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9 November 2010

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Abstract

Interest Rate rules are often estimated as simple reaction functions linking the policy interest rate to variables such as (forecasted) inflation and the output gap; however, the coefficients estimated with this approach are convolutions of structural and preference parameters. I propose an approach to estimate Central Bank preferences starting from the Central Bank's optimization problem within a small open economy. When we consider open economies in a regime of Inflation Targeting, the issue of the role of the exchange rate in the Monetary Policy rule becomes relevant. The empirical analysis is conducted on Sweden, to verify whether the recent stabilization of the Krona/Euro exchange rate was due to "Fear of Floating"; the results show that the exchange rate might not have played a role in monetary policy, suggesting that the stabilization probably occurred as a result of increased economic integration and business cycle convergence.

JEL Classification: E42, E52, F31

Keywords: Interest Rate Rules, Inflation Targeting, Central Bank Preferences, Fear of Floating.

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I thank Riccardo Rovelli, Roberto Golinelli and participants at the III Italian Doctoral Conference in Turin and seminars at the University of Bologna for useful suggestions and comments.

1. Introduction

Interest rate rules are often estimated as simple reaction functions à la Taylor [1993] rule linking the policy interest rate to variables such as future expected inflation and the output gap. However, it has been shown by Svennson [1997] that the coefficients estimated with this approach are convolutions of structural and preference parameters and thus are subject to the Lucas [1976] critique. Extending the work of Favero and Rovelli [2003], I propose an approach to estimate Central Bank preferences starting from the Central Bank's optimization problem within a small open economy. When we consider open economies that are in a regime of Inflation Targeting, the issue of the role of the exchange rate in the Monetary Policy rule becomes relevant. In particular, it is still widely debated whether Inflation Targeting Central Banks should, or do, limit exchange rate flexibility.

During the last decade, a large body of empirical literature has investigated the tendency of Central Banks to adopt *de facto* policies which are in conflict with the official statements, in particular with respect to the exchange rate regime. While, on one hand, there has been a tendency to move towards flexible exchange rates[1], on the other hand it has been shown[2] that the same countries still engage in active exchange rate management. The literature on the so-called "Fear of Floating" has documented on the countries of interest, in particular, lower nominal exchange rate volatility, and higher foreign exchange reserves volatility with respect to some benchmark floater.

Out of the 27 member states of the EU, only 16 have adopted the euro; six have floating exchange rates and an Inflation Targeting regime, while the remaining ones adopted some sort of exchange rate arrangement vis-à-vis the euro. Nevertheless, the bilateral exchange rates of inflation targeters with the euro have remained quite stable over the last decade, and this has raised the question of whether they have been – whether voluntarily or not – following the ECB policy with the aim of stabilizing the exchange rate[3].

When the country of interest has adopted an Inflation Targeting regime, the results obtained using exchange rate regime classification techniques might be misleading. Exchange rate smoothing can come as a side product when the Central Bank targets CPI inflation, and this

1 See Reinhard and Rogoff [2001].

2 See, for example, Calvo and Reinhard [2002], Levy-Yeyati and Sturzenegger [2003], [2005] and [2007], Frankel and Wei [2008].

3 See Van Dijk et al. [2005] and Reade and Volz [2009].

will depend on the degree of exchange rate pass-through and the share of imported final goods. As it was stated by Clarida [2001], "*in practice, a monetary policy aimed at achieving only domestic objectives may also serve to stabilize the exchange rate,* […] *and thus be difficult to distinguish from a policy of maintaining the exchange rate within a band*". In other words, an observational equivalence between Inflation Targeting and Managed Floating regimes arises that makes it hard to correctly classify them.

Moreover, exchange rate stabilization can come as the result of increased economic integration and business cycle synchronization, as suggested by the theory of endogenous optimum currency areas (see Frankel and Rose [1998]).

