THE INSTRUMENT PROBLEM UNDER INFLATION TARGETING IN AN OPEN ECONOMY: THE CASE OF COSTA RICA

DISSERTATION

Presented in Partial Fulfillment of the Requirements for

the Degree Doctor of Philosophy in the

Graduate School of The Ohio State University

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The Ohio State University

2004

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ABSTRACT

Since the early 1990s, an increasing number of central banks have adopted inflation targeting as the strategy to conduct their monetary policy. Most of the literature on this topic presupposes that the instrument of monetary policy should be the nominal interest rate. This dissertation revisits the instrument problem in the context of a small open economy that implements inflation targeting. It formulates a partial equilibrium monetary model that describes the inflation process. This model is used to analyze the interaction between the typical instruments of monetary policy, namely the nominal interest rate or a monetary aggregate, with particular exchange rate regimes. In an open economy, the issue is not what the best instrument to deliver the desired inflation rate is but, rather, what the best combination of a particular exchange rate arrangement and one of the two other policy instruments is. An analytical result is that inflation targeting is incompatible with a hard-peg exchange rate regime. The theoretical framework does not allow, however, a definitive answer about the most appropriate combination of policy instruments to reach a desired sustainable path for the inflation rate.

Given that the choice of the optimum instrument is an empirical problem, the monetary model of inflation is estimated econometrically using annual data for the past 53 years for Costa Rica. The estimated parameters are used to compute expressions for the mean-squared error for the inflation rate under different policy instrument combinations. A ranking of the mean-squared errors shows that the instrument combination that minimizes

the error in targeting a desired inflation rate, in the long run, is the nominal interest rate and a free exchange rate regime. The reason why, from the perspective of monetary policy, a free exchange rate regime is superior to other regimes is that the latter, in the presence of capital movements, requires some form of monetary sterilization, which in turn leads to debt accumulation. Eventually, this debt leads to central bank losses, which in the long run are a source of monetary expansion and thereby of inflationary pressures.

To Iliana, Miguel and Luis, and to my parents, Elizabeth and don Miguel

ACKNOWLEDGMENTS

Graduate school has been the most defining experience in my adult life. It is not easy to express with words my imperishable gratitude to the person who has led me during this long journey, don Claudio González-Vega, whose wisdom has been an inspiration in my professional activities and whose support and counseling, when I needed them the most, have helped me to get through this chapter of my life.

I am very grateful to Professor Huston McCulloch, for taking his time and engaging in long discussions, which encouraged me to further explore the theoretical and empirical dimensions of this research. The interaction with him allowed me to have a better understanding of inflation as a monetary phenomenon.

My gratitude also goes to Professor Cameron Thraen, who during the entire process, since the time I was one more student in his class, to the time when I was preparing for my candidacy exam, was very supportive. And now, once again in this last stage, he has provided me with valuable econometric advice.

I wish to thank Professor Phillip Viton for his patience and kindness in helping me with Scientific Work Place. His knowledge and approachability have been an invaluable help for me.

So many years and so many events make it really difficult to name all the wonderful people who in one way or another contributed to the success of my graduate studies. The completion of this effort has been also the result of the support from the Central Bank of

Costa Rica. Under the risk of being ungrateful by forgetting people who have helped me, I want to thank past and current authorities of the Central Bank, including Jorge Guardia, Eduardo Lizano, Francisco Gutiérrez, Luis Mora, Carlos Muñoz, José Brenes, Ana Rodríguez, Willian Calvo, and Claudio Ureña. I found support and very opportune help from Celia González, Evelyn Muñoz, Rebeca Porras, and William Mora; to all of them my gratitude and friendship.

Among the most appreciated gifts with which I have been rewarded during my stay at Ohio State is the friendship from many people, including Jorge Rodríguez-Meza, Louis DeVault, Rebecca Hunley, Piotr Korynski, Dony Azdan, Joan and Julian Loewenstein, Yvonne and Arthur Helf, and Doris and Elam Stauffer. I have long lasting memories from all of them; thank you my friends.

The culmination of this effort has also been the result of the set of values and principles that my parents inculcated in me; their way to show their love was by hard work and countless sacrifices to provide me with the opportunity to pursue college studies in Costa Rica. To you mom, thank you, and to you dad, the most influential person in my life, don Miguel, as I used to call you, thank you for your teachings and example throughout life.

Finally, I want to express my gratitude to Iliana, who has been with me during this long process. She has endured years of sacrifices; she has brought happiness to my life; she has been part of my success and she has been there, at my side, when by the inexorable realities of life, I have had to mourn.

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3. León, J., R. Madrigal-López, and E. Muñoz. (2003). "Un Enfoque Monetario de los Efectos sobre Precios y Tasas de Interés del Tipo de Cambio Fijo", en *Ensayos en Honor a Claudio González Vega*. Academia de Centroamérica, San José, Costa Rica.

FIELDS OF STUDY

Major Field: Agricultural, Environmental, and Development Economics

Minor Fields: Macroeconomics, Money and Banking, and Development Economics

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CHAPTER 1

INTRODUCTION

Every central bank in the world must answer the question: what is the purpose of monetary policy? Sometimes the political authorities, ostensibly in representation of society, determine objectives for the monetary authority. In other cases, currently regarded as more appropriate, the central bank itself has sufficient independence to define the goals of monetary policy. The controversy about what the central bank should and can do is not, however, completely resolved.

For many central banks, price stability is the goal of monetary policy. For others, the goal is to smooth the movements of the business cycle, to promote full employment or even to directly contribute to more general goals of economic development. Emphasis has been shifting, however, from promoting economic growth toward inflation goals, while price stability is expected to indirectly contribute to economic growth.

Since the early 1990s, there has been a growing consensus that maintaining price stability should be the primary objective of monetary policy [Poole, 1998]. This has been the case of the central banks of Australia, Brazil, Canada, Chile, Israel, Finland, Germany, New Zealand, Spain, Sweden, the United Kingdom, and the United States, among others. In fact, the Maastricht Treaty establishes price stability as the main goal of the European Central Bank [Bernanke and Mishkin, 1997; Kahn and Parrish, 1998]. Structural adjustment programs in developing countries have also shifted the focus of monetary policy towards price stability.

Once a central bank has chosen its objective, it has to answer the question of which policy instruments are available to accomplish the task. The literature agrees that, in the case of a closed economy, a central bank can conduct its monetary policy through one of two instruments: a monetary aggregate, such as high-powered money, or the interest rate. In an open economy, in addition, it is possible to use the exchange rate as an instrument of monetary policy.

The policy issue is: if more than one instrument is available, which one is the best? There have been major theoretical efforts to settle the *instrument problem* in monetary policy. In general, however, the results have been sensitive to the approach followed (*e.g.*, partial equilibrium or general equilibrium models, expectations formation process) and to the specific values of the structural parameters of the model.

The choice of the optimal monetary policy instrument remains, therefore, a question without a definitive answer in the literature. Because its effectiveness depends on empirical values, any policy recommendation must be supported by knowledge of a specific economic structure. Most theoretical and empirical contributions in this area rely on models for large industrialized countries. This dissertation explores this question for small open economies in which the central bank's policy strategy is inflation targeting.

In summary, there is an increasing consensus that central banks should pursue price stability. There is also theoretical agreement in the sense that central banks have three instruments to work with (money aggregates, interest rates, and the exchange rate). There is no theoretical consensus, however, with respect to which of these is the best policy instrument. Moreover, there may be no *a priori* answer to this question.

In this dissertation, I build a model for a small open economy and compare the relative effectiveness of a monetary aggregate and the nominal interest rate in combination with different foreign exchange rate regimes, as instruments of monetary policy in a context of inflation targeting.

In addition to deriving the analytical expressions that allow an evaluation of the relative effectiveness of each instrument, I estimate the model's parameters relevant for a small open economy such as Costa Rica. This exercise is an illustration of the usefulness of the model in its empirical application to actual situations.

One motivation has precisely been the opportunity to derive concrete policy recommendations for the monetary authorities of a country like Costa Rica. The econometric estimation, based on actual Costa Rican data, should provide insights valuable for the authorities of this country.

In general, the dissertation highlights theoretical and empirical difficulties faced by anyone who tries to offer an answer to the instrument problem of monetary policy.

From a theoretical point of view, the model developed here makes it possible to show that in a closed economy, under bounded rationality, inflation is the result of present and past monetary disequilibria. In this sense, even when there is a departure from the original formulation of the Quantity Theory of Money that gives expectations a role in the inflation formation process, the analytical result is basically that inflation is a monetary phenomenon.

In the case of an open economy, expectations are driven by past recent inflation and the exchange rate regime. Therefore, the choice of exchange rate regime is critical in the design of a monetary policy strategy based on inflation targeting.

A technical problem must be overcame, moreover, in the choice of the exchange rate regime. Any attempt to manage the exchange rate implies that the central bank has to make an intensive use of its international reserves, which have a limit, or accumulate debt, which also has a limit in the long run. Debt accumulation (and/or international reserves depletion) leads to central bank losses, which in the long run are a source of monetary expansion and inflationary pressures. Therefore, the harder is the peg of the exchange rate, the lower is the probability of implementing inflation targeting successfully.

Another interesting analytical result is that, if the central bank commits itself not to create monetary disequilibria in the long run, then the steady-state domestic inflation rate tends to converge to international inflation rate.

From an empirical point of view, the monetary model of inflation adopted here was estimated for Costa Rica. Four possible policy instrument combinations were considered and ranked according to their mean squared error (MSE). The results show that, in the case of Costa Rica, the combination of policy instruments that delivers the smallest error in pursuing a desired inflation rate is the use of the nominal interest rate under a free floating exchange rate regime.

The plan for the rest of the dissertation is as follows. Chapter 2 explores conceptual issues related to the instrument problem in monetary policy and examines in some detail what, according to the specialized literature, is understood by the term inflation targeting. A short section is devoted to the Lucas critique, as a remainder of the problems that can arise when policy recommendations are based on econometric estimates. Chapter 3 develops a model, for a closed economy, in which inflation can be expressed as a linear combination of past and present monetary disequilibria. This chapter also shows how, in this closed economy, the choice of the monetary policy instrument, in order to reach a desired inflation rate, is an empirical issue. Chapter 4 considers the case of an open economy, and it shows how the exchange rate regime is critical in the design of monetary policy. In particular, it analyzes two extreme exchange rate regimes, a hard peg and a free float. Between these extremes, it considers a crawling-peg regime that follows, in the long run, the relative version of purchasing power parity (PPP) theory. The motivation to investigate this case comes from the fact that, in the past 20 years, the design of the exchange rate regime in Costa Rica can be explained according to this rule.

The econometric estimation of the model is performed in Chapter 5. Four possible policy combinations are compared and evaluated. Finally, Chapter 6 summarizes the main conclusions and derives policy implications. Given the extensive notation used in the dissertation, Appendix A contains a summary of the variables used and their symbols in Chapter 4. Appendices B and C include the OLS output from EViews for the forecast of international inflation and rate of variation of foreign exchange rate.

CHAPTER 2

CONCEPTUAL ISSUES ON INFLATION TARGETING AND THE INSTRUMENT PROBLEM

2.1 The Purpose of Monetary Policy

Historically, central banks have pursued a number of policy goals: price stability, full employment, exchange rate stability, economic growth, and even some distributional objectives. In earlier decades, a multiplicity of objectives was common in developing countries.

Freedman [1989] recognizes that economists believed that central banks could simultaneously achieve goals about output, employment, and the rate of inflation by targeting real variables such as real output growth or the rate of unemployment. Thereby, monetary policy would be adjusted in response to forecasted movements in unemployment and inflation. The events of the second half of the past century in both industrialized and developing countries have shown, however, that such policies are ineffective.

Well-established theoretical developments also support the conclusion that money can induce only nominal effects. For example, Sargent and Wallace [1975] developed a model with rational expectations in which, if the money supply is correctly forecasted by the public, money growth cannot alter real output, employment, real wages, and the expected real interest rate. Therefore, even though some central banks may want to pursue several objectives, the range of targets that they can actually reach is very narrow.

There has been a growing consensus that monetary policy should pay attention only to nominal variables (namely, the price level) rather than to real variables. The argument, originating in the neoclassical dichotomy, is that real variables depend only on real magnitudes. The real side of the economy responds to resource endowments, the available technologies, existing institutions, and individual preferences and, therefore, it reflects relative scarcities, which in turn determine real income and relative prices. In the long run, monetary policy cannot change these real determinants of output and relative prices.

Despite this pessimistic view about the constrained effectiveness of monetary policy, it is important to stress that using nominal money growth to achieve goals for which money is ill suited can have devastating consequences on the economy.

In his seminal paper, Milton Friedman [1968] quotes John Stuart Mill [1929]:

> *There cannot ... be intrinsically a more insignificant thing, in the economy of society, than money except in the character of contrivance for sparing time and labour. It is a machine for doing quickly and commodiously, what would be done, though less quickly and commodiously, without it: and like many other kinds of machinery, it only exerts a distinct and independent influence of its own when it gets out of order.* (p.488)

It is because the faulty operation of this machinery has powerfully disruptive effects on the rest of the economy, that what monetary policy should accomplish is to prevent money from becoming a source of economic instability. Nevertheless, as a mechanism to lower transaction costs in output, factor, asset and liability markets, money plays a substantial role in increasing the efficiency of resource allocation (mostly through its effects on market size and the division of labor) and on the rate of economic growth [Gurley and Shaw, 1960; Kower, 2002]. The policies needed to promote money deepening, however, are different from monetary policy, except to the extent to which price stability is a necessary condition for money deepening. The latter also depends, in turn, on the development of an institutional framework of contracts and property rights and on innovations in financial technologies [Gonzalez-Vega, 1997]

Reflecting the growing consensus, Poole [1998] claims that, given the limitation on what central banks can do, the almost exclusive goal of monetary policy should be to maintain price stability.

2.2 Inflation Targeting

Even though the literature had been dealing with the question of what a central bank should do since the 1960s, it was not until the 1990s that a new term was coined to describe the central bank's task. The basic idea is that central banks can better conduct monetary policy if they have a nominal anchor to guide their policy and to keep the public's inflation expectations aligned with the central bank's target.[1] While it seems that a formal definition of inflation targeting is still in progress, it is possible to enumerate key elements of an inflation targeting regime.

From Cecchetti [1996], Dueker and Fischer [1996], Bernanke and Mishkin [1997], Archer [1997], Rich [1997], Kahn and Parrish [1998], Svensson [2000], and Bogdanski, Tombini and Werlang [2000], an inflation targeting regime can be characterized by:

(i) Long-term objective: There is a contract between the central bank and society, in which the primary objective of monetary policy is the stability of the general level of prices. Through this contract, the central bank commits itself to pursue a long-run path of low inflation. This path may be defined for the level of the price index or for the rate of inflation.

[1] During the 1970s and 1980s, many central banks used the nominal exchange rate as the nominal anchor. However, the consensus is that this approach did not work well. In this respect, Montiel [2003] concludes: *When the exchange rate is used as a nominal anchor and such [inflationary] inertia is allowed to persist, combining stabilization with domestic and external financial liberalization may provide the recipe for the failure of stabilization and a financial crash, as in the Southern Cone countries*. (p.145)

Even though there are several options for the price indicator, usually the consumer price index (CPI) is chosen for this purpose. The target itself may be expressed as a specific value of the index or as a value that may oscillate within a narrow range. Usually these values are between 0 and 4.5 percent for the annual inflation rate. Among inflation targeting countries, only Israel and more recently Brazil (1999, 2000) have specified a target rate of inflation higher than 5 percent per year.

(ii) Transparency: The government or the central bank publishes a report explaining what the level of the inflation target is and describing how inflation has behaved with respect to the target. More importantly, the report includes a forecast for inflation. In some cases, the central bank can use the report to explain why the target might have been missed and what actions are necessary to bring inflation back to the long-run target.

(iii) Central bank independence: The monetary authority must have enough degrees of freedom from the influence of other branches of government to implement the necessary actions leading to accomplishments of the target.

(iv) Accountability: The governor or the board of directors of the central bank are held accountable for the outcome of monetary policy. The executive or the legislative may monitor the central bank's performance. Different degrees of penalties may be imposed on the monetary authorities, including the dismissal of the central bank's governor.

(v) Flexibility: Given the difficulty of forecasting inflation as well as the variety of shocks that may affect it, including some that are beyond the control of the central bank, some inflation targeting regimes allow the central bank to miss the target. When this happens, the central bank must explain the reasons for the deviation. There is also flexibility in the sense that, even though the central bank is supposed to be independent, there are exceptional circumstances when the government can unilaterally and temporarily override the central bank's objective.

Calderón and Schmidt-Hebbel [2003] survey 20 countries that have implemented inflation targeting as their monetary regime and show that these countries have been able to systematically reduce both inflation rates and the error with respect to the target, once they switched to this monetary regime. In their own words:

> *On average, inflation rates have declined from 8% in the first year of IT [inflation targeting] adoption to 3% in the 8^{th} year after adoption....There is evidence that IT has been successful in raising monetary policy credibility, reducing output volatility, and stabilizing inflation expectations....However, it is not clear what determines the success (or failure) of IT central banks in hitting their targets.*

Similar evidence is found by Wu [2004], in an empirical study using quarterly data from 1985 to 2002, for 22 OECD countries. The basic findings of this study are that countries that have officially implemented inflation targeting regimes have been able to reduce their inflation rates and that this reduction has had to do with more than simply increasing their real interest rates. Therefore, when the interest rate effect is controlled for, there is still a causal effect that goes from the adoption of inflation targeting to decreasing inflation rates.

Next, I consider the instruments available to the central bank and their effectiveness, in an effort to establish how the choice of instrument influences the success of central banks in hitting their inflation targets.

2.3 The Interest Rate and Monetary Aggregates as Policy Instruments

A long-standing debate in monetary economics concerns the choice of the appropriate policy instrument. One of the first formal treatments of the instrument problem was undertaken by Poole [1970]. The problem is that, in a closed economy, central banks can conduct their monetary policy through interest rate changes or through money stock changes but not through both of them independently.

Poole [1970] models the problem in an IS-LM framework, with uncertainty, in which the policymaker's objective is to reach full-employment income. His conclusion is that the solution to the instrument problem depends on the value of the parameters (on the slopes of the IS-LM functions) and on the relative size of the variances of the random disturbances that affect the model. The answer to the problem is an empirical issue rather than a theoretical question.

