.41E-06	-1.14E-07	-6.82E-07
C(16)	-1.05E-06	-3.00E-06	-1.34E-06	-5.52E-05	4.29E-05	4.02E-06	6.82E-05	3.96E-07	4.04E-06	-1.86E-05	-2.90E-07
C(21)	2.52E-07	-2.46E-08	-1.08E-07	-2.48E-07	1.29E-06	5.70E-08	3.96E-07	3.03E-06	-3.83E-05	-1.39E-05	-3.37E-07
C(22)	-7.77E-07	-6.65E-06	1.46E-06	1.81E-05	-0.000108	-4.41E-06	4.04E-06	-3.83E-05	0.004646	0.000197	-0.000231
C(23)	9.49E-07	3.42E-06	4.78E-07	5.93E-07	-3.10E-06	-1.14E-07	-1.86E-05	-1.39E-05	0.000197	0.000554	-1.77E-05
C(24)	-3.72E-08	1.24E-07	5.05E-08	3.82E-06	-1.25E-05	-6.82E-07	-2.90E-07	-3.37E-07	-0.000231	-1.77E-05	0.000109

TABLE 6

EULER EQUATION OF THE FOC OF THE INTERTEMPORAL OPTIMIZATION PROBLEM OF THE CENTRAL BANK: GMM ESTIMATION.

The general specification is:

$$E_t(\bar{\pi}_{t+2}) = \pi^* - \frac{\rho\gamma_2}{\alpha_5} E_t(TC_{t+2}) - \partial\alpha_1 E_t(\pi_{t+3}) - \frac{\partial\lambda\beta_2}{\alpha_5} E_t(x_{t+3}) - \frac{\partial\rho\gamma_1\gamma_2}{\alpha_5} E_t(TC_{t+3})$$

But as we already know the parameters of the structure of the economy (α,β,γ) and the intertemporal discount rate (δ) as well, we include them explicitly in order to estimate the remaining unknown parameters. These correspond to the preferences of the Central Bank.

INFLAC(2) = **C(1)** + **C(2)***((0.048444 / 0.016112)***TCGAP(2)**) +
C(3)*((0.975*0.212714 / 0.016112)***PBIGAP(3)**) +
C(4)*((0.975*0.048444*0.408591 / .016112)***TCGAP(3)**) +
C(5)*(((0.975^2)*((0.347459^2)*0.016112+0.118307*0.048444) / 0.016112)***INFLGAP(4)**) +
C(6)*(((0.975^2)*((-0.474022*0.212714)+0.248762) / 0.016112)***PBIGAP(4)**) +
C(7)*(((0.975^2)*(0.408591^2)*(0.048444) / 0.016112)***TCGAP(4)**)

The GMM estimation rendered the following results:

Dependent Variable: INFLAC(2)
Method: Generalized Method of Moments
Date: 06/28/99 Time: 05:59
Sample(adjusted): 1993:02 1998:09
Included observations: 68 after adjusting endpoints
No prewhitening
Bandwidth: Fixed (3)
Kernel: Bartlett
Convergence achieved after: 64 weight matricies, 65 total coef iterations
Instrument list: C DUM M2INST(-1TO-12) PASINST(-1TO-3) PBICOM PBICONS RININST CUINST(-1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.008017	0.000465	17.23245	0.0000
(0.975*0.048444*0.408591/.016112)*TCGAP(3)	-0.220413	0.079720	-2.764846	0.0074
DUM	0.011208	0.001104	10.15261	0.0000

R-squared	0.265195	Mean dependent var	0.010115
Adjusted R-squared	0.242586	S.D. dependent var	0.008147
S.E. of regression	0.007090	Sum squared resid	0.003268
Durbin-Watson stat	0.778265	J-statistic	0.158045

DUM is a dummy variable equal to 1 for observations within the period 1992:01-1994:06. This captures the difference of inflation rates between this period and the months after.