The objective of this paper is therefore threefold. First of all, it aims at bridging the gap between the literature on exchange rate regime classification and that on monetary policy rules estimation. This, as it was stated above, is done by suggesting an approach for the estimation of Monetary Policy Rules and the identification of Central Bank preferences in a small open economy that builds on previous work by Favero and Rovelli [2003] and Collins and Siklos [2004]. Rather than limiting ourselves to the estimation of Taylor rules, we take the Lucas [1976] critique seriously by identifying separately the parameters describing the structure of the economy and those describing Central Bank preferences, explicitly considering exchange rate smoothing or "Fear of Floating" as one possible regime. The second objective is to show, through a simple and stylized theoretical model, how the speed at which the real exchange rate converges to the PPP can influence its role in the monetary policy rule, an aspect which has not been considered in the literature on monetary policy rules estimation, even when the exchange rate is included as a regressor. Third, by using real-time data, we explicitly address the critique by Orphanides [2001] and Molodsova et al. [2008] who suggested that estimation of policy rules should be run on real time rather than revised data.

The subject of the empirical analysis is Sweden. While, officially, it has been on an Inflation Targeting regime since 1995, Sweden exhibited - at least until the economic and financial crisis that started at the end of 2008, which put small currencies through a lot of stress – a remarkable stability of the bilateral exchange rate of its currency, the Krona, with the Euro.

For these reasons, it is an obvious candidate to study how to discern between "honest" Inflation Targeting which has exchange rate stabilization as a side product, and "Fear of Floating".

The structure of the paper is the following. Section 2 describes the position of Sweden with respect to the Euro as well as some stylized facts on the Swedish and Euro Area economy during the last 15 years. Section 3 presents a brief review of the related literature. Section 4 describes Inflation Targeting as a monetary policy rule, as it has been designed by the economic literature (in particular Svensson [1996]) and the Central Banks' statements during the years. Section 5 introduces a simple model for the derivation of interest rate rules in an open economy. In Section 6, a parsimonious structural model of the Swedish economy is estimated, which is the empirical counterpart of the theoretical model in section 5. In Section 7 we estimate Central Bank preferences corresponding to alternative monetary policy rules, to see which one fits best the behaviour of the Swedish Riksbank. Section 8 concludes.

2. Sweden and the Euro

After the collapse of the Exchange Rate Mechanism at the end of 1992, Sweden entered a floating exchange rate regime and then formally adopted Inflation Targeting in January 1995.

The introduction of the euro in 1999 created a huge debate in Sweden, concerning the adoption of the common currency; the Government decided that the country would not be part of the leading group of the Monetary Union, because of both political and economic considerations. The political considerations mainly dealt with the fact that Sweden had joined the EU only a few years earlier (in 1995) and the population was supposed not to be “ready” to give up their national currency yet. The economic considerations were the result of the report of the Calmfors Commission, which had been appointed by the Government to evaluate the costs and benefits of joining the Monetary Union for Sweden. In the end, the government decided that a national referendum had to be held in order to let the people decide on the adoption of the euro.

In September 2003 the referendum was held, where the majority of voters (56%) rejected the proposal of joining the EMU, and since then it has not been clear what Sweden is going to do with the euro. In theory, it has to join the Monetary Union sooner or later. In fact, the Maastricht Treaty only considers the opt-out possibility for Denmark and the United Kingdom, while other countries and new member states have to join the EMU as soon as they fulfill the convergence criteria of the Treaty. Out of the five criteria, in the last few years Sweden has fulfilled four, and manages to stay out by not joining ERM II[4].

[4] The Maastricht Treaty requires that a country that wants to join the EMU has been a member of ERMII without realignments of the central parity of the last two years.

The economic and stock markets crisis that has hit the world since the last quarter of 2008 did not leave Sweden untouched. As in all advanced economies, production, inflation and interest rates have been falling; the krona experienced a large depreciation, as most of the other small currencies, against the euro, and the debate on joining the Monetary Union came back to relevance.

In particular, one might ask to which extent the conduct of monetary policy in european countries that have not adopted the euro is constrained or influenced by shocks originating in the EMU, with which they are highly integrated, and whether they are actually setting their monetary policy in step with the ECB, regardless of official policy statements, i.e. whether there is some evidence of "Fear of Floating" (Calvo and Reinhard [2002]).