Carlstrom and Fuerst [1996] retake the problem and analyze it in the context of a general equilibrium model with microeconomic foundations, in which agents try to maximize some objective function. Specifically, a benevolent central bank is assumed to conduct its policy so as to maximize household welfare.

These authors conclude that, in this framework, a monetary aggregate rule (for example, constant money growth) is not an optimal policy, because changes in technology and in government spending cause large fluctuations in the nominal interest rate. These fluctuations distort investment decisions and force households to adjust, which is costly in welfare terms.

In contrast, according to these authors, pro-cyclical money growth that pegs the interest rate is welfare improving, even though output variability is higher than in the case of the constant money-growth rule. With productivity shocks, mean consumption is higher than with constant money growth. With government spending shocks, in spite of greater output variability, consumption is less variable (because the interest rate is pegged). Less consumption variability is valued by households as welfare improving.

McCallum [1989] revisits the problem by building a stochastic model of the money market. Even though, in his approach, it is not clear what the purpose of the central bank in pursuing a specific level of the money stock is, this author poses the problem as if the central bank wanted to achieve a given target value of money balances, M^T. This target can be reached by using a money aggregate such as base money, which the central bank can control more closely than actual money balances, M, or by using the nominal interest rate as the mechanism to achieve the desired money stock.

McCallum's conclusions are completely symmetric to those of Poole. The answer to the instrument problem is still an empirical matter, which depends on the interest rate elasticities of the demand for and supply of money (namely, the structural parameters of the model) and on the variances of the stochastic terms in the supply and demand functions.

A breakthrough in macroeconomics was the introduction of the rational expectations hypothesis. Its appeal has in part been due to its reliance on an optimizing principle: if individuals are rational, they do not make systematic errors in forecasting the future.

With this in mind, Sargent and Wallace [1975] retook the instrument problem and compared the conclusions under two alternative processes of expectations formation, namely: adaptive expectations (an autoregressive scheme) and rational expectations. The latter process assumes that individuals base their forecasts not only on past experience (that is, that the process is autoregressive), but they base forecasts on all the available information known at the current time. This includes information about the policy rules being used by the monetary authorities.

Sargent and Wallace [1975] define a loss function for an IS-LM macro-economic model and evaluate two policy rules: (i) a rule that pegs the interest rate and (ii) a money supply growth rule. The problem seems to be straightforward: the instrument that delivers the smallest value of the loss function is the one that should be used.

Under adaptive expectations, the results of Sargent and Wallace [1975] are exactly the same as those of Poole [1970]. The solution to the instrument problem depends on all the parameters of the model, which should include the matrix of variances of the stochastic disturbances. When rational expectations are introduced, however, these authors concluded that, if the public knows the central bank's money supply rule, there is no way to affect real magnitudes with monetary policy. Therefore, any monetary rule is as good as any other for this particular purpose.

The intuition is that, given that the public is informed about the money supply to be set by the central bank for the next period, prices, wages, and the interest rate adjust in a way that incorporates the central bank's intention about money growth. Only unexpected changes in money supply can have real effects on output.

When the policy instrument is the interest rate, however, the model does not have a solution. This outcome results from the fact that the public expects that the central bank will match any quantity of money demanded at the pegged interest rate. Therefore, any increase in prices will be matched by the central bank with a corresponding increase in the nominal money stock, so the interest rate remains fixed. This means that any expectation for the price level is as good as any other, which makes the model indeterminate and there is no solution.

2.4 The Lucas Critique

A macroeconometric model can be seen as a set of rules (equations) that specify the decision rules of economic agents in a given state of the economy. Such decision rules depend on their expectations about future policies. Under rational expectations, if the policymakers change their policies, individuals will change their expectations about future policies, which in turn will alter their decision rules.

It is a common practice, however, to econometrically estimate macroeconomic models and to perform, based on the parameter estimates, evaluations of alternative policy regimes. In such evaluations there is the implicit assumption that the parameters are invariant to the change in policy regime. Given that econometric estimates ignore the change in individual decision rules, the policy evaluation as well as any recommendation derived from it are faulted.

Sargent and Wallace [1976] illustrate the problem with a business cycle model. A condensed version of such illustration is presented next.

Suppose that the authority is interested in controlling y_t, that is, the deviation of real GNP from potential GNP.

The structural model for y_t is:

$$y_t = b_0 + b_1 \left[m_t - \underset{t-1}{E}(m_t) \right] + b_2 y_{t-1} + u_t \tag{2.1}$$

where u_t is a serially independent, identically distributed random variable with variance σ_u^2 and zero mean, and m_t is the rate of growth of the money supply. Here, $\underset{t-1}{E}(m_t)$ is the mathematical expectation of m_t, calculated using all information available at the end of period t-1.

Assume that m_t behaves according to:

$$m_t = g_0 + g_1 y_{t-1} + \varepsilon_t \tag{2.2}$$

where ε_t is a serially independent random term with zero mean and statistically independent of u_t.

Equation 2.2 governs the supply of money. The policy parameters for the money supply rule are g_0 and g_1.

Taking the mathematical expectation of 2.2, we get:

$$\underset{t-1}{E}(m_t) = g_0 + g_1 y_{t-1} \tag{2.3}$$

According to 2.3, the public knows the monetary rule and takes it into account when it forms its expectations. Therefore, unanticipated movements in the money supply have effects on y_t, but expected movements do not.

Solving the equation system 2.1, 2.2 and 2.3, a reduced form for y_t is obtained:

$$y_t = a_0 + a_1 y_{t-1} + b_1 m_t + u_t \tag{2.4}$$

where

$$a_0 = b_0 - b_1 g_0 = f_1(g_0) \quad \text{and} \quad a_1 = b_2 - b_1 g_1 = f_2(g_1)$$

Here it is clear that the coefficients of the reduced form of y_t (a_0 and a_1) depend on the policy rule (control) parameters.

Suppose that, for the next period, the policy rule will change and that this is public information. The new parameters will be $\widetilde{g}_0$ and $\widetilde{g}_1$. Consequently, an econometric estimation will not take into account the effect of the change in the policy rule on the coefficients of the reduced form of y_t.

A policy evaluation using the estimates for a_0 and a_1 would be misleading because the new and true parameters are $\widetilde{a}_0$ and $\widetilde{a}_1$, which incorporate the change in the policy rule.

The Lucas critique can thus be summarized as follows [Lucas, 1976]. Under rational expectations, a component of the individual's information set are the policy rules that are relevant at the moment of determination of the forward-looking variables. The estimated coefficients of observable equations implicitly contain, however, policy parameters that describe what the policy rules had been in the past, not what policy will be in place in the future, which is what is really relevant for the expectations formation process. Hence, if the econometric model does not decompose between structural (invariant) and policy parameters, the estimates derived under the set of old policies would be inappropriate in simulating new policies.

CHAPTER 3

THE CENTRAL BANK'S PROBLEM

The purpose of this dissertation is to answer the question of how a central bank that wishes to achieve an inflation target, should conduct its monetary policy. The analysis is undertaken for a small open economy.

In implementing its monetary policy, the central bank must choose the most appropriate instrument. There is no straightforward answer to this question. Two tasks are accomplished here. First, a definition of instrument is reviewed. Second, the selection of a procedure for the identification of the most appropriate instrument is discussed.

A monetary instrument is a variable over which the central bank has some influence. The central bank attempts to manipulate this variable with the intention of indirectly achieving control over some other target variable [McCallum, 1989].

When the target variable for the central bank is the rate of inflation, the objective of monetary policy is to keep the rate of growth of some price index, usually the consumer price index, under control. This must be distinguished from the choice, with the same purpose, of a given price level as the target [Cecchetti,1998].

In a closed economy, central banks can conduct their monetary policy by influencing either some money aggregate (typically, base money) or the nominal interest rate. The central bank cannot independently influence both at the same time. Therefore, it must choose one of these two instruments [Poole, 1970]. In an open economy, the link between foreign and domestic interest rates through the exchange rate allows the central bank to consider the exchange rate as an alternative instrument in the design of monetary policy [Bruno, 1993].

If the monetary authorities have several instruments to choose from, the question is: which one is the best instrument? What specific circumstances make one instrument superior to others?

To answer this question, I start by building a simple model of the monetary sector of a closed economy. The purpose is to illustrate the relative merits of each instrument. Next, I consider an open economy, to introduce the problem that a central bank faces when it has to deal with the new source of monetary expansion created by an inflow of foreign exchange. As a result, the model must consider the links between the exchange rate and other macroeconomic variables.

3.1 A Deterministic Monetary Framework for a Closed Economy

3.1.1 Money Demand

The initial assumption is that there is a function, (L), that denotes the demand for real money balances. Even though a particular functional form is not yet specified, a widely used formulation considers that the demand for money should at least include as arguments an indicator of the volume of transactions and an indicator of the opportunity cost of holding money rather than other assets.

Such a general specification of the demand for money [McCallum, 1989] is:

$$\left(\frac{M_t}{P_t}\right)^D = L\left(Y_t, R_t\right) \tag{3.1}$$

The relevant demand is for real money balances. The reason to consider real rather than nominal money balances is the assumption that rational individuals recognize the existence of inflation and make decisions based on the expected purchasing power of monetary assets (*i.e.*, the absence of money illusion). The nominal quantity of money demanded, M_t, is therefore deflated by the price level, P_t.

Real output, Y_t, is included as a proxy, as the relevant behavioral relationship is between real money balances demanded and the volume of transactions. The general idea is that economic agents hold money because it reduces the costs of transacting. More real money will be held as the volume of transactions increases.

The nominal interest rate, R_t, indicates that there is a cost of holding money balances. This cost results not only from the real rate of return on alternative tangible assets but also from the erosion of its purchasing power that money suffers in an inflationary world.

Given that R_t is the opportunity cost of holding money balances, the higher R_t is, the less the real money balances that individuals plan to hold are. Therefore: $L_{Y_t} > 0$ and $L_{R_t} < 0$.

Before going any further, let me rewrite, for a specific functional form, equation 3.1 as

$$ln \left(\frac{M_t}{P_t}\right)^D = ln\ L\left(Y_t, R_t\right) = m_t^D = m^D\left(Y_t, R_t\right) \tag{3.2}$$

3.1.2 Money Supply

For a closed economy, the nominal stock of money, M_t, is the sum of two assets held by the public: currency, C_t, and non-interest-bearing bank deposits, D_t.[2]

$$M_t = C_t + D_t \tag{3.3}$$

[2] Interest-bearing bank deposits compensate the opportunity cost of money holdings with interest earnings. This simple model ignores this feature without affecting the results. Interest earnings on deposits positively influence the demand for money and change the composition of the money stock away from currency.

Base money or high-powered money, H_t, is currency held by the public and by the banks plus deposits of the commercial banks at the central bank. Currency held by the banks plus their deposits at the central bank constitute the banks' reserves, K_t.

$$H_t = C_t + K_t \tag{3.4}$$

For current purposes, K_t includes two kinds of reserves. The first one are legal or required reserves, which are the portion of D_t that the banks must keep at any moment because the central bank mandates so. The proportion of mandatory non-remunerated reserves on deposits is designated by q. The second one are surplus reserves, S_t. It is assumed that voluntary surplus reserves are either held as cash or as additional deposits with the central bank. Thus, the following identity for bank reserves holds:

$$K_t = q D_t + S_t \tag{3.5}$$

Now, dividing expressions 3.3 and 3.4 by D_t and writing in lower case the resulting ratios:

$$\frac{M_t}{D_t} = c_t + 1 \tag{3.6}$$

$$\frac{H_t}{D_t} = c_t + k_t \tag{3.7}$$

Then, $\frac{M_t}{H_t}$ can be written as:

$$\frac{M_t}{H_t} = \frac{c_t + 1}{c_t + k_t} \tag{3.8}$$

So far, these expressions about money supply are mere identities. It is time to give them some behavioral content. Let us start with S_t. To hold reserves in excess is costly for a bank. It means that the bank is keeping assets for which it does not accrue any return.[3]

[3] When bank reserves are remunerated, interest earnings partially offset this opportunity cost. Again, this is ignored here without affecting the conclusions of the model. Also ignored are the costs of liquidity management for a bank thas has insufficient reserves and has to rely on alternative mechanisms to face an unexpected withdrawal of deposits.

Instead, the bank can lend such reserves at the current real interest rate, r_t, plus a premium for anticipated inflation, π_t^a.[4]

Given the cost of holding reserves, there is an inverse relationship between S_t and R_t. Here:

$$S_t = S(R_t) \tag{3.9}$$

where $S_{R_t} < 0$.

Equation 3.5 can be rewritten as:

$$k_t = q + s(R_t) \tag{3.10}$$

In this framework, the value of c_t, which reflects how the public allocates monetary assets between currency and bank deposits, is given by institutional characteristics of the economy, such as how the individuals arrange their payments (the transactions technology) and how costly it is to transform D_t into C_t, including the risk of bank bankruptcy. Whatever the reasons for the specific value of c_t, the important feature is that for present purposes it can be treated as a constant.

[4] McCallum [1989] clarifies why, from the perpective of the money supply function, the argurment should be the nominal instead of the real interest rate.

> *...with the price level changing over time, the economically relevant rate of interest on a loan with provisions specified in monetary terms depends on the anticipated inflation rate. Imagine, for example, a loan of \$1000 for a period of one year, with the provision that the borrower must pay the lender \$1100 at the end of the year. In monetary terms, the rate of interest on this loan is 0.10 (or 10 percent). But if the lender expects the price level to be 10 percent higher at the end of the year than at the time of the loan, he expects to be repaid an amount that is worth in real terms only just as much as the amount lent. Thus to him the (expected) real rate of interest on the loan is zero. If, however, he expected the price level to be only 4 percent higher, he would anticipate receiving a payment worth in real terms 106 percent of his loan. In this case, the real interest rate as viewed by the lender would be 0.10-0.04=0.06 or 6 percent. From this type of reasoning we see that in general the real rate of interest on a loan specified in monetary terms is the nominal (monetary) rate of interest minus the expected inflation rate....*(p.112-3)

By plugging 3.10 into 3.8, the relationship between base money and the money supply can be obtained as:

$$\frac{M_t}{H_t} = \frac{c+1}{c+q+s(R_t)} \tag{3.11}$$

This can be written as:

$$\frac{M_t}{H_t} = \Phi_t = \Phi\left(R_t; c, q\right) \tag{3.12}$$

A functional form for the money supply can be derived from this expression:[5]

$$M_t^S = \Phi(R_t, c, q) H_t(R_t) \tag{3.13}$$

Again, for notational convenience, let me rewrite equation 3.13 as:

$$ln\ M_t^S = ln\ \Phi_t + ln\ H_t = \phi_t + h_t = m_t^S = m^S\left[\phi_t, h_t\right] \tag{3.14}$$

where $\phi_t = ln\ \Phi_t$ and $h_t = ln\ H_t$.

It is worthwhile to note that the usual textbook approach for equation 3.13 is that it tells how much money should be supplied by the central bank for given magnitudes of H_t, R_t, c and q [McCallum, 1989]. In the context of this dissertation, however, I recognize that the money supply summarizes the combined effect of decisions involving the public, the banks, and the central bank. Therefore, R_t may not only affect the multiplier Φ_t but also the size and composition of H_t.

A major implication of R_t as an argument of H_t is that, *a priori*, it is not possible to infer the sign of the slope of M_t^S as a function of R_t. Consequently, this sign is an empirical issue that has to be addressed for the particular economy under study.[6]

[5] Here $s(R_t)$ is the fraction of deposits that banks keep as excess reserves. If banks undertake efficient cash management, and there is no reason to assume that they do not, the sensitivity of s_t to changes in R_t should be almost nil.

[6] Also notice that Φ_t depends on R_t, c and q. But, if the effect of R_t on the base money multiplier, Φ_t, is almost imperceptible, then I can treat it as a constant and make $\phi_t = \phi$.

So far I have described the relationship between M_t and H_t; next, I will explain the process of base money creation.

From an accounting point of view, base money represents a part of the central bank's liabilities with the rest of the economy. These liabilities are the counterpart of assets originated mainly in credit operations with the rest of the economy. Two of the major users of the central bank's credit are the commercial banks and the government.

Thus, it is reasonable to state that there should be a positive relationship between H_t and Y_t. Moreover, there is historical evidence that the main force that drives nominal monetary expansions are fiscal deficits [Capie, 1998]. In his own words:

> *But what lies behind the growth in the monetary stock? The dominant factor was the need to monetize government deficits, that is, to print money to cover the deficit. That is what produced the monetary expansion. The monetization occurred when the growth in government expenditure could not be matched by raising revenue or by borrowing. And what produced this was an imbalance present between those spending and those paying; in other words, when the government was relatively weak in relation to the governed -when it felt unable to impose taxes and took the easier option of printing money. Governments resort to the printing press in order to buy the resources they need to survive.*(p.29)

On the basis of this historical regularity, I can express the monetary base, H_t, as a function, among other arguments, of the fiscal deficit, G_t.

$$H_t = H(G_t, R_t) \tag{3.15}$$

Moreover, the fiscal deficit, G_t can be specified as a function of Y_t and R_t. I will assume that the government's goal is to keep the fiscal deficit not larger than a given proportion of Gross National Product. Besides, if the economy has a chronic deficit problem, then the government will be carrying an outstanding debt. This debt has a financial cost, (R_t), which contributes to the deficit. Thus,

$$G_t = G(Y_t, R_t) \tag{3.16}$$

3.1.3 Inflation

A money market disequilibrium is the difference between the money stock and money demand. However, in what follows, a monetary disequilibrium will be defined as the difference in the rates of growth of such magnitudes. The rate of growth of the money stock minus the rate of growth of the demand for real money balances will represent the magnitude of the disequilibrium in this dynamic setting.

To relate this definition of monetary disequilibrium to inflation let me refer succinctly to Fisher's [1911] equation of exchange:

$$M_t V_t = P_t T_t \tag{3.17}$$

where M_t is the money stock, V_t is velocity of circulation, P_t is the price level, and T_t is the level of transactions. Making $T_t = Y_t$, and $\frac{Y_t}{V_t} = m_t^D$, expressing equation 3.17 in logarithms, and taking the first difference, I get:[7]

$$\pi_t = p_t - p_{t-1} = \left(m_t^S - m_{t-1}^S\right) - \left(m_t^D - m_{t-1}^D\right) = \dot{m}_t^S - \dot{m}_t^D = m_t^x \tag{3.18}$$

where the monetary disequilibrium, m_t^x, is the difference between the growth rate of the money stock and the growth rate of the demand for real money balances. This is just a

[7]From making $M_t = M_t^S$ it follows that $P_t = \frac{M_t^S}{m_t^D}$. Under the assumption that this identity holds at any time, then $P_{t-1} = \frac{M_{t-1}^S}{m_{t-1}^D}$. If we define the rate of inflation between time t and t-1, π_t, as the difference between the logarithm of the price levels at those dates, then we see that $\pi_t = \dot{m}_t^S - \dot{m}_t^D = m_t^x$, where $\dot{m}_t^S$ is $ln(M_t^S) - ln(M_{t-1}^S)$ and $\dot{m}_t^D = ln(m_t^D) - ln(m_{t-1}^D)$.

restatement of the old Quantity Theory of Money, where inflation is caused only by an excess of money creation over the growth of real money demand.