TABLE 7

MONETARY POLICY RULE OF THE CENTRAL BANK: GMM ESTIMATION

The specification of the estimated policy rule is:

$$M_t = c_1 + c_2 * E_t(\pi_{t+1}) + c_3 * \pi_{t-1} + c_4 * TC_t + c_5 * PAS_t + c_6 * E_t(TC_{t+3}) + c_7 * DUMY$$

Dependent Variable: M0INST
Method: Generalized Method of Moments
Sample(adjusted): 1992:09 1998:09
Included observations: 73 after adjusting endpoints
No prewhitening
Bandwidth: Fixed (3)
Kernel: Bartlett
Convergence achieved after: 50 weight matricies, 51 total coef iterations
Instrument list: M0INST(-1TO-7) RININST(-1TO-7) CUINST(-1TO-7) PASINST(-1TO-7) @SEAS(1) @SEAS(7) @SEAS(8) @SEAS(12) DUMY

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.012834	0.002105	6.098258	0.0000
INFLGAP(1)	4.068558	0.607989	6.691832	0.0000
INFLGAP(-1)	-2.307309	0.472517	-4.883019	0.0000
TCGAP(3)	-1.101366	0.198391	-5.551500	0.0000
TCGAP	-1.053300	0.228062	-4.618492	0.0000
@SEAS(1)	-0.120848	0.007512	-16.08676	0.0000
@SEAS(7)	0.117461	0.012001	9.787553	0.0000
@SEAS(8)	-0.070336	0.007134	-9.859355	0.0000
@SEAS(12)	0.118978	0.007108	16.73921	0.0000

R-squared	0.584274	Mean dependent var	0.021143
Adjusted R-squared	0.532309	S.D. dependent var	0.069729
S.E. of regression	0.047686	Sum squared resid	0.145534
Durbin-Watson stat	2.232747	J-statistic	0.180549

It was required to include seasonal dummies (@seas1,7,8,12) to capture the seasonality of the dependent variable. The Wald test show the restrictions imposed on the coefficients are not satisfied.

Wald Test: Equation: EQGMMM0

Null Hypothesis:	C(1)=0.045618173
	C(2)=-21.56523088
	C(3)=-23.44041708
	C(5)=-7.342787984
	C(4)=14.57104074

F-statistic	17012.74	Probability	0.000000
Chi-square	85063.68	Probability	0.000000

TABLE 8

MONETARY POLICY RULE WITH BRAINARD-STYLE UNCERTAINTY

Dependent Variable: M0INST
Method: Generalized Method of Moments
Date: 06/28/99 Time: 16:23
Sample(adjusted): 1992:12 1998:09
Included observations: 70 after adjusting endpoints
No prewhitening
Bandwidth: Fixed (3)
Kernel: Bartlett
Convergence achieved after: 51 weight matricies, 52 total coef iterations
Instrument list: ENCINST(-1TO-5) RININST(-1TO-5) PBICOM CUINST(-1TO-5)
PASINST(-1TO-5) R_CD(0TO-5) INFLGAP(-2TO3) TCGAP(2TO3)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.007946	0.001942	4.091083	0.0001
M0INST(-2)	-0.132196	0.023330	-5.666366	0.0000
INFLGAP(2)	1.411654	0.275841	5.117645	0.0000
INFLGAP(3)	-0.712793	0.304632	-2.339848	0.0226
TCGAP(2)	-0.319285	0.152979	-2.087117	0.0411
TCGAP(3)	0.372159	0.116110	3.205225	0.0022
@SEAS(12)	0.114924	0.007568	15.18457	0.0000
@SEAS(1)	-0.031309	0.012183	-2.570014	0.0127
@SEAS(8)	-0.065785	0.008794	-7.480646	0.0000
@SEAS(7)	0.086582	0.011798	7.338419	0.0000

R-squared	0.696525	Mean dependent var	0.020680
Adjusted R-squared	0.651004	S.D. dependent var	0.071169
S.E. of regression	0.042044	Sum squared resid	0.106061
Durbin-Watson stat	2.457160	J-statistic	0.197929

APPENDIX 7

BRAINARD RESTRICTIONS

To test the presence of Brainard uncertainty in the monetary policy rule we require several coefficient restrctions to hold:

- Coefficient of M_{t-2}

This restriction is satisfied as the Wald test shows.

Wald Test:
Equation: EQGMMBRAINARDV1

Null Hypothesis:	C(2) = -0.097722096		
F-statistic	2.183524	Probability	0.144725
Chi-square	2.183524	Probability	0.139495

- No constant term

The coefficient is statistically significant different from zero.