By looking at the graph of the exchange rate of the Swedish Krona *vis à vis* the Euro, one can notice that the latter has remained very stable since the adoption of inflation targeting in Sweden in 1995, and even more so between january 2002 and september 2008, that is, after the euro banknotes and coins were finally introduced[5]: the bilateral exchange rate remained within a band of ± 2.50% around a mean of 9.22 krona per euro (See Figure 1).

It is also interesting to observe the evolution of the variables describing the Swedish and EMU business cycles, namely inflation, output and interest rates. Figures 2-4 show that, since the introduction of flexible exchange rates in 1993, the CPI inflation, output gap, and policy interest rates in Sweden and the EMU tended to move quite closely together. This is clear also from Table 2.1, which reports some correlations on the same variables and also shows how exchange rate volatility has decreased in the last part of the period, while the other correlations have remained quite stable.

The natural question that arises is therefore the following: what was the source of the stabilization of the SEK/Euro exchange rate?

[5] During the last quarter of 2008 the bilateral exchange rate experienced a large increase in volatility, and the Krona suffered a depreciation of over 15%. The last months of 2008 were characterized by a sharp depreciation of minor currencies, and this was aknowledged also by the Riksbank in its Monetary Policy report of October 23rd 2008: "*The krona has weakened agains almost all of the largest currencies since September. It is unclear exactly what this weakening is due to, but in times of great anxiety, small countries' currencies are usually regarded as uncertain and they weaken. The krona weakened, for instance, after the crises in 1997-98 and* (…) *in September 2001. This is clear, for instance, from the krona's position against the euro* (…). *The weakening of the trade-weighted krona , which is largely assumed to be due to the current crisis, is expected to persist for the remainder of the year(...). After that, the krona will return to more normal levels.* (…) *A weakening of the exchange rate usually has a positive effect on exports in Sweden*". The Riksbank's report highlights two elements: first, the krona is expected to appreciate when the crisis is over; second, the Riksbank is not going to intervene to defend the currency: in a situation of falling inflation and falling output, a depreciation of the currency is nothing but good in order to go over the crisis.

Table 2.1. The business cycle in Sweden and the EMU, 1993-2008

	1993.01-1994.12	1995.01-1998.12	1999.01-2001.12	2002.01-2008.12
Output gaps correlation	0.69	0.84	0.81	0.88
Inflation rates correlation	-0.71	0.71	0.79	0.70
Policy rates correlation	0.94	0.82	0.87	0.84
Index of exchange rate stability[6]	0.667	0.865	0.945	0.996

Has the Riksbank actually been limiting the SEK/Euro exchange rate flexibility, despite its official claims of being an inflation targeter, or is such an exchange rate stabilization endogenous, i.e. the result of an increasing convergence of EMU and Swedish business cycles, so that "*faced with similar data, the Riksbank and ECB tend to synchronize their interest rate decisions: this helps explaining why the exchange rate has been so stable*"[7]?

Apart from alternative exchange rate regimes and arrangements, we can identify four possible sources of exchange rate stabilization: two are voluntary and two involuntary. Exchange rate volatility can be reduced through direct intervention using foreign exchange reserves or credit lines; otherwise, the central bank can stabilize the exchange rate through the policy interest rate, changing it in step with the anchor country (an example in this sense is Denmark).

Alternatively, exchange rate stabilization can be the result of a synchronization of monetary policy interventions that is due to the convergence of business cycles, as suggested by Giavazzi and Mishkin [2005] for the case of Sweden. Finally, Reade and Volz [2009] suggest that Sweden might be unable to run a monetary policy that is independent from that of the EMU. The authors investigated this issue by looking at interbank interest rates in a Cointegrated VAR framework and concluded that the two interest rates are cointegrated with only the Swedish rate adjusting, and this indicates that the Riksbank is, "*de facto, not a master in its house*"[8]. In other words, since the two Central Banks behave similarly, it should not be costly for Sweden to give up its monetary policy independence.