The magnitude m_t^x, the rate of growth of money supply in excess of the rate of growth of real money demand is, in this dissertation, described as the monetary disequilibrium. This variable can take any value such that, for a given R_t, it can be positive or negative, and it will be zero only when R_t is the equilibrium nominal interest rate. For each value of the monetary disequilibrium, there will be a corresponding interest rate. This makes it possible to express the nominal interest rate as a function of the net excess money supply growth:

$$R_t = \Theta\left(m_t^x\right) \tag{3.19}$$

For this economy, inflation is basically a monetary phenomenon. However, it is widely recognized that other variables can influence actual inflation. Among them are the public's expectations about inflation. So, we can assume that inflation is the outcome of the combined effect of two processes. One, a monetary disequilibrium, m_t^x, which results from the difference between the rates of growth of money supply and money demand. Two, the public's perception about expected inflation, which may be based on the public's knowledge of recent past inflation or on beliefs about future inflation.

In a world without any inflationary experience, it is natural to assume that the public's inflation expectations are null; therefore, excess money supply growth will surprise the public. However, after this initial surprise, the public will begin to develop ideas about what the inflation rate for the next period will be and will behave accordingly.

Notice that this "psychological" element in the actual level of inflation was originated by past inflation, which in turn was the consequence of past monetary disequilibria, so, in this sense, it is still true that inflation is essentially a monetary phenomenon. Therefore, the inflation rate can be expressed as a weighted average of monetary disequilibrium and expected inflation:

$$p_t - p_{t-1} = \pi_t = \alpha m_t^x + (1-\alpha)\pi_t^a \tag{3.20}$$

where $0 < \alpha < 1$ and π_t^a is the public's anticipated rate of inflation for period t.[8] Anticipated inflation results from the knowledge that the public already has about the recent evolution of the price level.[9]

Specifically, the assumption here is that people form their own idea about expected inflation based on a weighted average of inflation rates over the past few periods. Therefore, π_t^a is the average inflation rate of the past few periods, available at period t, which incorporates observed information up to period t-1.

$$\pi_t^a = \sum_{i=1}^{q} \omega_i \pi_{t-i} \tag{3.21}$$

where ω_i is the weight associated with the inflation rate of period t-i.

Plugging equation 3.21 into equation 3.20 allows me to express the inflation rate as:

$$\pi_t = \alpha\,[\Psi\,(L)]\,m_t^x \tag{3.22}$$

where:

$$[\Psi\,(L)] = \sum_{i=1}^{\infty} \psi_i L^i = \left(1 - \sum_{i=1}^{q} \omega_i L^i\right)^{-1} \tag{3.23}$$

[8] Here I am using the convention that, for a rate of growth of the form $\frac{X_t - X_{t-1}}{X_{t-1}}$, the expression $x_t - x_{t-1}$ is a *good* approximation. As a notational device, a variable in lower case denotes the natural logarithm of such variable, unless other explicit provision is made. So, $x_t = ln\ X_t$.

[9] This hipothesis about the inflation process comes from "The Microfoundations of the Moderate Quantity Theory" [McCulloch,1980]. Specifically, in a deterministic world, this author proposes: $\pi_t = \gamma m_t^x + \pi_t^a$, where γ is an adjustment coefficient. However, in this case, the monetary disequilibrium is defined as the difference between the level of the money stock and the level of the demand for real money balances. The coefficient γ depends on structural parameters such as the proportion of wealth that is held as money, the elasticity of the marginal utility of a monetary unit, and the average time lag in the consumer's price information.

and L^i is the lag operator.[10]

Note that equation 3.22 makes it possible to express the inflation rate (even the component based on expectations) as a result of past and current monetary disequilibria.

3.1.4 Monetary Policy

The objective of the central bank is to keep inflation under control. This basically means that monetary policy is intended to achieve a low and stable rate of inflation.

The problem for this central bank is: how much M_t to supply, given the inflation target, π_t^T, which is consistent with the expected real output level $\widehat{Y}_t$. In a deterministic closed economy, the central bank has two instruments of monetary policy with which to pursue its inflation target, and it has to chose one of them.

One view is that monetary policy should set the money stock, at the level required to meet the inflation target, M_t^T, and let the market set R_t. An alternative view is held by those who argue that the central bank should work through the money market in the implementation of its monetary policy. Specifically, proponents of this view argue that the interest rate is the best variable for the central bank to influence money market conditions [Poole,1970].

Let me assume that the central bank wants to achieve a specific target for the inflation rate, π_t^T. Also, I will start by assuming that the central bank will use a money aggregate as the policy instrument of choice.

The process of policy implementation proceeds as follows. Given the inflation target set by the central bank, π_t^T, and estimates for α and π_t^a, equation 3.20 can be solved and a

[10]Hamilton [1994], Chapter 2, shows how to algebraically manipulate expressions with the lag operator as polynomials. In particular, he shows how to get equation 3.22 from equations 3.21 and 3.20.

numeric value for m_t^x can be found, namely m_t^{xT}. This value is the monetary disequilibrium implied by the policy action.

From equation 3.19 and m_t^{xT}, the central bank is then able to compute R_t^T, the level of the nominal interest rate that is consistent with its inflation target.

Also note that real output, Y_t, is not an observable magnitude at time t. Therefore, in any estimation of the numeric value of the monetary policy instrument, the central bank has to rely on a forecasted value, $\widehat{Y}_t$.

Once the central bank has the numeric values for R_t^T and $\widehat{Y}_t$, equations 3.2, 3.14, 3.15 and 3.16 can be solved, and specific values for m_t^{ST}, m_t^{DT}, g_t^T and h_t^T can be found. These are the values that will be consistent with the inflation target, π_t^T.

From the perspective of monetary policy, it is necessary not only to know the level of the money stock that is consistent with the inflation target; it is also necessary to know how to achieve it. If the policy instrument is a monetary aggregate, for example, if it is the stock of high-powered money, the central bank may adjust q (the reserve requirement), which is a magnitude under its control, and thereby induce, by equation 3.13, the amount of M_t^T that is consistent with the inflation target. Because the central bank is using H_t to achieve its policy goal, the instrument is a monetary aggregate.

Even though this is a deterministic model, there is no guarantee that the realized value of M_t will be equal to M_t^T. This is because the value of M_t^T was obtained using a money demand function that includes $\widehat{Y}_t$ and R_t^T as arguments, and there is no reason to assume that either magnitude will be equal to its realized value. Therefore, the best that the central bank can do is to induce a value of M_t that is in the neighborhood of M_t^T. This implies that the central bank will miss its inflation target.

Alternatively, the central bank may use the nominal interest rate as the instrument of monetary control. First, from equation 3.20, as before, the central bank determines the size of the monetary disequilibrium that is compatible with the inflation target. Once m_t^{xT} is known, the central bank, by equation 3.19, computes the corresponding level of the required nominal interest rate, R_t^T.

Under this alternative instrument, all the central bank has to do is to supply the amount of high-powered money (*e.g.*, through open market operations) such that the nominal interest rate is kept at the constant level R_t^T. Note that, in this case, there is not target value for H_t; instead, the central bank will let H_t be any value that would keep R_t at the target value R_t^T. Therefore, M_t^S will adjust freely as long the nominal interest rate is kept constant at the target level.

As when the instrument is high-powered money, in this case the central bank will not be able to induce exactly the required monetary disequilibrium, m_t^{xT}, but rather a value that is in its neighborhood; as a result, it will miss the inflation target. The source of error, in this deterministic world, is the fact that all the calculations are based on the relationship between m_t^x and R_t and implicitly on a money demand function that considers $\widehat{Y}_t$ rather than the realized value Y_t.

However, if there were no sources of error in the estimation of money demand and money supply, in this deterministic world it would be reasonable to expect that there would be no difference as to whether the instrument is base money or the interest rate. Poole [1970] reaches a similar conclusion, even though in his case the purpose of monetary policy is to target the income level.

A more realistic approach to the instrument problem, however, should recognize that there is uncertainty, and the evaluation of alternative instruments should be undertaken in a context that accounts for some degree of randomness.

3.2 A Monetary Framework that Incorporates Uncertainty

To illustrate the instrument problem that a central bank faces in a world with uncertainty, I will follow an approach similar to that in McCallum [1989]. Nonetheless, where it may be appropriate to do so, the variables will be presented in terms of rates of growth and not in logarithms.

The monetary sector can be represented by the following system of equations:[11]

$$\dot{m}_t^D = \gamma_1 \dot{y}_t + \gamma_2 (R_t - R_{t-1}) + u_{\dot{m}_t^D} \tag{3.24}$$

$$\dot{m}_t^S = \dot{\phi}_t + \dot{h}_t \tag{3.25}$$

$$G_t = B_{t-1} R_t \tag{3.26}$$

$$\dot{h}_t = \left[R_t - \dot{b}_t^S \right] d_{t-1} \tag{3.27}$$

$$\dot{b}_t^D = \pi_t + \dot{y}_t \tag{3.28}$$

$$m_t^x = \dot{m}_t^S - \dot{m}_t^D \tag{3.29}$$

$$\pi_t = \alpha m_t^x + (1 - \alpha)\pi_t^a + u_{\pi_t} \tag{3.30}$$

Equations 3.24 and 3.25 are obtained from first differences of specific functional forms for demand and supply of money, namely 3.2 and 3.14. Equation 3.26 describes the government's deficit in period t, which is assumed to be given only by the interest payments

[11] All variables are in logarithmic terms, with the exception of the nominal interest rate, anticipated inflation, and the stochastic terms. Therefore rates of growth over time, are approximated as the logarithm of a variable in time t minus the logarithm of the same variable in time t-1.

over the outstanding balance of the government's net liabilities at the beginning of period t, (B_{t-1}). Equations 3.27 and 3.28 describe the market for public debt and its interaction with the money-creation process. There are two possible sources of financing for the deficit. One of them is the creation of base money; the other one is sales of bonds. So, the rate of growth of base money will be determined by the portion of the deficit that is financed by money creation, given that the rest of the deficit is financed by issuing new debt. It is assumed that the demand for bonds can be expressed as a constant ratio of nominal income.[12]

Equations 3.29 and 3.30 are the same as 3.18 and 3.20. According to the behavioral assumptions discussed for such functions, $\gamma_1 > 0, \alpha > 0$ and $\gamma_2 < 0$. Now the model has incorporated terms that account for uncertainty. The variables $u_{m_t^D}$ and u_{π_t} are stochastic disturbances, with a probability distribution such that:

$$E(u_{\dot{m}_t^D}) = 0, \;\; E(u_{\pi_t}) = 0 \quad \forall t \tag{3.31}$$

$$E(u_{\dot{m}_t^D} u_{\dot{m}_{t-j}^D}) = \left\{ \begin{array}{c} Var(u_{m^D}) \; for \; j = 0 \\ 0 \; for \; j \neq 0 \end{array} \right\} \tag{3.32}$$

$$E(u_{\pi_t} u_{\pi_{t-j}}) = \left\{ \begin{array}{c} Var(u_{\pi}) \; for \; j = 0 \\ 0 \; for \; j \neq 0 \end{array} \right\} \tag{3.33}$$

The u_{π_t} term in equation 3.30 is just a stochastic error that accounts for all other factors that may influence the inflation rate besides the monetary disequilibrium and the public's idea of the expected (or anticipated) inflation rate. Notice that $E\left(u_{m_t^D} u_{\pi_t}\right) = 0$, meaning that the stochastic components of money demand and the inflation rate are independent.

[12]The process of financing the deficit is described as follows. $G_t = B_{t-1}R_t = (H_t\text{-}H_{t-1}) + (B_t\text{-}B_{t-1}) \Longrightarrow B_t = B_{t-1}R_t + B_{t-1}\text{-}H_{t-1}\dot{h}_t \Longrightarrow lnB_t\text{-}lnB_{t-1} = \dot{b}_t^S \approx R_t\text{-}\frac{\dot{h}_t}{d_{t-1}}$, where $d_{t-1} = \frac{B_{t-1}}{H_{t-1}}$. Therefore, $\dot{h}_t = \left[R_t - \dot{b}_t^S\right] d_{t-1}$. Similarly if $B_t^D = \eta Y_t^N = \eta P_t Y_t^R \Longrightarrow \dot{b}_t^D = \pi_t + \dot{y}_t$, where η is the ratio of government debt to nominal income Y_t^N. Nominal national income can be expressed as national real income, Y_t^R, times the price level P_t.

The effect of any money demand shock is captured by the term αm_t^x in equation 3.30 and not by u_{π_t}. The latter term accounts for all other influences on the inflation rate beyond monetary effects.

With this model, it is now possible to address the instrument problem in an explicit way.

3.2.1 Using a Monetary Aggregate to Target a Desired Level of Inflation

When the policy instrument is base money, the central bank has to figure out a value that is compatible with the inflation target, π_t^T.

The first step is to set the inflation target, π_t^T. Given that π_t^a and α can be empirically estimated, the central bank can calculate the magnitude of the monetary disequilibrium, m^{xT}, that is necessary to induce the inflation rate to reach the target value. Therefore, from equation 3.30, I get:

$$m_t^{xT} = \frac{\pi_t^T - (1-\alpha)\pi_t^a}{\alpha} \tag{3.34}$$

Next, from equation 3.29, the central bank makes $\dot{m}_t^{ST} = m_t^{xT} + \widehat{\dot{m}}_t^D$. Equation 3.25 shows that the growth rate of the money stock is given by the change in the base money multiplier $(\dot{\phi}_t)$ plus the growth rate of base money itself $(\dot{h}_t)$. According to the assumptions made above, the value of the multiplier basically depends on the ratio of required reserves on deposits. For the purposes of this dissertation, I will assume that the central bank keeps such reserve ratio constant; therefore, $\dot{\phi}_t = 0$, so $\dot{m}_t^S = \dot{h}_t$

From equations 3.26 and 3.27, the central bank can estimate an interest rate that is consistent with its inflation target:

$$\tilde{R}_t = \pi_t^T + \widehat{y}_t + \frac{\dot{h}_t}{d_{t-1}} \tag{3.35}$$

With an expression for $\tilde{R}_t$ and an estimation for $\dot{y}_t = \widehat{\dot{y}}_t$, the central bank solves for the desired value of $\dot{h}_t = \dot{h}_t^T$ that is consistent with the target for the inflation rate. Notice that $\tilde{R}_t$ is not the market interest rate, but rather the level that the central bank, according to its best information, believes it should have under a monetary aggregate policy instrument. It is just the interest rate that the central bank takes as reference in setting the value of $\dot{h}_t^T$. Such value is given by:

$$\dot{h}_t^T = \frac{\left[m_t^{xT} + \gamma_1 \widehat{\dot{y}}_t + \gamma_2 \left(\pi_t^T + \widehat{\dot{y}}_t - R_{t-1}\right)\right] d_{t-1}}{d_{t-1} - \gamma_2} \tag{3.36}$$

Now that the central bank has determined the required rate of growth of base money and, consequently, the growth of the money stock, the interaction with the growth of money demand generates the market nominal interest rate that is compatible with the inflation target:

$$R_t = \frac{\dot{h}_t^T - \gamma_1 \dot{y}_t + \gamma_2 R_{t-1} - u_{\dot{m}_t^D}}{\gamma_2} \tag{3.37}$$

This will be the nominal interest rate that will prevail in the money market.

Two features of this solution must be highlighted.

One, when the central bank uses base money as the monetary policy instrument, it implicitly assumes that the sources of primary money creation can be kept under control. This presupposes a given level for the fiscal deficit, such that the portion of the deficit that is financed with monetary expansion does not exceed the level of expansion of the money stock that is necessary to reach the inflation target. The portion of the deficit that is not funded with base money is financed by issuing bonds. Nevertheless, the creation of liabilities also has a limit. An increase in the outstanding balance of net debt beyond the level that is consistent with the inflation target plus the level of growth of real income signals a potential solvency problem for the government, which eventually will rely on money creation to repay its debt. If this were the case, then, the inflation target might not be seen as credible, making fruitless the central bank's efforts to keep inflation low and stable.

Therefore, the successful implementation of a policy that relies on the monetary aggregate as the instrument depends on the central bank's ability to resist pressures from other government branches, when the latter ask for funds to finance their budget deficits. Moreover, besides the required fiscal discipline, it is in this sense that a sufficient degree of independence of the central bank is needed, in order to guarantee a monetary policy that is congruent with the price stability goal.

Two, once the central bank has set the level of base money, the equilibrium value of the nominal interest rate becomes a random variable. Consequently, by using base money, the central bank gives up the stability of the nominal interest rate. The volatility implicit in the money demand function will be transmitted to the interest rate.

Given that the ultimate goal for the central bank is to keep the price level stable, it is necessary to evaluate by how much the intended inflation target is missed under this policy instrument,

Taking the difference between the equations for $\pi(\dot{h}_t^T)$ and $\pi^T\left(\dot{h}_t^T\right)$, we can compute the size of the error in achieving the inflation target resulting from a monetary policy that uses base money as the policy instrument.

The actual inflation rate is $\pi\left(\dot{h}_t^T\right) = \alpha m_t^x + (1-\alpha)\pi_t^a + u_{\pi t}$, while $\pi^T\left(\dot{h}_t^T\right) = \alpha m_t^{xT} + (1-\alpha)\widehat{\pi}_t^a$ is the inflation rate target. In both cases, base money is the policy instrument. Similarly, $m^x\left(\dot{h}_t^T\right) = \dot{m}^{ST}\left(\dot{h}_t^T\right) - \dot{m}^D\left(\dot{h}_t^T\right)$ is the actual size of the monetary disequilibrium when the policy instrument is base money, whereas $m^{xT}\left(\dot{h}_t^T\right) = \dot{m}^{ST}\left(\dot{h}_t^T\right) - \widehat{\dot{m}}^D\left(\dot{h}_t^T\right)$ is the intended size of the monetary disequilibrium under the monetary aggregate instrument.