Wald Test:
Equation: EQGMMBRAINARDV1

Null Hypothesis:	C(1) = 0		
F-statistic	16.73696	Probability	0.000130
Chi-square	16.73696	Probability	0.000043

- Variances of the Coefficients

Coefficient associated to π_{t+3}:

$$c(4) = -\frac{\partial a_1 a_5}{\sigma^2(1+\rho+\partial)} = -0.712793$$

from where its possible to obtain σ^2 = 0.00248623. The covariance associated to those coefficients $(\alpha_1\alpha_5)$ is in absolute value 5.52 E-05. The estimated covariance of our model is higher that the one we should have get from the estimation of the structure of the economy.

Coefficient associated to $TCGAP_{t+2}$:

$$c(5) = -\frac{\rho\, c_2}{\sigma^2(1+\rho+\partial)} = -0.319285$$

after some algebra we get σ^2 = 0.004863636. The estimated variance of γ_2 is equal to 0.000564. Again the variance is too high.

TABLE 9

MONETARY POLICY RULE WITH AN EXPLICIT ADJUSTMENT FACTOR, GOODFRIEND (1987): GMM ESTIMATION

To estimate the rule we use GMM over the following expression:

$$M_t = \frac{1}{1+\partial^2} M_{t-2} + \frac{\partial^2}{1+\partial^2} M_{t+2} - \frac{\partial^2 a_5}{\mu(1+\partial^2)} * E_t(\pi_{t+2}) - \frac{\partial^2 \rho c_2}{\mu(1+\partial^2)} * E_t(TC_{t+2}) - \frac{\partial^3 a_1 a_5}{\mu(1+\partial^2)} * E_t(\pi_{t+3}) - \frac{\partial^3 \rho c_1 c_2}{\mu(1+\partial^2)} * E_t(TC_{t+3})$$

The only term that was not significative was M_{t+2}. This rule is characterized for including forward looking variables as the inflation expectations and the depreciation expectations.

Dependent Variable: M0INST
Method: Generalized Method of Moments
Date: 06/28/99 Time: 13:58
Sample(adjusted): 1992:10 1998:09
Included observations: 72 after adjusting endpoints
No prewhitening
Bandwidth: Fixed (3)
Kernel: Bartlett
Convergence not achieved after: 99 weight matricies, 100 total coef Iterations
Instrument list: R_CD(0TO-1) M0INST(-1TO-7) ENCINST(-1TO-7) M1INST(-1TO-7) RININST(-1TO-7) INFLGAP(-1TO-7) PBIGAP(-1TO-7) CUINST(-1TO-7) PASINST(-1TO-7)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.002956	0.000510	5.796016	0.0000
M0INST(-2)	-0.108739	0.005989	-18.15650	0.0000
INFLGAP(1)	-0.507314	0.056114	-9.040774	0.0000
INFLGAP(2)	1.821040	0.090311	20.16398	0.0000
INFLGAP(3)	-0.238716	0.055194	-4.325018	0.0001
TCGAP(2)	-0.247467	0.014792	-16.73019	0.0000
TCGAP(3)	0.201432	0.018953	10.62797	0.0000
@SEAS(7)	0.142871	0.001811	78.90764	0.0000
@SEAS(1)	-0.064125	0.001212	-52.92801	0.0000
@SEAS(8)	-0.047260	0.001018	-46.43338	0.0000
@SEAS(12)	0.131749	0.002475	53.23027	0.0000
R-squared	0.740902	Mean dependent var		0.020952
Adjusted R-squared	0.698427	S.D. dependent var		0.070199
S.E. of regression	0.038550	Sum squared resid		0.090653
Durbin-Watson stat	2.386687	J-statistic		0.248233

We also include seasonal dummies in the estimation.

Estimation of the adjustment coefficient

From the estimation of the coefficient of $TCGAP_{t+2}$ of equation (17) we obtain:

$$C(6) = -\frac{\partial^2 \rho c_2}{\mu(1+\partial^2)} = -0.247467$$

Solving for μ, we found a value of μ=0.02168211.