6 Stability of the exchange rate is defined here as the probability that the percentage change, in absolute value, of the exchange rate within a given month is lower than 2.25%. The probability is calculated using observed monthly exchange rate changes over a two-year rolling window (see also Calvo and Reinhart [2002]).

7 F. Giavazzi, F. Mishkin, (2007) p. 54.

8 Reade and Volz (2009), p. 26.

Figure 1. SEK-euro Exchange Rate

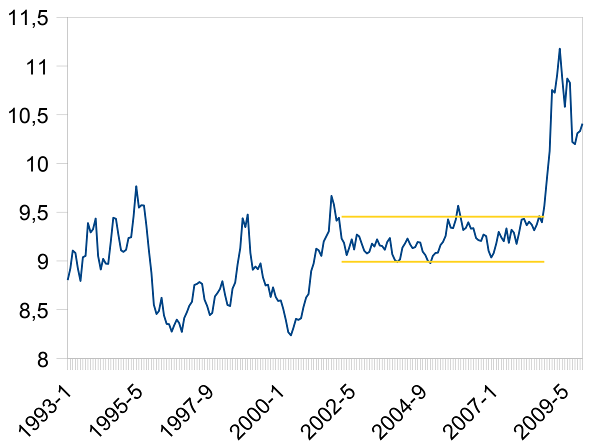


Figure 2. The Output Gap

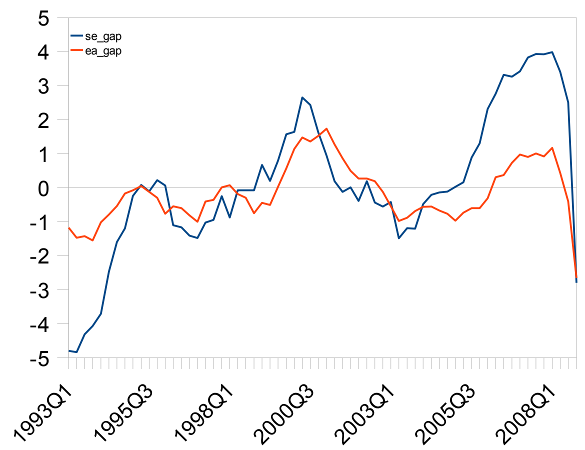


Figure 3. Policy Interest Rates

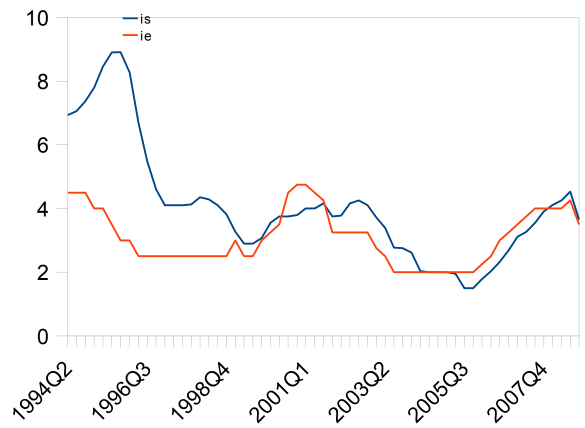
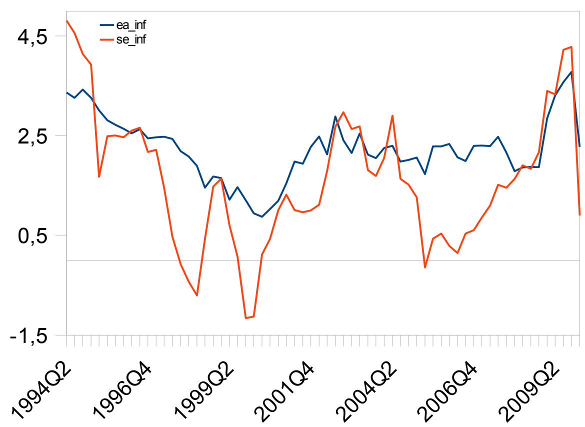


Figure 4. Inflation Rates



3. Review of related literature

Since the seminal paper by Taylor [1993], which introduced the use of simple interest rate rules for the analysis of monetary policy, a lot of theoretical and empirical research has been developed on the issue. According to the "Taylor Rule", in each period the Central Bank sets the interest rate to respond to deviations of inflation from a pre-specified target (in his paper, 2%) and of output growth from the long-run growth rate of output.