Only for the purposes of notation, let the error in reaching the inflation target under this police regime be $\varepsilon_{\pi^T(\dot{h}_t^T)} = \left[\pi\left(\dot{h}_t^T\right) - \pi^T\left(\dot{h}_t^T\right),\right]$, let the error in forecasting real income be $\varepsilon_{\widehat{\dot{y}}_t} = \left(\dot{y}_t - \widehat{\dot{y}}_t\right)$, and let the error in forecasting the public's inflationary expectations be $\varepsilon_{\widehat{\pi}_t^a} = \left(\pi_t^a - \widehat{\pi}_t^a\right)$. Then, the inflation target will be missed by:

$$\varepsilon_{\pi^T(\dot{h}_t^T)} = \alpha\left[m^x\left(\dot{h}_t^T\right) - m^{xT}\left(\dot{h}_t^T\right)\right] + (1-\alpha)\left(\pi_t^a - \widehat{\pi}_t^a\right) + u_{\pi_t} \tag{3.38}$$

where

$$m^x\left(\dot{h}_t^T\right) - m^{xT}\left(\dot{h}_t^T\right) = -\left[\left(\gamma_1 + \gamma_2\right)\varepsilon_{\widehat{\dot{y}}_t} + \gamma_2\left(\pi_t - \pi_t^T\right) + u_{\dot{m}_t^D}\right] \tag{3.39}$$

After some algebra, the solution for the inflation rate error under the monetary aggregate instrument is:

$$\varepsilon_{\pi^T(\dot{h}_t^T)} = \pi\left(\dot{h}_t^T\right) - \pi^T\left(\dot{h}_t^T\right) = \frac{-\alpha\left[\left(\gamma_1 + \gamma_2\right)\varepsilon_{\widehat{\dot{y}}_t} + u_{\dot{m}_t^D}\right] + (1-\alpha)\varepsilon_{\widehat{\pi}_t^a} + u_{\pi_t}}{1 + \alpha\gamma_2} \tag{3.40}$$

The error when targeting a specific rate of inflation, using base money as the policy instrument, is a linear combination of the difference between estimated and actual output, the difference between the empirically estimated and actual anticipated inflation, and the stochastic errors in the money demand and inflation functions.

Once the size of the deviation between actual inflation and its target rate is known, the next step is to ask: What would be the size of such error if, instead of using base money as the instrument, we used the nominal interest rate?

3.2.2 Using the Nominal Interest Rate to Target a Desired Level of Inflation

A process similar to that followed from equation 3.34 throughout 3.40 must be followed again. This time, however, the objective is to set the nominal interest rate at a level that is consistent with the inflation target set by the central bank.

As before, the central bank sets π_t^T and from there estimates m_t^{xT}, computes an estimated $\dot{h}_t = \tilde{\dot{h}}_t^T$, and sets $R_t = R_t^T$. Then, the required interest rate is:

$$R_t^T = \pi_t^T + \widehat{y}_t + \frac{\tilde{\dot{h}}_t}{d_{t-1}} \tag{3.41}$$

where $\tilde{\dot{h}}_t$ is given by equation 3.36.

It is important to bear in mind that $\tilde{\dot{h}}_t$ is not the actual rate of growth of high-powered money; rather, it is a value that the central bank computes as a reference to set R_t^T. At this target nominal interest rate, the central bank will allow base money and, therefore, the money stock to adjust freely, such that R_t can remain constant at R_t^T. In this case, the interest rate is fixed but the money stock moves randomly according to stochastic shocks in money demand. Therefore, the actual outcome of the money stock will be governed by equation 3.24, given the value of $R_t = R_t^T$.

The resulting monetary disequilibrium, when the nominal interest rate is the policy instrument, is given by:

$$m^x\left(R_t^T\right) - m^{xT}\left(R_t^T\right) = -\left[\gamma_1 \varepsilon_{\widehat{y}_t} + u_{\dot{m}_t^D}\right] \tag{3.42}$$

This monetary disequilibrium will determine the error in reaching the inflation rate target. Such error is given by the following difference:

$$\varepsilon_{\pi^T(R_t^T)} = \pi\left(R_t^T\right) - \pi^T\left(R_t^T\right) = -\alpha\left[\gamma_1 \varepsilon_{\widehat{y}_t} + u_{\dot{m}_t^D}\right] + (1-\alpha)\varepsilon_{\widehat{\pi}_t^a} + u_{\pi_t} \tag{3.43}$$

Equation 3.43 states that the deviation between the inflation target and the actual inflation rate, when the interest rate is the policy instrument, is a linear combination of all sources of error in the model. Such errors can be estimation errors as well as stochastic disturbances. Specifically, the estimation errors are the difference between actual and forecasted output and the difference between estimated and actual inflation expected by the public. The stochastic errors are the random terms in the money demand and inflation functions.

3.2.3 Comparing the Effectiveness of Policy Instruments

From the exercise of the previous section, the first conclusion is that in a world with uncertainty in contrast to a deterministic world, the choice of monetary policy instrument matters. The solutions for different instruments are not equivalent, while different magnitudes of the deviation between the inflation target and actual inflation are associated with the instrument chosen.

The next step is to compare the errors in achieving the inflation target under each policy instrument. A first approach would be to determine which error is smaller and to conclude that, under an inflation targeting regime, monetary policy should be conducted by using the instrument associated with the smallest error. If the difference between equations 3.40 and 3.43 is a positive magnitude, then the optimal instrument will be the nominal interest rate. Obviously, if such difference is negative, then the optimal instrument will be a monetary aggregate such as base money. The difference in errors in targeting inflation under one or the other policy instrument is:

$$\varepsilon_{\pi^T(\dot{h}_t^T)} - \varepsilon_{\pi^T(R_t^T)} = a_1 \varepsilon_{\widehat{y}_t} + a_2 u_{\dot{m}_t^D} + a_3 \left[(1-\alpha) \varepsilon_{\widehat{\pi}_t^a} + u_{\pi_t} \right] \tag{3.44}$$

where

$$a_1 = \frac{\alpha\left(\alpha\gamma_2^2 - \gamma_1\right)}{1+\alpha\gamma_2}; \quad a_2 = \frac{\alpha^2\gamma_2}{1+\alpha\gamma_2}; \quad a_3 = \frac{-\alpha\gamma_2}{1+\alpha\gamma_2} \tag{3.45}$$

In order to assess the sign of expression 3.44, it is necessary to know the specific values of the parameters (α, γ_1 and γ_2) and the signs of the error terms and the stochastic terms involved. Thus, this expression does not help in definitively answering the question about the instrument problem under an inflation targeting regime.

A meaningful comparison should take a large number of periods into account. In this second approach, the best one would be the instrument that, on average, induces the smallest error. A measure that helps with such comparison is the mean-squared error.[13] When the monetary aggregate instrument $\left(\dot{h}_t^T\right)$ is used, the mean-squared error is:

$$E\left[\varepsilon_{\pi^T\left(\dot{h}_t^T\right)}\right]^2 = MSE\left[\pi^T\left(\dot{h}_t^T\right)\right] \tag{3.46}$$

where[14]

$$MSE\left[\pi^T\left(\dot{h}_t^T\right)\right] = \upsilon_1^2\sigma^2_{\varepsilon_{\widehat{y}_t}} + \upsilon_2^2\sigma^2_{u_{\dot{m}_t^D}} + \upsilon_3^2\left[(1-\alpha)^2\sigma^2_{\varepsilon_{\widehat{\pi}_t^a}} + \sigma^2_{u_{\pi_t}}\right] \tag{3.47}$$

$$\upsilon_1 = \frac{-\alpha\left(\gamma_1+\gamma_2\right)}{1+\alpha\gamma_2}; \quad \upsilon_2 = \frac{-\alpha}{1+\alpha\gamma_2}; \quad \upsilon_3 = \frac{1}{1+\alpha\gamma_2} \tag{3.48}$$

Likewise, when the monetary policy instrument is the nominal interest rate, the mean-squared error is:

$$MSE\left[\pi^T\left(R_t^T\right)\right] = w_1^2\sigma^2_{\varepsilon_{\widehat{y}_t}} + w_2^2\sigma^2_{u_{\dot{m}_t^D}} + (1+w_2)^2\sigma^2_{\varepsilon_{\widehat{\pi}_t^a}} + \sigma^2_{u_{\pi_t}} \tag{3.49}$$

[13]The mean-squared error is defined as follows. Suppose that there is a random variable x, which can be observed, but that we want to predict its value before the observation is made. We choose some value $\widehat{x}$ as the prediction of x. We want to know how big the error is in predicting x by choosing $\widehat{x}$. The answer to this question is given by the expected value of the square of the error $(x-\widehat{x})$, which is denoted by $E\left[(x-\widehat{x})^2\right]$. This expression is known as the mean-squared error of the prediction $\widehat{x}$, and it is also denoted by *MSE($\widehat{x}$)*.

[14]Following the usual convention in statistical notation, the variance of a variable x is represented as σ_x^2.

$$w_1 = -\alpha \gamma_2; \qquad w_2 = -\alpha \tag{3.50}$$

These results assume that all of the covariances among the different error terms are zero. For example, we can expect that the estimation error concerning the rate of output growth is independent of the estimation error concerning expected inflation and of the stochastic terms in the money demand and inflation equations. Also, it is plausible to assume that the stochastic error in the demand for real money balances is independent of the stochastic error in the inflation function and the forecast of expected inflation. It is assumed that the same is true for the two latter variables.

The reason for assuming zero covariances is that the sources of randomness in these variables come from unrelated sources. The variability in the estimation errors for real output and anticipated inflation comes mainly from the information available to undertake the estimation and from the estimation method used. Instead, the variability in money demand and in inflation comes from other variables not explicitly considered in the model.

The decision about which instrument of monetary policy induces less error in achieving the inflation target must be based on a comparison of expressions 3.47 and 3.49.

But again, this comparison depends on the actual magnitudes of the parameters (α, γ_1 and γ_2) and of the variances of the random terms. Therefore, in this stochastic framework, the answer to the question about the appropriateness of a particular monetary policy instrument under inflation targeting requires the empirical estimation of these magnitudes. Similar to the conclusion of Poole [1970] in his classical paper, the choice of the monetary policy instrument will depend on the characteristics of the idiosyncratic uncertainty of the economy under analysis. This dissertation explores this question for a small, open, developing economy, relying on data for Costa Rica as an illustration. This requires, however, a consideration of the question for an open economy, which is accomplished next.

CHAPTER 4

MONETARY POLICY IN AN OPEN ECONOMY

Since the early 1990s, an increasing number of countries have adopted inflation targeting regimes. Their main goal has been to reduce inflation from historical levels and to provide a new nominal anchor for the price level. The empirical evidence of the past 15 years indicates that those central banks that have implemented inflation targeting regimes have usually been able to deliver greater price stability, compared to banks that have chosen other monetary policy arrangements. However, there are not many studies of inflation targeting regimes for open economies.

Two remarkable exceptions are the theoretical pieces of Ball [1998] and Svensson [2000]. Both use a neo-Keynesian macroeconomic model as a framework, where inflation is mainly explained through an aggregate supply equation (Phillips curve), and both assume that the optimum instrument is either the short-term interest rate or a weighted sum of the short-term real interest rate and the real exchange rate, also known as the Monetary Condition Index.

This dissertation follows a monetary rather than a neo-Keynesian approach. The transmission channel of monetary policy considered here is, therefore, different from the channel specified in the models developed by Ball [1998] and Svensson [2000]. Moreover, instead of assuming that the use of a particular instrument is appropriate, the question that the dissertation addresses, for a given economic structure (set of parameters), is the choice of the best monetary policy instrument to reach a sustainable inflation target.

So far, I have considered the case of a central bank that chooses between only two policy instruments, namely a monetary aggregate or the nominal interest rate. These instruments are not independent, so the central bank can control one or the other but not both of them simultaneously.

When the foreign sector is added to the model, a new source of money creation must be considered. In addition, the central bank can set, through market intervention, the value of the exchange rate. However, when setting the exchange rate, the central bank has to be able to buy and sell any quantity of foreign exchange that the public wants at the preset rate. When the central bank does this, the money stock fluctuates according to the purchases and sales of foreign exchange. Thereby, the central bank gives up control of the money stock as the instrument to achieve a specific inflation rate target.

To complicate matters further, if the country is small and open to international markets, the returns on domestic and foreign financial assets will tend to equalize, through a process of arbitration, once a risk premium is considered. This means that, under a fixed exchange rate, nominal domestic interest rates will align to international rates plus the risk premium.

Openness, therefore, gives the central bank an additional instrument which, in principle, can be used to pursue an inflation target. Again, however, this instrument –the exchange rate– is not independent of the other two. This interdependence among instruments, as in the case of the closed economy, constrains the central bank's policy options, in the sense that the choice of a particular instrument has implications on the other two magnitudes and on the central bank's success in accurately meeting its own inflation target.

In order to formalize the instrument problem in the context of an open economy, I start by assuming that the public can hold financial assets in both domestic and foreign currency. I also assume that there are no restrictions on capital movements and that the country is a price taker in international financial markets. Consequently, the country does not have any influence on the determination of international interest rates.

The monetary authority can also buy and sell foreign assets. When it does so, it changes the money supply. This is shown next. On the asset side of the balance sheet of the central bank there are domestic assets (A_t) and the net foreign asset position ($X_t F_t$). Here, F_t are net foreign assets denominated in the foreign currency. To express them in the domestic currency, it is necessary to multiply their value by the nominal exchange rate X_t, defined as the number of units of the domestic currency needed to buy one unit of the foreign currency. The balance sheet identity thus yields:

$$H_t = C_t + K_t = A_t + X_t F_t \tag{4.1}$$

The central bank's holdings of foreign assets are the result of the interaction of the domestic economy with the rest of the world. They are closely related to the performance of the current and capital accounts of the balance of payments. From a monetary perspective, the main determinants of the net foreign asset holdings are the nominal exchange rate, X_t, the expected rate of change in the exchange rate, $\underset{t}{E}(\dot{x}_{t+1})$, the domestic nominal interest rate, R_t, and international nominal interest rate, R_t^*.

$$F_t = F\left[X_t, \underset{t}{E}(\dot{x}_{t+1}), R_t, R_t^*\right] \tag{4.2}$$

Ceteris paribus, a higher exchange rate stimulates exports and depresses imports, thus having a positive impact on the current account, which increases the central bank's holdings of foreign assets. However, an increase in the expected rate of change of the exchange rate or an increase in international interest rates will make foreign financial assets relatively more attractive to hold than before, compared to domestic assets. This will tend to reduce the holdings of foreign assets, also called international reserves, by the central bank. In contrast, an increase in the domestic interest rate will attract foreign investors and international reserves will thereby increase.

From a behavioral point of view, openness introduces a new consideration. Both holders of financial assets and users of credit must compare the domestic cost of funds, namely, the domestic interest rate, R_t, to the cost of funds in international markets, which is given by the international interest rate plus the expected rate of change in the exchange rate, $R_t^* + \underset{t}{E}(\dot{x}_{t+1})$.[15]

Substituting identity 4.1 for 3.4, assuming as before that c, q and s are constants, and repeating the procedures implemented from identity 3.3 through identity 3.13, the following expression for the money stock can be obtained:

$$M_t = \left(\frac{c+1}{c+q+s}\right)\left\{A\left[X_t, \underset{t}{E}(\dot{x}_{t+1}), R_t, R_t^*)\right] + F\left[X_t, \underset{t}{E}(\dot{x}_{t+1}), R_t, R_t^*)\right]\right\} \quad (4.3)$$

The terms c, q, s have the same meanings as in equation 3.11.

This presentation of the money stock highlights the ways in which the central bank can *create* or *destroy* money, namely, through changes in the deposit multiplier, changes in the components of high-powered money, or a combination of both. Therefore, money can be created (destroyed) by the central bank when it issues (collects) domestic credit, A_t, to the commercial banks and the government, when it lowers (increases) the proportion of

[15]Here it is assumed that $R_t^* \dot{x}_t \approx 0$. Rates of change are expressed in percentages.

mandatory reserves, q, and when it buys (sells) foreign assets, mainly foreign exchange, F_t.

An increase in domestic interest rates, on the one hand, lowers the excess reserves of commercial banks and the demand for credit from the central bank, which reduces base money. On the other hand, however, it also increases the willingness of the public to sell foreign exchange to the central bank, which increases base money if the exchange rate is fixed. If the exchange rate is flexible, nevertheless, the outcome will depend on the elasticities of the demand and supply of foreign exchange. In sum, an increase in the domestic interest rate does not necessarily imply a reduction in money supply, as was the case in a closed economy. The consequence is that the depressing effect of the interest rate on the money stock, through the domestic credit channel, may more than or less than offset the potential expansionary effect of the interest rate on the money stock, through the net foreign assets channel. Thus, in addition to the rate of mandatory reserve requirements on deposits, used to control the expansion of base money, and to its own credit policy, the central bank can use the exchange rate, as a tool to alter base money.

The effectiveness of the monetary aggregate or the interest rate as instruments of monetary policy is, moreover, conditioned by the exchange rate regime.

4.1 The Impossibility of Inflation Targeting under a Fixed Exchange Rate

Let me start by considering the case where the exchange rate is set at a fixed level by the central bank. This regime requires the central bank to possess enough international reserves to fully satisfy the demand for foreign exchange at the fixed rate or even to face out speculative attacks against the exchange rate. I assume that the central bank is able to buy and sell any amounts of foreign exchange that the public wants to sell and buy at the predetermined fixed exchange rate.

Given that the central bank has to make the exchange rate regime credible and sustainable, it needs a policy instrument with which it can induce adjustments in its foreign exchange holdings. For example, assume that the central bank sets a floor, $\underline{F}_t$, for the level of international reserves that is compatible with the fixed exchange rate regime. If an external shock reduces the level of foreign exchange holdings below $\underline{F}_t$, the central bank then needs to take some action in order to increase F_t.

Assuming a logarithmic functional form for equation 4.2, it can be written as:

$$f_t = f_0 + \theta_1 X_t + \theta_2 R_t + \theta_3 \left[R_t^* + \underset{t}{E} \left(\dot{x}_{t+1} \right) \right] + u_{f_t} \tag{4.4}$$

The term f_0 is a parameter and u_{f_t} is a stochastic term that accounts for the combined effects of all other variables no explicitly included as explanatory arguments of f_t.

Taking the total differential of f_t, I obtain:

$$df_t = \theta_2 dR_t + \theta_3 dR_t^* + du_{f_t} \tag{4.5}$$

Note that under a fixed exchange rate regime $X_t = X$, then $dX_t = 0$ and consequently $d\underset{t}{E} \left(\dot{x}_{t+1} \right) = 0$. Likewise, $df_0 = 0$. Given the small open economy assumption, the central bank does not exert any influence on the international interest rate R_t^*.

Expression 4.5 shows that, in a fixed exchange rate regime, the only policy variable that the central bank can use to induce an increase in international reserves, when they are below $\underline{F}_t$, is the domestic nominal interest rate. However, if at the same time the central bank is pursuing a price level target, and for this purpose it is using the interest rate as the instrument, there will be no guarantee that the interest rate level that is compatible with the defense of the exchange rate regime will be the same rate that is consistent with the inflation target.

If, instead, the central bank attempts to use the rate of change of the monetary aggregate, $\dot{h}_t$, as the policy instrument, it will introduce some policy complexities. First, as equation 4.3 shows, any movement in the holdings of foreign assets (F_t) causes a movement in the stock of high-powered money. The central bank may avoid this by imposing controls on capital movements. According to international experience, however, these controls are not very effective.[16] The central bank may alternatively attempt to sterilize capital inflows with open market operations. By doing this, however, the central bank must issue debt, which in the medium and long term may create a deficit problem, given the limited ability of the central bank to generate earnings on its own assets at the same level of interest rate that it pays on its debt. Hence, the central bank cannot accumulate debt forever without inflationary consequences.

León, Madrigal-López and Muñoz [2003] show how a central bank with a fixed exchange rate, which sterilizes capital inflows, will eventually run into inflation. The reason is that an ever increasing stock of debt will generate an ever increasing deficit. Such central bank losses may be covered with additional debt or with the creation of base money. If the central bank's debt reaches a magnitude beyond the demand for its liabilities, the central bank must increase base money in order to cover its deficit. Once the central bank is forced

[16] Montiel [2003] argues that:

> *Overal, then, the evidence from emerging economies on whether capital account restrictions have typically been effective in altering the total magnitude of capital flows is mixed. At best, there is weak evidence of their effectiveness. However, there appears to be much more consensus that controls may be effective in altering the composition of flows.* (p. 266)

to create money to finance its own deficit, it can no longer control inflation and the situation may even deteriorate into a hyperinflation.

Second, when the exchange rate is fixed and the central bank cannot sterilize capital inflows, the money stock will not be under the central bank's control. In this case, the money stock will fluctuate according to the inflows and outflows of foreign assets. In turn, the nominal interest rate will be a magnitude determined by the interaction of the money stock (and thereby capital movements) and domestic money demand. The central bank, therefore, cannot set the level of the interest rate at will.

In conclusion, under a sustainable fixed exchange rate regime, it will be impossible for the central bank to exogenously set either the interest rate or the money stock. The ability to maintain a fixed exchange rate requires, among other things, a monetary policy subordinated to the goal of keeping the exchange rate at its specified level. In this sense, a fixed exchange rate implies that the central bank gives up the control of the domestic money stock and that monetary policy cannot perform its intended duty in promoting a low and stable level of inflation.

Here, there is clearly a conflict of objectives. With a hard peg on the nominal exchange rate and an inflation target, the central bank is trying to use two nominal anchors. Therefore, it is necessary to give priority to one of them. By now, international experience tells us that central banks usually face a great deal of difficulty in sustaining nominal exchanges rates. Frankel and Saiki [2002] express their view against using the exchange rate as the nominal anchor:

> *... pegs have been implicated in most of the crises in emerging markets in the last ten years. Almost all victims of balance of payments crises have found it necessary to devalue and move to more flexible arrangements...fluctuations in the value of a particular currency to which the home country is pegged can*

produce needless volatility in a country's international competitiveness...Dollar-induced overvaluation was also one of the problems facing such victims of currency crises as Mexico (1994), Thailand and Korea (1997), Russia (1998), Brazil (1999) and Turkey (2001). (pp. 419, 423)

4.2 Inflation Targeting under Flexible Exchange Rates

Given that an inflation targeting policy is incompatible with a fixed exchange rate regime, it is necessary to incorporate a rule for the determination of a nominal exchange rate that allows for some degree of flexibility. First, I will consider the extreme case where the exchange rate is completely flexible, so the central bank can choose between a monetary aggregate or the interest rate as the instruments of monetary policy. Later on, I will assume another rule, which allows for flexibility in the exchange rate but where the rate of devaluation is controlled by the central bank. In the latter case, the instrument will be the nominal exchange rate combined with one of the other two instruments. After that, it will become possible to establish which exchange rate regime and which policy instrument combination delivers the smallest SME for the inflation target π_t^T.

4.2.1 Inflation Targeting under Free Floating of the Exchange Rate

As in the case of the closed economy, I will develop a model for the monetary sector. The model describes how the external sector introduces a new source of money creation and how domestic prices and interest rates are determined in these circumstances. A key assumption is that the exchange rate can freely float without central bank intervention that prevents the exchange rate to reach a specific level.

The monetary sector is represented by the following equations (to be explained below):

$$\dot{m}_t^D = \gamma_1 \dot{y}_t + \gamma_2 (R_t - R_{t-1}) + u_{\dot{m}_t^D} \tag{4.6}$$

$$\dot{m}_t^S = \dot{\phi}_t + \dot{h}_t \tag{4.7}$$

$$\dot{h}_t = n_{t-1}\left(1 + \dot{x}_t\right) \dot{f}_t^D + \left[\bar{R}_t - \dot{b}_t^S\right] d_{t-1} \tag{4.8}$$

$$\dot{f}_t^D = \tau_1 \dot{y}_t + \tau_2 \dot{x}_t + u_{\dot{f}_t^D} \tag{4.9}$$

$$\dot{b}_t^D = \pi_t + \dot{y}_t \tag{4.10}$$

$$\dot{x}_t = \pi_t - \pi_t^* + u_{\dot{x}_t} \tag{4.11}$$

$$R_t = R_t^* + \dot{x}_t + \rho_t \tag{4.12}$$

$$\underset{t}{E}\left[\dot{x}_{t+1}\right] = \dot{x}_t + u_{\dot{x}_{t+1}} \tag{4.13}$$

$$m_t^x = \dot{m}_t^S - \dot{m}_t^D \tag{4.14}$$

$$\pi_t^a = \beta_1 \pi_{t-1} + \beta_2 \left[\left(1 + \hat{\pi}_t^*\right)\left(1 + \widehat{\dot{x}}_t\right) - 1\right] \tag{4.15}$$

$$\pi_t = \alpha m_t^x + (1 - \alpha)\pi_t^a + u_{\pi_t} \tag{4.16}$$

These equations introduce new variables: the ratio of international reserves to base money in period t-1, namely, n_{t-1}; the rate of growth of the central bank's demand for international reserves, $\dot{f}_t^D$; the average interest rate on the central bank's liabilities, $\bar{R}_t$, which is a weighted average of the domestic nominal interest rate and the international nominal interest rate, and the domestic interest rate premium, ρ_t.

Equations 4.6, 4.7, 4.10, 4.14, and 4.16 are exactly the same equations shown before as 3.24, 3.25, 3.28, 3.29 and 3.30.

Equation 4.8 represents the rate of growth of high-powered money as a function of the changes in the central bank's net international reserves, the central bank's losses, and the rate of growth of the central bank's debt. In order to make explicit how this equation fits into the model, I have to deviate somewhat from the presentation of the central bank's balance sheet shown in equation 4.1.

The new presentation breaks the central bank's balance sheet down as follows :

$$A_t + X_t F_t = H_t + B_t \tag{4.17}$$

On the asset side, there are net domestic assets, A_t, and net foreign assets, F_t, the latter also called net international reserves. In turn, liabilities include high-powered money and the central bank's debt, which includes interest-bearing liabilities denominated in domestic currency as well as medium and long-term debt denominated in foreign currency.[17] As is customary among central banks, the monetary presentation of their balance sheet includes equity accounts as part of their liabilities. As a result, if a central bank has accumulated losses such that its equity is negative, then equity will be registered as one of the components of domestic assets.

For the current purposes, I define the central bank's deficit in units of monetary base, as $d_{t-1}\bar{R}_t$, and equivalent to the interest payments on the debt outstanding at the end of period t-1. This formulation ignores the earnings originated as interest on international assets held by the central bank. Such amount can expressed as $a_{t-1}R_t^*(1+\dot{x}_t)$, where a_{t-1} is the ratio of foreign assets to base money at t-1. For simplicity, and without any loss of generality, this term will be omitted in the characterization of the deficit.

Under the assumption that the only source of growth in net domestic assets is the central bank's deficit, $B_{t-1}\bar{R}_t$, I can express changes in the base money as:

$$H_t - H_{t-1} = B_{t-1}\bar{R}_t + (F_t - F_{t-1})X_t - (B_t - B_{t-1}) \tag{4.18}$$

[17]Net foreign assets are defined as international assets minus short-term foreign debt. The liabilities included in this presentation are: the monetary base, the central bank's debt originated from open market operations, and medium and long-term foreign debt. Therefore, domestic assets are net of liabilities such as non-interest-bearing government deposits and mandatory reserves on the public's foreign exchange deposits with the commercial banks.

From equation 4.18, I can derive the rate of growth of base money as follows:

$$\frac{H_t}{H_{t-1}} = 1 + n_{t-1}(1+\dot{x}_t)\dot{f}_t + \left(\bar{R}_t - \dot{b}_t^S\right) d_{t-1} \tag{4.19}$$

$$\Rightarrow \dot{h}_t \approx n_{t-1}(1+\dot{x}_t)\dot{f}_t + \left(\bar{R}_t - \dot{b}_t^S\right) d_{t-1}$$

where $n_{t-1} = \frac{X_{t-1}F_{t-1}}{H_{t-1}}$ is the ratio of international reserves to base money in the previous period, and $d_{t-1} = \frac{B_{t-1}}{H_{t-1}}$ is the ratio of the central bank's interest-bearing liabilities to base money, in period t-1.

What expression 4.8 tells us is that the central bank can temporarily increase its level of international reserves without increasing the money stock. But, in order to accomplish this, it must necessarily issue more debt, which will lead to a greater deficit (smaller surplus) in the future, as interest payments on this debt are not compensated by sufficient asset earnings.

Equation 4.9 is the central bank's demand for international reserves. So far, the model has assumed that the exchange rate regime allows for the free floating of the exchange rate. The central bank, however, is still a key player in the foreign exchange market, where for instance it can buy and sell foreign exchange in order to service its debt, at the rate set by market forces.

Equation 4.11 is the relative version of the purchasing power parity (PPP) statement, which claims that the rate of change of the exchange rate is a function of the difference between the rate of domestic inflation and the rate of international inflation.[18] The validity of

[18] Hallwood and MacDonald [1995] remind us that:

> *From the beginning, the PPP doctrine was related to a monetary interpretation of the exchange rate.* (p.116)

These authors also indicate that:

> *...absolute PPP may not hold if there are restrictions on trade such as tariffs or quotas, if there are transport costs or if there is imperfect information about prices in the two countries.*

this hypothesis has been widely studied. Empirical research regarding whether PPP holds shows mixed results. Hallwood and MacDonald, [1995], for example, quote Krugman:

> *There is some evidence then that there is more to exchange rates than PPP. This evidence is that the deviations of exchange rates from PPP are large, fairly persistent, and seem to be larger in countries with unstable monetary policy* (p.129).

The same authors claim, however, that a less strict interpretation or weak version of PPP would allow for short-run deviations that eventually will cancel out in the long run. They find evidence of this outcome in the works of MacDonald [1993], Huizinga [1987], and Abuaf and Jorion [1990], to conclude that:

The tide would seem to be turning in favour of some form of purchasing power parity! (p.132).

Holmes [2001] conducts a test for 30 developing countries for the 1973-1997 period and concludes that:

> *...PPP is generally confirmed and, unlike earlier studies, there is no evidence that PPP is confined to high-inflation developing countries.* (p.197)[19]

Using data for five Asian countries for the 1975-2001 period, Liew [2003] claims that there is *...robust empirical evidence supporting the validity of the long-run PPP.* (p. 9)

Equation 4.12 is an extension to interest rates of the PPP hypothesis, under the assumption that a sort of Fisher's equation for nominal interest rates holds. According to Fisher's equation, $R_t = r_t + \pi_t$ and $R^*_t = r^*_t + \pi^*_t$. If the change in the rate of growth of the

> *As a matter of practicality, the relative PPP theory is used to overcome these problems. Thus ... we get the proportionate change in the exchange rate,..., as a function of the difference in the proportionate changes in home and foreign prices.* (p.118)

[19] Holmes uses a technique that is an extension of the principal components methodology. This technique is a test for stationarity of the first largest principal component (LPC) on the real exchange rate with respect to the U.S. dollar for 30 developing countries.

exchange rate is governed by the difference between domestic and international inflation rates, then, $\dot{x}_t = \pi_t - \pi_t^*$. The difference between the nominal domestic and international interest rates is: $R_t - R_t^* = \dot{x}_t + r_t - r_t^*$, which makes it possible to express the domestic nominal interest rate as in equation 4.12, namely, as $R_t = R_t^* + \dot{x}_t + \rho_t$, where ρ_t accounts for the difference between domestic and international real interest rates. Also, ρ_t can be seen as the country's risk premium.

Equation 4.13 describes the expectation formation process for the exchange rate. The assumption incorporated here is based on the seminal paper by Messe and Rogoff [1983], which claims that, in an out-of-sample context, a simple random walk outperforms a variety of economic models in forecasting exchange rate movements. Even more, Hallwood and MacDonald [1995] explain that:

> *...taking account of information contained in money supplies, income levels and interest rates does not provide better forecasts of the exchange rate than simply taking the lagged exchange rate.* (p.179)

Almost twenty years later, Rogoff [2001] boasts that:

> *...not only have a subsequent twenty years of data and research failed to overturn the Messe-Rogoff result, they have cemented it...*(p.1)

Finally, equation 4.15 describes how expectations about inflation are formed. Economic agents take into account the available information in order to form their own inflation expectations. Here, it is assumed that the relevant information is summarized by recent past domestic and international inflation rates. A forecast of international inflation expressed in domestic terms is $\left[\left(1 + \hat{\pi}_t^*\right)(1 + \widehat{\dot{x}}_t)\text{-}1\right]$, where $\hat{\pi}_t^*$ is the public's forecast of international inflation and $\widehat{\dot{x}}_t$ is the public's forecast of the rate of change of the foreign exchange rate. Both forecasts are made with information available up to period t-1. Thus, anticipated inflation is just a weighted average of past domestic inflation and forecasted international inflation expressed in domestic terms.

Now that the model has been made explicit, I will compare the policy options for the central bank to reach its intended inflation target.

4.2.1.1 Using a Monetary Aggregate to Target a Desired Level of Inflation

When the policy instrument is high-powered money, the central bank has to set $\dot{h}_t$ according to its inflation target π_t^T. The procedure is very similar to the steps followed from equation 3.34 through 3.40.

Making use of its best information, the central bank has to estimate the rate of growth of high-powered money that is consistent with the inflation target. To accomplish this, the central bank estimates all the values that determine base money. First, an expression for the interest rate premium, ρ_t, is obtained from the bonds market equations 4.8 and 4.10. Also, from the money market equilibrium conditions in equations 4.6 and 4.7, another expression for ρ_t can be found. Then, by making them equal, the estimated rate of growth of base money is finally obtained. Such expression is:

$$\dot{h}_t^T = \frac{d_{t-1}\{\gamma_2[\pi_t^T + \widehat{\dot{y}}_t - \widehat{R}_t^* z_{t-1}^*(1+\widehat{\dot{x}}_t)] + z_{t-1}^d(m_t^{xT} + \gamma_1 \widehat{\dot{y}}_t - \gamma_2 R_{t-1})\} - \gamma_2 n_{t-1} \widehat{\dot{f}}_t (1+\widehat{\dot{x}}_t)}{d_{t-1} z_{t-1}^d - \gamma_2} \tag{4.20}$$

where $z_{t-1}^d = \frac{B_{t-1}^d}{B_{t-1}}$, $z_{t-1}^* = \frac{B_{t-1}^* X_{t-1}}{B_{t-1}}$, and $z_{t-1}^d + z_{t-1}^* = 1$. That is, abstracting from earnings on international assets, the central bank's deficit is $\bar{R}_t B_{t-1}$. In the case of an open economy, there are liabilities denominated in domestic currency and in foreign currency; then $B_{t-1} = B_{t-1}^d + B_{t-1}^* X_{t-1}$. Therefore:

$$\bar{R}_t B_{t-1} = R_t B_{t-1}^d + R_t^* B_{t-1}^* X_{t-1}(1 + \dot{x}_t) \tag{4.21}$$

Dividing both sides by B_{t-1} makes it possible to write

$$\bar{R}_t = R_t \frac{B^d_{t-1}}{B_{t-1}} + R^*_t(1+\dot{x}_t)\frac{B^*_{t-1}X_{t-1}}{B_{t-1}} = z^d_{t-1}R_t + z^*_{t-1}R^*_t(1+\dot{x}_t) \tag{4.22}$$

Once the central bank has figured out the magnitude of the monetary expansion needed to induce a particular inflation target, the market clears for the risk premium in the interest rate. Thus, both the domestic interest rate and the rate of growth of the exchange rate are determined by the interaction of the money stock set by the central bank and the economic forces behind money demand, the debt market, and the foreign exchange market.