The original interest rate rule by Taylor has been modified in later empirical and theoretical works. In particular, it has been noticed (see, for example, Clarida et al. [1998]) that Central Banks respond to *forecasts* of inflation rather than current inflation, due to time lags in the effectiveness of monetary policy. Moreover, interest rates show a high degree of persistence, and the fit of estimated interest rate rules can be improved a lot by augmenting the Taylor Rule with the lagged policy rate. In this sense, the observed interest rate can be interpreted as a weighted average of the target rate and the rate in the previous period; this behaviour has been termed *interest rate smoothing* and the theoretical justification would be that Central Banks change their policy rates gradually in order to avoid generating excessive macroeconomic volatility. However, the role of the lagged interest rate in the monetary policy rule has been challenged in several works (see Rudebusch [2002], English [2003], Castelnuovo [2007]), suggesting that the persistence of the policy rate might be due to serially correlated errors rather than optimal partial adjustment. Recently, Consolo and Favero [2009] have shown that the observed inertia in monetary policy, resulting in very high (generally between 0.8 and 0.9) coefficients on the lagged policy rate, might be the consequence of a weak instrument problem in the GMM estimations performed.

The empirical literature has generally estimated monetary policy reaction functions (in the form of forward-looking Taylor [1993] rules) using a GMM approach[9] (see, for example, Clarida et al. [1998] and [2000]); however, as it was pointed out in Favero and Rovelli [2003], since Euler equations are the natural object of the GMM approach, it would be more natural to use first order conditions, derived from the Central Bank's optimization problem, to estimate the policy rule. Favero and Rovelli [2003] apply this approach for the estimation of Central Bank preferences to the U.S. A similar attempt was done by Collins and Siklos [2004] who

[9] To be precise, the GMM approach is used when official forecasts for the inflation rate are not available, and therefore least squares estimation of a forward-looking Taylor Rule setting $E_t \pi_{t+k} = \pi_{t+k}$ would result in an endogenous error term. When the Central Bank's inflation forecasts are available, however, nonlinear least squares are suited for the estimation of a forward-looking Taylor Rule with interest rate smoothing (see Castelnuovo [2007] and De Aurelio [2005]).

estimate Central Bank preferences for Australia, New Zealand and Canada. However, their approach suffers from several limitations: first, their empirical analysis heavily relies on HP filters; second, they solve an infinite-horizon optimization problem which, although more realistic than the finite-horizon approach we adopt in sections 5 and 7, yields results which are less comparable to previous works that estimated simple interest rate rules. We believe that the finite-time approach adopted here is not an excessive simplification; moreover, it allows us to derive an analytical solution to the Central Bank's optimization problem which would not be possible otherwise.

An issue which is not solved is related to the role of the exchange rate in the monetary policy rule of inflation targeting Central Banks. According to Svensson [2003] there are no good reasons for separate – real or nominal – exchange rate objectives, under flexible inflation targeting, at least for advanced economies, while exchange rate smoothing would be more motivated for developing countries, which typically have foreign currency-denominated debt as well as other financial stability-related problems. At the same time, Svensson [1997] states that exchange rate targeting, as well as money growth targeting, would be better than inflation forecast targeting as a means to curb inflation only in the case they are sufficient statistics for future inflation; if they are not, as it generally happens, then exchange rate and money growth targeting lead to worse outcomes[10] with respect to inflation forecast targeting.