As in the case of the closed economy, the required monetary disequilibrium, that is in line with the inflation target, m^{xT}_t, will not be equal to the actual monetary disequilibrium that effectively happens after the central bank has increased base money by $\dot{h}^T_t$. The reason for this discrepancy is that the central bank sets the rate of change of base money from expected values and from estimates for some variables that are not necessarily equal to their realized values. In the end, the monetary disequilibrium will be m^x_t and not m^{xT}_t, and actual realized inflation will be π_t and not π^T_t. The question then is, what is the size of the error, which the central bank incurs as it uses base money as the policy instrument, when it targets a specific level of inflation, in a context of a free floating exchange rate? This error, is labeled as $\varepsilon_{\pi^T(\dot{h}^T_t,,\dot{x}_t)}$

This error will be:

$$\begin{aligned}\varepsilon_{\pi^T(\dot{h}^T_t,,\dot{x}_t)} = \upsilon_{1t}\varepsilon_{\widehat{y}_t} + \upsilon_{2t}\left(\varepsilon_{\widehat{R}^*_t} + \varepsilon_{\widehat{\zeta}^*_t}\right) + \upsilon_{3t}\left(\varepsilon_{\widehat{\pi}^*_t} - u_{\dot{x}_t}\right) + \\ \upsilon_{4t}\left(-\alpha u_{\dot{m}^D_t} + \varepsilon_{\widehat{\pi}^a_t} + u_{\pi_t}\right)\end{aligned} \tag{4.23}$$

where:

$$\begin{aligned}\upsilon_{1t} &= \tfrac{-\alpha(\gamma_1 z^d_{t-1}+\gamma_2)d_{t-1}}{Đ_t}; \quad \upsilon_{2t} = \tfrac{\alpha\gamma_2 z^d_{t-1}d_{t-1}}{Đ_t}; \\ \upsilon_{3t} &= \tfrac{-\alpha\gamma_2 n_{t-1}\dot{f}_t}{Đ_t}; \quad \upsilon_{4t} = \tfrac{z^d_{t-1}d_{t-1}}{Đ_t}\end{aligned} \tag{4.24}$$

$$Đ_t = z^d_{t-1} d_{t-1} + \alpha\gamma_2 \left(d_{t-1} - n_{t-1}\dot{f}_t\right); \qquad \hat{\zeta}_t = \hat{R}^*_t \widehat{\dot{x}}_t \tag{4.25}$$

In the steady state $\upsilon_{1t} = \upsilon_1$, $\upsilon_{2t} = \upsilon_2$, $\upsilon_{3t} = \upsilon_3$, $\upsilon_{4t} = \upsilon_4$, $Đ_t$ =Đ, and the MSE of $\pi^T\left(h^T_t, \dot{x}_t\right)$ will be:

$$MSE\left[\pi^T\left(\dot{h}^T_t, \dot{x}_t\right)\right] = \upsilon_1^2 \sigma^2_{\varepsilon_{\widehat{\dot{y}}_t}} + \upsilon_2^2\left(\sigma^2_{\varepsilon_{\widehat{R}^*_t}} + \sigma^2_{\varepsilon_{\widehat{\zeta}^*_t}}\right) + \tag{4.26}$$
$$\upsilon_3^2\left(\sigma^2_{\varepsilon_{\widehat{\pi}^*_t}} + \sigma^2_{u_{\dot{x}_t}}\right) + \upsilon_4^2\left[\alpha^2\sigma^2_{u_{\dot{m}^D_t}} + (1-\alpha)^2\sigma^2_{\varepsilon_{\widehat{\pi}^a_t}} + \sigma^2_{u_{\pi t}}\right]$$

In an open economy, when the central bank uses base money as the policy instrument, there are new sources of error. All of them $\left(u_{\dot{x}_t}, \hat{R}^*_t, \widehat{\pi}^*_t, \hat{\zeta}_t\right)$ are related to the openness of the economy and to the exchange rate regime. The rate of growth of high-powered money that is in line with the inflation target depends not only on domestic variables, but it also depends on international inflation and international nominal interest rates. If the central bank errs in estimating these magnitudes, such errors will increase the deviation between the inflation target and the actual inflation rate.

It is important to realize that the variability of the exchange rate is part of the deviation of actual inflation with respect to the target. This means that any unexpected shock that affects the exchange rate will be transmitted to the domestic inflation rate.

4.2.1.2 Using the Nominal Interest Rate to Target a Desired Level of Inflation

Alternatively, the central bank can use the interest rate as the monetary policy instrument. In a small open economy, under relatively efficient capital markets, the domestic nominal interest rate is related to movements in international nominal interest rates and the exchange rate.

In acknowledging this constraint, the central bank can not "blindly" set domestic nominal interest rates. However, it can set the interest rate premium such that the parity between domestic and international nominal rates is governed by equation 4.12. In this case, the premium will be the central bank's policy instrument.

The idea is that the central bank estimates a premium ρ_t^T, which jointly with the international nominal interest rate and the rate of change of the exchange rate determines the domestic nominal interest rate, such that $R_t = R_t^* + \dot{x}_t + \rho_t^T$.

In contrast to the closed economy case, now both high-powered money and the nominal interest rate are variables subject to random shocks. The central bank will adjust the base money to the point where $R_t - \left(R_t^* + \dot{x}_t\right) = \rho_t^T$. What the central bank can set is just the domestic component of the nominal interest rate, because the other two components are given by the market. The foreign exchange rate is free to float and R_t^* is given by international capital markets.

The operational procedure to find the appropriate magnitude for ρ_t^T can be described as follows. First, the central bank chooses a desired inflation target, and then, according to equation 4.16, it computes the size of the monetary disequilibrium, m_t^{xT}, that is necessary to reach π_t^T. Based on available information, it computes an estimated $\widetilde{\dot{h}}_t$ (as in equation 4.20) and from there solves for the interest rate premium consistent with the inflation target. Such expression is:

$$\rho_t^T = \frac{1}{z_{t-1}^d}\left[\pi_t^T + \widehat{\dot{y}}_t + \frac{\widetilde{\dot{h}}_t - n_{t-1}\widehat{\dot{f}}_t\left(1+\widehat{\dot{x}}_t\right)}{d_{t-1}} - \widehat{R}_t^* z_{t-1}^*\left(1+\widehat{\dot{x}}_t\right)\right] - \widehat{R}_t^* - \widehat{\dot{x}}_t \quad (4.27)$$

In this case, the monetary disequilibrium planned or intended by the central bank is $m_t^{xT} = \widetilde{\dot{h}}_t - \left[\gamma_1 \widehat{\dot{y}}_t + \gamma_2(\widehat{R}_t^* + \widehat{\dot{x}}_t + \rho_t^T - R_{t-1})\right]$, but the actual realized disequilibrium is $m_t^x = \dot{h}_t - \left[\gamma_1 \dot{y}_t + \gamma_2(R_t^* + \dot{x}_t + \rho_t^T - R_{t-1}) + u_{\dot{m}_t^D}\right]$. Given that the desired and the realized monetary disequilibria are not the same, this will cause an error in reaching the inflation target.

This error will be:

$$\varepsilon_{\pi^T(R_t^T \dot{x}_t)} = w_1 \varepsilon_{\widehat{y}_t} + w_2 \left(\varepsilon_{\widehat{\pi}_t^*} - u_{\dot{x}_t} - \varepsilon_{\widehat{R}_t^*} \right) + w_3 \left[(1-\alpha) \varepsilon_{\widehat{\pi}_t^a} + u_{\pi_t} - \alpha u_{\dot{m}_t^D} \right] \quad (4.28)$$

where

$$w_1 = \frac{-\alpha \gamma_1}{1 + \alpha \gamma_2}; \quad w_2 = \frac{\alpha \gamma_2}{1 + \alpha \gamma_2}; \quad w_3 = \frac{1}{1 + \alpha \gamma_2} \quad (4.29)$$

The MSE corresponding to $\pi^T \left(R_t^T, \dot{x}_t \right)$ will be:

$$MSE \left[\pi^T \left(R_t^T, \dot{x}_t \right) \right] = w_1^2 \sigma^2_{\varepsilon_{\widehat{y}_t}} + w_2^2 \left(\sigma^2_{\varepsilon_{\widehat{\pi}_t^*}} + \sigma^2_{u_{\dot{x}_t}} + \sigma^2_{\varepsilon_{\widehat{R}_t^*}} \right) + w_3^2 \left[(1-\alpha)^2 \sigma^2_{\varepsilon_{\widehat{\pi}_t^a}} + \sigma^2_{u_{\pi_t}} + \alpha^2 \sigma^2_{u_{\dot{m}_t^D}} \right] \quad (4.30)$$

As indicated in Chapter 3, any meaningful comparison should be over the mean-squared error of $\pi^T \left(\dot{h}_t^T, \dot{x}_t \right)$ and $\pi^T \left(R_t^T, \dot{x}_t \right)$, which requires the empirical estimation of the parameters involved in these expressions.

To summarize, in an open economy, an inflation targeting regime is incompatible with a totally fixed exchange rate (hard peg).

If the central bank chooses a foreign exchange rate regime that allows free floating, however, then it is possible to use a monetary aggregate or the nominal domestic interest rate as the policy instrument. If the central bank uses high-powered money, the domestic interest rate will be affected not only by the randomness of money demand, as in the case of the closed economy, but it will also be influenced by movements in the exchange rate, international interest rate, and international inflation rate. Thus, openness introduces new sources of volatility in domestic nominal interest rates, all of which produce noise in hitting the desired inflation target.

Alternatively, if the instrument chosen is the nominal interest rate, the central bank can no longer set it at a predetermined level, as it can do in a closed economy. The reason for this is that, in the case of a small open economy, domestic interest rates will be determined not only by domestic monetary conditions but also by parity conditions, where both international interest rates and the exchange rate play a role. Nevertheless, the central bank can set the premium in the interest rate, commit itself to a predetermined value of this premium, and adjust base money as much as it would be necessary so the premium can be kept constant.

Independently of which instrument the central bank uses, there will always be a deviation between the actual inflation rate and the intended target. To exactly evaluate under which instrument this error is smaller, as measured by the mean-squared error, one requires the empirical estimation of the parameters of the model.

4.2.2 Inflation Targeting under a Managed Exchange Rate

So far, the discussion has focused on how the central bank can induce the required size of a monetary disequilibrium with the purpose of reaching a specific inflation target. Two extreme exchange rate regimes have been considered, at each end of the spectrum: a hard peg and a free float. In practice, however, many countries choose an intermediate regime. In this respect, Eichengreen [2002] indicates:

> *The hot debate over the best monetary-cum-exchange-rate regime for developing countries shows no signs of cooling down. The Asian crisis and its fallout in Latin America and Eastern Europe have convinced many observers that soft currency pegs are crisis prone and that emerging markets should embrace greater exchange rate flexibility. The Turkish crisis reinforced that view. But worries that greater flexibility will impede market access, hinder financial development, and undermine rather than underpin financial stability have let others to advocate moving in the opposite direction –that is, hardening the peg by installing a currency board or dollarizing. While there are prominent examples of countries that have moved both ways –Ecuador and El Salvador have dollarized while Brazil has embraced greater flexibility– many developing countries continue to occupy the middle ground in the sense of making*

extensive use of their reserves so as to limit the variability of their exchange rates. (p.1)

I will now consider the instrument problem for one such intermediate regime. Equation 4.16 shows that the determinants of the inflation rate are basically two: a monetary disequilibrium and expectations. In the case of the closed economy, under bounded rationality, it has been shown that even when inflation expectations play a role in the determination of the actual rate of inflation, the latter is a function of past and present monetary disequilibria.

In an open economy, however, expectations are also influenced by the behavior of the exchange rate. As Svensson [2000] indicates, it is well known that there is a direct exchange rate channel for the transmission of monetary policy to inflation. This channel emerges because the exchange rate influences the domestic prices of exported and imported goods. In addition, there is an indirect channel, which emerges because movements in the exchange rate are a hint for economic agents about what to expect in the near future about inflationary pressures.[20]

Therefore, the central bank has the option of inducing the public's expectations about inflation by setting a path for the exchange rate. In order to achieve this, the central bank can abandon the free float regime and advocate a different foreign exchange arrangement, in which the rate of growth of the exchange rate is aligned to the inflation target.

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[20] Svensson [2000] claims:

> *...by inducing exchange rate movements, monetary policy can affect CPI with a shorter lag....the exhange rate is inherently a forward-looking and expectations-determined variable. This contributes to making forward-looking behavior and the role of expectations essential in monetary policy.* (p.4)

Such a *managed exchange rate* regime will be assumed here. This is an intermediate arrangement between the two extremes considered above. Given the influence of the foreign exchange regime on the outcome of this dissertation, its features are specified in detail. This *sui generis* regime is assumed to reflect circumstances prevailing in many developing countries.

The foreign exchange market is characterized by individual freedom to buy and sell any amount of foreign exchange (that is, by full convertibility and free capital movements). The central bank, however, is assumed to be an important player on both sides of the market, as a supplier and as a demander of foreign exchange. This specification represents stylized facts of an economy with a managed crawling peg such as Costa Rica.[21]

In contrast to the hard peg case, there are no major foreign exchange controls. The central bank no longer commits itself to keeping a predetermined nominal parity, under any circumstances. Even though the central bank is an important holder of foreign exchange, there are other agents that can interact as suppliers and demanders of international reserves. One implication of this decentralization of foreign exchange transactions is that not all movements in the current and capital accounts of the balance of payments will have a counterpart in a change of the central bank's stock of international reserves. Therefore, deficits in the current account may be partially financed by the central bank's losses of international reserves and by changes in the composition between domestic and foreign assets of private individuals. As a result, there is less stress on the stock of international reserves held by the central bank.

In addition to the concern about its own net foreign assets, the central bank faces the dilemma that upward movements in the exchange rate exert upward pressures on domestic

[21] At this point, the purpose of the exercise is not to find the optimum exchange rate regime but rather to evaluate the instruments of monetary policy, given this particular exchange rate system.

prices. To keep inflation rates low, the central bank may thus attempt to slow down the pace of devaluation. If, in order to accomplish this, the central bank intervenes too much in the market (by selling foreign exchange), there is the risk of harming the country's competitiveness in international markets (that is, the country will experience a real appreciation) or the risk of depleting the central bank's international monetary reserves in the process. The central bank is thus constrained (even though in a less stressful way than under a hard peg regime) by its stock of foreign assets and by concerns about international competitiveness.

I assume that the central bank makes public, on a daily basis, the exchange rate that it will apply in its transactions. The rest of the market has freedom to engage or not in such transactions with the central bank. If the market considers the exchange rate as too low, the central bank will lose international monetary reserves through its net sales. When the rate is viewed as too high, the central bank accumulates foreign assets, but in the process of doing so it increases the stock of base money, thereby jeopardizing the central bank's ability to keep the rate of money growth in line with the inflation target. It may instead issue debt, which may also create future inflationary pressures.

Given these constraints, if the central bank wants to use the exchange rate in order to influence the public's expectations, this cannot be done contemporaneously. According to equation 4.15, the information relevant for today's expected inflation is yesterday's exchange rate. This means that today's exchange rate policy has to be designed according to the inflation target for tomorrow. Moreover, the central bank must avoid setting the exchange rate at a level too far away from the level compatible with market forces. Therefore, two considerations must be kept in mind by the central bank authorities. First, today's exchange rate must be consistent with tomorrow's desired inflation rate. Second, even though there may be short-run deviations of the exchange rate from relative PPP, the central bank must avoid setting an exchange rate that exacerbates and amplifies such deviations in the long run. For this reason, an error correction mechanism is necessary in the central bank's exchange rate rule.

As a matter of central bank transparency, which is one of the necessary conditions for implementing an inflation targeting regime, the monetary authorities can make public, in a general statement, they will adjust the exchange rate according to the evolution of both domestic and foreign inflation. In this way, the central bank signals that, when circumstances demand it, it will allow the exchange rate to offset the negative effects of domestic inflation on the country's competitiveness with respect to the rest of the world.

The interaction of the central bank with the foreign exchange market and the statement about exchange rate policy suggest that some kind of a relative purchasing-power-parity rule with feedback is being followed in the determination of the managed exchange rate. Such a relationship, in place of equation 4.11, can be described as:

$$\dot{x}_t^T = \mathcal{F}\left(\pi_{t+1}^a\right) + \left[\dot{x}_{t-1}^P - \left(\pi_{t-1}^T - \hat{\pi}_{t-1}^*\right)\right] \tag{4.31}$$

where $\dot{x}_t^T$ is the rate of growth of the exchange rate set by the central bank.

The term $\mathcal{F}\left(\pi_{t+1}^a\right)$ is the component in today's exchange rate that affects tomorrow's inflation expectations. The specific form of $\mathcal{F}\left(\pi_{t+1}^a\right)$ will be shown shortly.

The term $\dot{x}_{t-1}^P$ is the growth rate of the exchange rate in the previous period had the nominal exchange rate been adjusted according to the relative PPP hypothesis; hence, $\dot{x}_{t-1}^P = \pi_{t-1} - \pi_{t-1}^*$. In turn, the difference $\left(\pi_{t-1}^T - \hat{\pi}_{t-1}^*\right)$ is the exchange rate variation that should have occurred a period ago, consistent with both the inflation target set for that period and the relative PPP hypothesis. Hence, $\left[\dot{x}_{t-1}^P - \left(\pi_{t-1}^T - \hat{\pi}_{t-1}^*\right)\right]$ is a correction term that approximately adjusts the current exchange rate by the deviation with respect to relative PPP in the previous period. This can be seen as a correction term, whose purpose is to avoid long-term misalignments in the exchange rate and the country's international competitiveness.

Equation 4.31 indicates that the purpose of the central bank's intervention in the foreign currency market is to induce inflation expectations according to its inflation target for the next period, which is given by the term $\mathcal{F}\left(\pi_{t+1}^{a}\right)$. At the same time, the central bank observes if in the previous period there was any significant deviation with respect to PPP, in which case it adjusts the exchange rate by $\left[\dot{x}_{t-1}^{P}-\left(\pi_{t-1}^{T}-\hat{\pi}_{t-1}^{*}\right)\right]$.

Only after the empirical evidence tells the authorities that they missed the inflation target in the previous period (and, thereby, that the exchange rate deviated from the purchasing power parity rule), they will adjust the path of depreciation of the domestic currency, thus reversing the deviation with respect to relative PPP.

To see how the central bank determines $\mathcal{F}\left(\pi_{t+1}^{a}\right)$, let me plug equation 4.15 into 4.16 and write it for period t+1. This will show how to align today's exchange rate with the inflation target for tomorrow. The central bank, using this equation, will set this target as:

$$\pi_{t+1}^{T}=\alpha m_{t+1}^{xT}+(1-\alpha)\left\{\beta_{1}\pi_{t}^{T}+\beta_{2}\left[\left(1+\hat{\pi}_{t}^{*}\right)\left(1+\dot{x}_{t}^{T}\right)-1\right]\right\} \qquad (4.32)$$

If the central bank wants that today's exchange rate affect tomorrow's inflation expectations, it has to set the rate of change of the exchange rate in line with tomorrow's inflation target. In principle, the central bank could set $\dot{x}_{t}^{T}=\pi_{t+1}^{T}-\hat{\pi}_{t+1}^{*}$. However, this cannot exactly be the desired rate of change of the exchange rate because we must remember that, besides considerations about influencing inflationary expectations, the central bank wants to add a correction term, in order to avoid long-run deviations with respect to relative PPP. The component in the rate of change of the exchange rate that is related to tomorrow's inflation expectations will be labeled as $\mathcal{F}\left(\pi_{t+1}^{a}\right)$, such that:

$$\mathcal{F}\left(\pi^{a}_{t+1}\right) = \pi^{T}_{t+1} - \hat{\pi}^{*}_{t+1} \tag{4.33}$$

Then, the rate of change of the exchange rate, at period t, is set by the central bank at:

$$\dot{x}^{T}_{t} = \pi^{T}_{t+1} - \hat{\pi}^{*}_{t+1} + \dot{x}^{P}_{t-1} - \left(\pi^{T}_{t-1} - \hat{\pi}^{*}_{t-1}\right) \tag{4.34}$$

Hence, the central bank, instead of allowing the exchange rate to move freely, sets it at a value that is consistent with a predetermined path for the inflation target plus a correction term that accounts for last period's deviation with respect to relative PPP.

At this point, it is worthwhile to identify some features of this exchange rate adjustment rule. If we wanted to know what would be a steady-state rate of growth of the exchange rate, we can write equation 4.34 as:

$$\dot{x}^{ssT} = \pi^{T} - \hat{\pi}^{*} + \dot{x}^{P} - \left(\pi^{T} - \hat{\pi}^{*}\right) \tag{4.35}$$

Equation 4.35 implies that:

$$\dot{x}^{ssT} = \dot{x}^{P} = \pi - \pi^{*} \tag{4.36}$$

This means that, under the central bank's exchange rate rule described above, relative PPP holds in the steady state.

Also, the steady-state anticipated inflation π^{a} must be π. That is, by equation 4.32, the steady-state monetary disequilibrium must be $m^{ssx} = 0$. Therefore, in the long-run, the expected steady-state domestic inflation rate is π^{*}. In steady-state we have the following: $\dot{x}^{ss} = \pi - \pi^{*}$; $\pi^{ssa} = \pi$; $\dot{x}^{ssm} = 0$. Also, we know that:

$$\pi^{ssa} = \left[\omega_1 \pi^{ss} + \omega_2 \left(1 + \pi^{*}\right)\left(1 + \dot{x}^{ss}\right) - 1\right] \tag{4.37}$$

If we calculate equation 4.32 for the steady-state, we have:

$$\pi^{ssa} = \alpha x^{ssm} + (1-\alpha)\left\{\omega_1 \pi^{ss} + \omega_2 \left[(1+\pi^*)(1+\dot{x}^{ss}) - 1\right]\right\} \tag{4.38}$$

Solving for π^{ss}, we find that $\pi^{ss} = \pi^*$. Therefore, in a small open economy, steady-state inflation is equal to the international inflation. This means that the long-run domestic inflation target should be set at the international inflation rate. In other words, a time-consistent monetary policy should be one that sets the long-run monetary disequilibrium equal to zero and the target for domestic inflation equal to international inflation.

4.2.2.1 Comparison of Policy Instruments Under a Managed Exchange Rate

To evaluate the policy options that the central bank has, I will not compare a given instrument against another one, but instead I will consider two mixes of instruments. The combinations considered here are, on the one hand, the exchange rate and a monetary aggregate and, on the other, the exchange rate and interest rate premium.

The comparison about the relative efficiency of the combination of policy instruments requires, first, a computation of the errors in achieving the inflation target under each combination of instruments and, then, a computation of the mean-squared error of the inflation target for each case.

For this purpose, it is necessary to reformulate the exercise carried out in sections 4.2.1.1 and 4.2.1.2, taking care of the fact that the rate of change of the nominal exchange rate is not a variable but a value set by the central bank, according to the rule described above.

The results of this exercise are described here. Using the combination of a monetary aggregate and a managed exchange rate, the deviation between actual inflation and the target is:

$$\varepsilon_{\pi^T(\dot{h}_t^T, \dot{x}_t^T)} = \upsilon_1 \varepsilon_{\widehat{y}_t} + \upsilon_2 \varepsilon_{\widehat{R}_t^*} + \upsilon_3 \left(-\alpha u_{\dot{m}_t^D} + \varepsilon_{\widehat{\pi}_t^a} + u_{\pi_t} \right) \tag{4.39}$$

where:

$$\upsilon_1 = \frac{-\alpha \left(z_{t-1}^d \gamma_1 + \gamma_2 \right)}{z_{t-1}^d + \alpha \gamma_2}; \quad \upsilon_2 = \frac{\alpha \gamma_2 z_{t-1}^* \left(1 + \dot{x}_t^T \right)}{z_{t-1}^d + \alpha \gamma_2}; \quad \upsilon_3 = \frac{z_{t-1}^d}{z_{t-1}^d + \alpha \gamma_2} \tag{4.40}$$

The mean-squared error of $\pi^T \left(\dot{h}_t^T, \dot{x}_t^T \right)$ is:

$$MSE\left[\pi^T \left(\dot{h}_t^T, \dot{x}_t^T \right) \right] = \upsilon_1^2 \sigma_{\varepsilon_{\widehat{y}_t}}^2 + \upsilon_2^2 \sigma_{\varepsilon_{\widehat{R}_t^*}}^2 + \upsilon_3^2 \left[\alpha^2 \sigma_{u_{\dot{m}_t^D}}^2 + \sigma_{\varepsilon_{\widehat{\pi}_t^a}}^2 + \sigma_{u_{\pi_t}}^2 \right] \tag{4.41}$$

When the combination of instruments is the interest rate premium and a managed exchange rate, the deviation between actual inflation and the target is:

$$\varepsilon_{\pi^T(R_t^T, \dot{x}_t^T)} = w_1 \varepsilon_{\widehat{y}_t} + w_2 \varepsilon_{\widehat{R}_t^*} - \alpha u_{\dot{m}_t^D} + \varepsilon_{\widehat{\pi}_t^a} + u_{\pi_t} \tag{4.42}$$

where:

$$w_1 = -\alpha \gamma_1; \qquad w_2 = -\alpha \gamma_2 \tag{4.43}$$

The mean-squared error of $\pi^T \left(R_t^T, \dot{x}_t^T \right)$ is:

$$MSE\left[\pi^T \left(R_t^T, \dot{x}_t^T \right) \right] = w_1^2 \sigma_{\varepsilon_{\widehat{y}_t}}^2 + w_2^2 \sigma_{\varepsilon_{\widehat{R}_t^*}}^2 + \alpha^2 \sigma_{u_{\dot{m}_t^D}}^2 + \sigma_{\varepsilon_{\widehat{\pi}_t^a}}^2 + \sigma_{u_{\pi_t}}^2 \tag{4.44}$$

One observation is that there are less sources of variability when the exchange rate is set by the central bank than when it can freely float. Therefore, in this sense, it seems that when it tries to achieve a specific inflation target, by managing the exchange rate the central bank can reduce the volatility in its error.

The question about which policy instrument combination is better still remains. Once again, a definitive answer depends on the empirical values of the parameters and the variances of the sources of error (which are random variables) involved in the computation of the MSE.

Furthermore, the conclusion that there are less sources of variability under a managed exchange rate than under a free float may be misleading, in the following sense. What really matters is not how many sources of randomness or variability there are in the model. Instead, what matters is their size and how they interact among themselves. This requires knowledge of the specific values of the parameters and variances. But even in the case where the MSEs under a managed exchange rate are smaller than under a free float, not any foreign exchange rule will deliver these results.

In order to work, the exchange rate rule must be sustainable. At least two conditions are necessary for this. First, the rule must not ignore the market forces, so that in the long run it is consistent with some sort of PPP. In this sense, the purpose of a managed exchange rate is not to avoid movements in the nominal exchange rate (that disturb inflationary expectations) but to smooth such movements. Notice that this rule assumes that relative PPP holds, however, if for some reason that is not the case, the devaluation rule must be adapted to consider movements over time in the real exchange rate.

Second, the rule must keep the rate of change of the exchange rate along a desired path. In an open economy with free capital movements, this goal requires enough international reserves for the central bank to effectively intervene in the market, when it identifies market pressures not related to the fundamentals of the real exchange rate. In addition, this requires some means to sterilize the potentially destabilizing effects of capital inflows on base money. Some form of controls on capital movements, which in practice are very difficult to implement effectively, might be needed. Alternatively, the central bank may use open market operations to sterilize these inflows. However, by doing so, the central bank may run into financial deficits. This may happen if the interest rate earned on the central bank's international assets is lower than the interest rate used in its own open market operations.

Therefore, the success of a policy arrangement that combines a managed exchange rate with any other of the two instruments requires that financial deficits be covered with non-inflationary seigniorage or from any other non-inflationary source, such as explicit government budget transfers.

CHAPTER 5

EMPIRICAL APPLICATION FOR THE CASE OF COSTA RICA

The idea that the main policy purpose of a central bank is to keep inflation low and stable was discussed in earlier chapters. A specific policy strategy to reach this goal is to implement an inflation targeting regime. There are two basic requirements for the successful implementation of this regime: a particular institutional arrangement and sufficient technical knowledge about how to effectively control the inflation process. From an institutional perspective, the explicit central bank's commitment to reach a pre-announced inflation target and greater independence for the central bank to pursue this objective are essential. This implies that monetary policy must become more transparent and the central bank's authorities must become more accountable. From the technical perspective, precise understanding of what drives inflation must improve. This includes knowledge of the instruments that the central bank can use and of their effectiveness under different exchange rate regimes.

The conclusions obtained so far about the relative effectiveness of alternative policy instruments are conditional on the values of two sets of parameters. One set consists of the structural parameters of the model, namely α, β_1, β_2, γ_1, and γ_2. The other set comes from measures of the variability (sources of error) implicit in the model. Such variability is represented by the values of $\sigma^2_{\varepsilon_{\widehat{y}_t}}$, $\sigma^2_{\varepsilon_{\widehat{R}^*_t}}$, $\sigma^2_{u_{\widehat{m}_t^D}}$, $\sigma^2_{\varepsilon_{\widehat{\pi}^a_t}}$, $\sigma^2_{u_{\pi_t}}$, and $\sigma^2_{u_{\dot{x}_t}}$. Therefore, in order to provide concrete policy recommendations for a small open economy such as Costa Rica, it is necessary to estimate the values of such parameters.

To carry out this exercise, I estimate the model of Chapter 4 using data for the Costa Rican economy, from 1950 to 2003. Under the assumption that these estimates make it possible to explain the interaction between the policy instruments and the rate of inflation, I compare the MSE for the inflation target under different policy instrument combinations.

As operational variables to estimate the model, I use the rate of change of the consumer price index (CPI) as an indicator of domestic inflation, M_1 as the monetary aggregate, real GDP as a proxy for real income, the six-month nominal interest rate as the opportunity cost of holding real money balances, the US prime rate as the nominal foreign interest rate, and the rate of change of USCPI as an indicator of international inflation. All the variables are annual averages.

5.1 Econometric Estimation of the Reduced Model

From equations 4.6, 4.7, 4.14, 4.15 and 4.16, I obtain a reduced form of the monetary model of inflation, which is:

$$\pi_t = c_1 \dot{m}_t + c_2 \dot{y}_t + c_3 (R_t - R_{t-1}) + (1 - c_1) c_4 \pi_{t-1} + (1 - c_1)(1 - c_4) \hat{\pi}_t^{*c} + u_{\pi_t} \quad (5.1)$$

where

$$c_1 = \alpha, \quad c_2 = -\alpha\gamma_1, \quad c_3 = -\alpha\gamma_2, \quad c_4 = \beta_1, \quad (1 - c_4) = \beta_2 \quad (5.2)$$

All the variables in equation 5.1 are observable, except for the public's forecast of international inflation expressed in domestic terms $\left(\hat{\pi}_t^{*c}\right)$. In this case, I assume that economic agents forecast both international inflation and the rate of variation of the foreign exchange rate, according to the observed recent evolution of each variable. The particular regressions used to describe the public's forecasts are shown in Appendices B and C. With forecasts of $\hat{\pi}_t^*$ and $\widehat{x}_t$, a forecast of international inflation in domestic terms is obtained according to equation 4.15.

Using the econometric software EViews, I first run an ordinary least squares regression, in order to estimate the coefficients of equation 5.1, under the restrictions implied by expression 5.2. Preliminary results showed the presence of heteroskedasticity. This is, the stochastic term of equation 5.1 does not have a constant variance, which invalidates statistical inference from this regression. As a matter of fact, inflation in Costa Rica has had a volatile behavior during the period under considerations. Initially, in the 1950s and 1960s, the average inflation rate was less than 2.0%, per year and showed little variability. During the 1970s, however, average inflation was more than five times the rate for the previous decades and became more volatile. From 1980 to 1995, the annual average inflation rate doubled the average rate for the previous decade, reaching some unusually high levels in a few years, followed by lower rates. During the last eight years it has been stable around 10% per year. The variability of the inflation rate thus shows an unstable path. For example, the variance during the 1970s was about 14 fold the variance during the previous 20 years. From 1980 to 1995, this variance was almost three times what had been in the 1970s. Lastly, from the mid-1990s to 2003, there has been a drastic drop in inflation variance, to the point that today is it less than a hundredth of the variance for 1980-95. Hamilton [1994] and the EViews User's Guide [2000] suggest that it is not uncommon to find financial data that present a type of heteroskedasticy called exponential GARCH (EGARCH). Therefore, it is worthwhile to investigate the structure of the variance of the error term of equation 5.1.

EViews output for				
$\pi_t = c_1\dot{m}_t + c_2\dot{y}_t + c_3(R_t - R_{t-1}) + (1-c_1)c_4\pi_{t-1} + (1-c_1)(1-c_4)\hat{\pi}_t^{*c} + u_{\pi_t}$				
Under EGARCH for the u_{π_t} terms				
Method: ML - ARCH (BHHH)				
Bollerslev-Wooldrige robust standard errors and covariance				
	Coefficient	Std. Error	z-Statistic	Prob.
c_1	0.299404	0.049452	6.054459	0.0000
c_2	-0.386400	0.042868	-9.013678	0.0000
c_3	0.619733	0.117150	5.290073	0.0000
c_4	0.544742	0.052654	10.34571	0.0000
Other	Statistics			
$R^2=$	0.614645	Mean of $\pi_t=$	0.108655	
$\bar{R}^2=$	0.530055	$\sigma_{\pi_t}= 0.115119$		$\sigma_{\hat{u}_t}= 0.078917$

Table 5.1: Reduced Model Estimation

Using the options that EViews offers to estimate a model with this kind of heteroskedasticity, I obtain the results shown in Table 5.1.

These results show that all the coefficients have the expected sign and are statistically significant. The ultimate interest is not in the value of these coefficients *per se* but in the estimates of the structural parameters, according to expression 5.2. These estimated parameters are:

$$\hat{\alpha} = 0.299, \quad \hat{\gamma}_1 = 1.291, \quad \hat{\gamma}_2 = -2.070, \quad \hat{\beta}_1 = 0.545, \quad \hat{\beta}_2 = 0.455 \qquad (5.3)$$

An interpretation of these coefficients is as follows.

The parameter α indicates the magnitude by which the monetary disequilibrium drives the current rate of inflation. Thus, a monetary disequilibrium of one percentage point (a one percentage point difference between the rate of growth of money supply and money demand) drives the rate of inflation up by 0.3 percentage points.

The parameter γ_1 is the income elasticity of money demand, which is 1.3 in this estimation. The fact that this value is greater than unity suggests that, for the period under consideration, a money deepening process took place in Costa Rica. Such deepening of the monetization process is consistent with other transformations of the Costa Rican economy. In the early 1950s Costa Rica was, in many respects, a traditional rural economy with a strong agrarian base. [Céspedes and Gonzalez-Vega, 1993] An important share of household output was used for self-consumption. Thus, the Clower constraint was not binding, not all transactions were made in markets using money, checking accounts were only beginning to emerge, and access to financial services was limited for large segments of the population. A half-century later, the Costa Rican economy is more urban, there is substantial market integration, both domestically and internationally, and there is an extensive network of financial services, where public and private banks compete for domestic savings and the supply of credit. As a result, ratios of money to GDP have increased substantially over the long period. Estimations for shorter recent periods are likely to yield a lower elasticity.

The semi-elasticity of money demand with respect to the interest rate is represented by γ_2. Its value of -2.07 implies, according to the average level of domestic interest rates, an elasticity of -0.23. The value of semi-elasticity indicates that an increase of one percentage point in the interest rate reduces money demand by 2 percentage points.

Finally, the values of β_1 and β_2 are the relative weights in the formation of inflationary expectations. According to these estimates, lagged domestic inflation has a larger influence (0.55) than the forecast of the current international inflation expressed in domestic terms (0.45)

Given the exchange rate regime and under the assumption that the central bank knows these estimates, the best the monetary authority can do is to set a target for the inflation rate and use the monetary policy instruments at its disposal to approximate the target. However, there is uncertainty and these variables are subject to random shocks, which will cause the central bank not to exactly reach the target. Thus, any policy strategy will be subject to error. This error is related to the implicit sources of variability of the model used by the central bank in the design of its policy. The specific stochastic structure of the model developed here is represented by $\sigma^2_{\varepsilon_{\widehat{\dot{y}}_t}}$, $\sigma^2_{\varepsilon_{\widehat{R}^*_t}}$, $\sigma^2_{\varepsilon_{\pi^*_t}}$, $\sigma^2_{u_{\widehat{\dot{m}}^D_t}}$, $\sigma^2_{\varepsilon_{\widehat{\pi}^a_t}}$, $\sigma^2_{u_{\pi_t}}$, $\sigma^2_{u_{\dot{x}_t}}$ and $\sigma^2_{\varepsilon_{\widehat{\zeta}^*_t}}$

Moreover, the central bank needs to forecast some variables before it can set a particular value for its instruments. One of these is GDP. For this purpose, the central bank assumes a potential rate of growth, which is computed using the Hodrick-Prescott filter. The difference between the potential rate of growth and the observed rate of growth accounts for the forecast error with respect to this variable. The variance can be computed by treating this error as a random variable.

Using the parameters estimated as above and the exogenous forecasts for the rate of output growth and the international interest rate, the central bank can estimate most of the variances involved in the policy comparison exercise.

However, there is a variable for which there are no reliable observations, and additional assumptions are needed to obtain a proxy. This variable is the rate of variation of the nominal exchange rate under a free float. The reason why there are no direct observations for this variable is that, with the exception of two short episodes, in the past 54 years a free floating exchange rate regime has never been adopted in Costa Rica.

The first of those episodes lasted from the end of 1980 to the middle of 1982. During those months, the Costa Rican economy experienced a severe crisis characterized, among other features, by high rates of inflation, a sharp contraction of real economic activity, total depletion of the international monetary reserves held by the central bank, inability to access international capital markets, and an overshooting of the nominal exchange rate. [Gonzalez-Vega, 1989]. When the Central Bank ran out of international reserves, it was forced by circumstances to allow the exchange rate to be determined by pure market forces, until the Central Bank regained control over the foreign exchange market.

The other episode corresponds to a few months between the first and second quarter of 1992, during a short-lived free float experiment. This experience was accompanied by the removal of controls on foreign exchange and capital movements, during a time when capital inflows to Latin American countries, and in particular to Costa Rica, were positive. Large capital inflows, relative to the size of the Costa Rican economy, caused an unexpected appreciation of the domestic currency (colón) with respect the US dollar, hurting the competitiveness of the export sector. The loss of competitiveness created political pressures against the Central Bank, forcing it to go back to the managed exchange rate regime that had been in place since the middle of 1982.

For current purposes, it becomes necessary to obtain an indicator of the variability that the nominal exchange rate would have had if there would have been a free floating rate, even though such a regime has not been in place in Costa Rica. One approximation is to assume that PPP holds for the Costa Rican economy, even though, in the current stage of the PPP controversy, there is evidence that it does not hold in the short run but that it could hold in the long run.

Under relative PPP, the rate of change of the foreign exchange rate can be expressed as [Frenkel, 1981]:

$$\dot{x}_t^P = \kappa_1 \pi_t + \kappa_2 \pi_t^* + u_{\dot{x}_t^P} \tag{5.4}$$

EViews output for				
$\dot{x}_t = \kappa_1 \pi_t + \kappa_2 \pi_t^* + u_{\dot{x}_t}$				
Method: Least Squares				
Sample(adjusted): 1950-2003. Excludes 1981 and 1991				
Newey-West HAC Standard Errors & Covariance				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
c	0.009027	0.008193	1.101766	0.2764
π_t	0.909618	0.051034	17.82375	0.0000
π_t^*	-0.942477	0.202331	-4.658102	0.0000
Dummy	-0.034604	0.021959	-1.575884	0.1221
AR(1)	-0.224248	0.168220	-1.333060	0.1892
Other Statistics				
$R^2 =$	0.856290	Mean of $\dot{x}_t =$	0.060635	D.W.= 2.061045
$\bar{R}^2 =$	0.843515	$\sigma_{\dot{x}_t} = 0.093469$		$\sigma_{\widehat{u}_{\dot{x}_t}} = 0.036975$
Wald Test: H0: $\kappa_1 = 1$ and $\kappa_2 = -1$				
	Value	df	Probability	
χ^2	3.885632	2	0.1433	

Table 5.2: Test for Relative Purchasing Power Parity

were $\dot{x}_t^P$ is the rate of change of the foreign exchange rate if PPP holds, in contrast to $\dot{x}_t$, which is the actual observed rate of change of the exchange rate. Relative PPP implies $\kappa_1 = 1$ and $\kappa_2 = -1$. The problem still remains because there are no actual values for $u_{\dot{x}_t}$. Only for the purpose of verifying how far the rate of change of the exchange rate in Costa Rica has diverged from this condition, a regression as in equation 5.4 was ran, using $\dot{x}_t$ instead of $\dot{x}_t^P$. The results are shown in Table 5.2.

These estimates indicate that, in spite of the Central Bank's intervention in the foreign exchange market, in Costa Rica the data adjust fairly well to the relative version of PPP. An explanation for this is that, after the crisis of the early 1980s, the authorities have been setting the rate of change of the exchange rate following a rule that approximates PPP.

Sources of Error Implicit in the Monetary Policy Instruments				
	Null Hypothesis	Mean	Variance	Jarque-Bera
Source of Error	Normally Distributed			Probability
$\varepsilon_{\widehat{y}_t}$	Not rejected	0.0	0.000685	0.419
$\varepsilon_{\widehat{R}_t^*}$	Not rejected	0.0	0.000211	0.962
$\varepsilon_{\widehat{\pi}_t^*}$	Not rejected	0.0	0.000302	0.086
$u_{\widehat{m}_t^D}$	Rejected	0.0	0.006305	0.000
$\varepsilon_{\widehat{\pi}_t^a}$	Rejected	0.0	0.002005	0.000
u_{π_t}	Rejected	0.0	0.005013	0.000
$u_{\dot{x}_y^P}$	Not rejected	0.0	0.001255	0.331
$\varepsilon_{\widehat{\zeta}_t^*}$	Rejected	0.0	0.000060	0.000

Table 5.3: Implicit Sources of Error in the Use of Monetary Policy Instruments

The Wald test is performed for the coefficients of π_t and π_t^*, and the null hypothesis that $\kappa_1 = 1$ and $\kappa_2 = -1$ cannot be rejected. Therefore, one can assume that the residuals of the estimated equation are an approximation of the residuals of equation 5.4. This completes the set of variances needed to perform the comparison among combinations of policy instruments. Table 5.3 summarizes the variability of the sources of error involved in the monetary model of inflation.

5.2 Policy Comparison

The next step is to compute and compare the MSE for the different combinations of policy instruments that the central bank may use. Such figures are shown in Table 5.4.

Before going into the specifics of these results, we have to be aware that the mean-squared error of π_t^T under any combination of policy instruments depends on the variance

MSE under Different Policy Combinations		
	Exchange Rate Regime	
Instrument	Free Float $\dot{x}_t$	Managed $\dot{x}_t^T$
$\dot{h}_t^T$	0.0253	0.1048
R_t^T	0.0113	0.9986

Table 5.4: MSE associated to Policy Instrument Combinations

of the u_{π_t} terms. As shown in Table 5.1, there is heteroskedasticity. Even though the estimated parameters are corrected for this problem, heteroskedasticity in the u_{π_t} remains and it affects the magnitude of the MSE computed in Table 5.4. Therefore, such MSE can be interpreted as a tool to establish an order or ranking of policy instrument combinations; they cannot be strictly interpreted as the actual MSE that would happen under any particular policy design.

What Table 5.4 indicates is that any policy combination under a free floating exchange rate regime dominates the combinations under a managed exchange rate. That is, in the long run actual inflation will deviate less from the target set by the central bank if the exchange rate is free to float, regardless of the instrument of monetary control that the central bank chooses. One of the reasons why a free floating exchange rate delivers less variability in the rate of inflation is that there is no reason for the central bank to sterilize capital inflows. The central bank thus avoids the building up of interest-bearing liabilities. This prevents a central bank deficit from emerging, which in the long-run is one of the sources of money creation and therefore of inflationary pressures.

Under a free floating regime, the results show that the error in targeting a predetermined value for the inflation rate is smaller when the instrument of monetary control is the nominal interest rate than when it is the monetary aggregate. In this particular case, the problem that the central bank faces is that the openness of the economy constrains the ability of the central bank to fix interest rates. At the very best, what the central bank can do is to fix the interest rate premium, but in doing this it forces economic agents to revise their portfolio composition between financial assets in dollars and in domestic currency. This creates capital movements that change the size of the money stock and therefore the magnitude of the monetary disequilibrium, before such disequilibrium is transformed into inflationary pressures.

A possible interpretation is the following. Suppose that we start with a situation in which there is a monetary disequilibrium. This will exert pressure on interest rates to go down, the rate of change of the exchange rate to go up, and the inflation rate to go up in the long run. Suppose that the central bank fixes the interest rate premium, so the return on financial assets denominated in foreign exchange will tend to increase. This creates the incentive for the public to reduce their domestic currency holdings relative to those denominated in foreign exchange. This asset recomposition will reduce the money stock and in consequence inflationary pressures. However, in the process, the rate of change of the exchange rate has increased and this will show up in the rate of inflation.

Finally, the worst policy instrument combination is to try to simultaneously manage the exchange rate and the interest rate. For example, suppose that the central bank sets the interest rate premium and the rate of change of the exchange rate at a level that promotes capital inflows. The money stock will tend to increase. If the demand for real money does not grow at the same pace (and there is no reason for it), it will generate a monetary disequilibrium. Under this combination of policy instruments, however, the self-regulating mechanisms of adjustments in the exchange rate and in the interest rate are not allowed to operate, leaving all the adjustment on the inflation rate.

CHAPTER 6

CONCLUSIONS

6.1 Main Conclusions

The choice of the best combination of monetary policy instruments in an inflation targeting context is an empirical problem, which depends on the sources of variability in money demand and money creation as well as on specific values of the parameters involved in functions for money demand, inflation, and inflation expectations. Nevertheless, some analytical results from the model developed in this dissertation are worth noting.

First, the model shows that in a closed economy, under bounded rationality, inflation is driven by monetary disequilibria. In this sense, even as the model incorporates a departure from the strict Quantity Theory of Money to give expectations a role in the inflation process, the analytical result is basically the same; *i.e.*, in the long run, inflation is a monetary phenomenon. The current rate of inflation can be explained as a weighted average of current and past monetary disequilibria.

In an open economy, expectations are driven by past recent inflation and the rate of change of the exchange rate, which in turn depends on the exchange rate regime. The choice of exchange rate arrangement is, therefore, critical in the design of a monetary policy based on inflation targeting.

Furthermore, any attempt to manage the exchange rate implies that the central bank must make intensive use of its international reserves, a stock that has a limit, or accumulate debt, a process that also has a limit in the long run. Debt accumulation (and/or international reserves depletion) leads to central bank losses, through interest payments on this debt, which are a source of monetary expansion and thereby of inflationary pressures in the long run.

In an extreme case, the exchange rate is fixed. In this regime, monetary policy is subordinated to the goal of keeping the exchange rate peg. Presumably, there would be two nominal anchors in this situation. If the central bank privileged the exchange rate goal, this would mean that there is no firm commitment to the inflation target. This signal would make any efforts to maintain inflation under control not credible, and expectations would be formed according to historic inflation rates. This would make it impossible to reduce inflation even though there is complete stability of the exchange rate. Therefore, the harder the peg of the exchange rate is, the lower the probability of successfully implementing inflation targeting will be.

Another interesting analytical result is that, if the central bank committed itself not to create any monetary disequilibria in the long run, then the steady-state domestic inflation rate would tend to equal international inflation rates. The intuition is that greater openness increases the proportion of goods and services that are directly and indirectly tradeable. Given a small open economy, the prices of tradeable are determined by international market forces rather than by domestic forces. In the extreme case, if all goods and services were tradeable and there were domestic monetary disequilibria, domestic inflation would converge to international inflation levels.

There is a great deal in the literature about what the inflation target level should be. However, in the case of a small open economy, a central bank that does not create monetary disequilibria can only commit to a long-run inflation rate equal to the international inflation rate.

From an empirical point of view, the conclusions are restricted to the case of Costa Rica. Once the monetary model of inflation was estimated econometrically for this country, four instrument combinations were ranked according to their MSE.

Money demand is the variable with the largest variance among all those considered in the model. This means that, for this economy, as an instrument of monetary control, the monetary aggregate will be relatively less precise than the interest rate.

In the case of Costa Rica, the instrument combination that delivers the smallest error in pursuing a desired inflation rate is the nominal interest rate in a free floating exchange rate regime.

A free floating regime reduces the error in targeting a desired level of inflation regardless of the monetary policy instrument used. The superiority of the free floating regime over other exchange rate arrangements derives from the fact that the latter require costly complementary policy actions that eventually result in inflationary pressures.

There is the risk that the central bank may keep, over a long period, the exchange rate at a level that is not compatible with market forces. Therefore, to sustain the exchange rate, the central bank must sterilize capital inflows by using open market operations (that is, by issuing domestic debt, in increasing amounts). If the situation is an outflow of capital, the central bank can use its international reserves or engage in an ever increasing foreign debt. However, none of these methods is sustainable in the long run without generating central bank losses and, thereby, inflationary pressures.

6.2 Policy Implications

Costa Rica has experienced, on average, an annual rate of inflation of around 12 percent during the past ten years. Given the success of inflation targeting in many countries, as the monetary strategy to, first, reduce inflation and, then, keep it low and stable, it is worthwhile to consider such an option for this small, open economy. Assuming that the institutional requirements can be met, there are still some challenges from a technical point of view.

In particular, both a serious questioning of the current exchange rate regime and a reduction of the central bank's deficit, originated in quasi-fiscal operations during the 1970s and early 1980s, are necessary. More recently, some of the central bank's losses have been due to the crawling-peg foreign exchange rate regime, which has promoted a real depreciation of the domestic currency, in a context of capital inflows.

In a first stage, if the authorities cannot move to a free floating exchange rate, the central bank could at least design a rule for the nominal exchange rate that follows market forces, such as the rule described in this dissertation.

In a second stage, if there is institutional commitment to reduce inflation, the central bank and the government authorities could agree on how to reduce the monetary impact of central bank losses. Basically, what is needed is to avoid such losses to become a source of monetary expansion in the long run.

In a third stage, without (with less) monetary pressures from the foreign exchange market and without the (with less) threat of deficit monetization in the future, the central bank could implement the basic elements of an inflation targeting strategy. A necessary condition for this is to reduce the degree of financial dollarization in Costa Rica, which currently is about 50% of the liabilities of the banking system. Dollarization can be seen as an extreme case of a hard peg regime, where the exchange rate is one to one. Domestic dollars created by commercial banks are an implicit and contingent claim on the Central Bank's international reserves and, thereby, an inflationary threat if the Central Bank accumulates reserves to respond to this potential demand. The fact that an important share of the financial system is dollarized increases its vulnerability, thus increasing the role of the central bank as a lender of last resort. For the central bank to effectively be such a lender, it has to hold enough international reserves, which as has been explained is costly and a potential source of inflation pressures in the long run.

Finally, after a learning period, in which the central bank has been able to reduce the monetary disequilibria and has been able to send clear signals that the priority of monetary policy is to keep inflation low and stable, it can let the exchange rate to freely float and apply a full-fledged inflation targeting regime.

APPENDIX A

SUMMARY OF VARIABLES USED IN CHAPTER 4

A_t: Net domestic assets

B_t: Level of central bank's interest bearing liabilities

B_t^d: Level of central bank's interest bearing liabilities in domestic currency

B_t^*: Level of central bank's interest bearing liabilities in foreign currency

C_t: Domestic currency issued by central bank

F_t: Net foreign assets, also called net international reserves.

H_t: Base money or high-powered money

K_t: Domestic currency deposits of comercial banks on central bank

M_t: Level of money stock, measured as currency plus demand deposits

R_t^*: International nominal interest rate

R_t: Domestic nominal interest rate

$\bar{R}_t$: Average interest rate on central bank's interest bearing liabilities

X_t: Exchange rate level

c: Ratio level money stock to demand deposits hold by the public

q: Rate of mandatory reserves on public's deposits on commercial banks

s: Ratio surplus reserves on commercial banks to demand deposits

α: Changes on inflation with respect to changes on monetary disequilibrium

β_1: Weight of past inflation on expected inflation

β_2: Weight of foreign inflation on expected inflation

γ_1: Real money demand elasticity with respect to real income

γ_2: Semi-elasticity of money demand with respect domestic nominal interest rate

r_t^*: International real interest rate

r_t: Domestic real interest rate

a_t: Ratio of foreign assets to base money

d_t: Ratio of central bank's interest bearing liabilities to base money

m_t^x: Monetary disequilibrium

π_t^a: Expected or anticipated domestic inflation

π_t^T: Inflation target

π_t: Domestic rate of inflation

π_t^*: International rate of inflation

ρ_t: Domestic interest rate premium

n_t: Ratio of international reserves to base money

z_t^d: Proportion of the central bank's interest bearing liabilities in domestic currency

z_t^*: Proportion of the central bank's interest bearing liabilities in foreign currency

$\dot{b}_t^D$: Rate of growth of demand for central bank's interest bearing liabilities

$\dot{b}_t^S$: Rate of growth of central bank's interest bearing liabilities

$\dot{f}_t^D$: Rate of growth of central bank demand for international reserves

$\dot{h}_t$: Rate of growth of base money

$\dot{m}_t^D$: Rate of growth of real money demand

$\dot{m}_t^S$: Rate of growth of money stock

$\dot{\phi}$: Rate of change in the base money multiplier

$\dot{x}_t$: Rate of growth of exchange rate under free floating exchange rate regime

$\dot{x}_t^T$: Rate of growth of exchange rate under managed foreign exchange rate regime

$\dot{x}_t^P$: Rate of growth of exchange rate assuming PPP

$\dot{y}_t$: Rate of growth of real income

APPENDIX B

INTERNATIONAL INFLATION FORECAST EQUATION

Dependent Variable: π_t^*

Method: Least Squares

Sample(adjusted): 1953 2003

Included observations: 51 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.010860	0.004267	2.544982	0.0142
π_{t-1}^*	0.966968	0.131355	7.361502	0.0000
π_{t-2}^*	-0.245098	0.131050	-1.870263	0.0676

R-squared	0.643363
Mean dependent var	0.037880
Adjusted R-squared	0.628503
S.D. dependent var	0.029130
S.E. of regression	0.017755
Akaike info criterion	-5.167309

Sum squared resid	0.015131
Schwarz criterion	5.053672
Log likelihood	134.7664
F-statistic	43.29523
Durbin-Watson stat	1.856687
Prob(F-statistic)	0.000000

APPENDIX C

AUTOREGRESSIVE EQUATION FOR RATE OF GROWTH OF EXCHANGE RATE

Dependent Variable: $\dot{x}_t$

Method: Least Squares

Sample(adjusted): 1952 2003

Included observations: 52 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.025236	0.014416	1.750553	0.0863
$\dot{x}_{t-1}$	0.437576	0.081311	5.381524	0.0000
Dummy 80s and 90s shocks	0.566424	0.065430	8.656946	0.0000

R-squared	0.674645
Mean dependent var	0.082077
Adjusted R-squared	0.661365
S.D. dependent var	0.155872
S.E. of regression	0.090706
Akaike info criterion	-1.906428
Sum squared resid	0.403150

Schwarz criterion	-1.793856
Log likelihood	52.56712
F-statistic	50.80226
Durbin-Watson stat	1.825188
Prob(F-statistic)	0.000000

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