The most widespread view in the literature is that the (real) exchange rate, therefore, would indeed play a role in the monetary policy rule when the central bank targets CPI inflation, but only indirectly, since it is a predictor of future inflation and it also affects the output gap; domestic inflation targeting presents worse outcomes in terms of output stabilization (see, for example, Gali and Monacelli [2005] and Svensson [2000]). Moreover, Taylor [2003] and Edwards [2006] discuss that if Central Banks responded directly to exchange rate changes by changing the policy interest rate, this would result in excessive interest rate volatility, which is not observed in practice. The model outlined in Section 5 will be on the same line, suggesting that, indeed, relatively high interest rate variability might be evidence of "fear of floating", in line with what suggested, in a different framework, by Levy-Yeyati and Sturzenegger [2005].

A country that is officially on a flexible exchange rate regime but actively intervenes to reduce the volatility of the exchange rate is said to have *Fear of Floating* (see Calvo and Reinhart [2002]). A large body of literature has recently introduced measures of exchange rate

[10] In particular, higher inflation and output variability.

flexibility[11], but only one paper, namely Ball and Reyes [2008], has focused on the challenges for exchange rate classification schemes when they are applied to IT countries. However, Ball and Reyes [2008] presents two main limits in the analysis of inflation targeting regimes: on the theoretical side, they only compare simple instrument rules rather than deriving the policy function from an optimizing behaviour of the Central Bank; this limited approach influences their empirical analysis, since they only focus on how the real interest rate responds differently to current and lagged inflation and changes in exchange rate under different official regimes, rather than estimating a policy rule.

4. Inflation Targeting as a Monetary Policy Regime

Inflation Targeting (henceforth IT) is defined as a monetary policy regime characterized by: (i) an explicit inflation target (normally around 2%, with the possibility of some tolerance bands around the target); (ii) a framework for policy decisions called *inflation-forecast targeting*, which uses an inflation forecast produced by the Central Bank, and made public, as an intermediate target for Monetary Policy; and finally, (iii) a high degree of transparency and accountability (see Svensson [1996]). Starting from the end of the 1980s, an increasing number of countries[12], generally small open economies, have adopted IT as the official monetary policy regime.

Adopting IT does not rule out the possibility that additional objectives, other than inflation stabilization, be pursued by the Central Bank, as long as these do not jeopardize the achievement of the inflation target. The presence of such additional objectives – for example, output stabilization and interest rate smoothing – allows us to distinguish between *strict* and *flexible* IT.

Official statements by the main IT Central Banks make it natural to regard IT, using Svensson's [2003] words, as a *targeting rule.* The Monetary Policy objective of the Bank of England is to

> “ [...] deliver price stability – low inflation – and, subject to that, to support the Government’s economic objectives including those for growth and employment. Price stability is defined by the Government’s inflation target of 2%. […] The Monetary Policy Committee’s aim is to set interest rates so that inflation can be brought

11 Calvo and Reinhart [2002], Reinhart and Rogoff [2004], Levy-Yeyati and Sturzenegger [2003] and [2005], Frankel and Wei [2008], just to name a few. In D'Adamo [2009] I have reviewed them and compared the results of such different approaches for a sample of 18 European Countries and other advanced economies.

12 To name a few, the United Kingdom, Canada, New Zealand, Australia, Sweden, Poland, the Czech Republic, Israel.

back to target within a reasonable time period without creating undue instability in the economy."

Similarly, in Australia, which adopted inflation targeting in 1993, the Statement of Conduct of Monetary Policy established that

> "monetary policy's principal medium-term objective is to control inflation. [...] The appropriate target for monetary policy is to achieve an inflation rate of 2-3 per cent on average, over the cycle [...]. The inflation target is defined as a medium-term average rather than as a hard-edged target band within which inflation is to be held at all times. This formulation allows for the inevitable uncertainties that are involved in forecasting, and lags in the effects of monetary policy on the economy. [...] The inflation target is, necessarily, forward-looking, as evidenced by the operation of monetary policy since its introduction. This approach allows a role for monetary policy in dampening the fluctuations in output over the course of the business cycle."

Finally, the Swedish Riksbank, which is at the center of the present analysis[13], has stated that

> "The Riksbank has specified an explicit inflation target whereby the annual change in the Consumer Price Index (CPI) is to be 2 per cent with a tolerance interval of plus/minus 1 per cent. Monetary Policy is also guided by various measures of "underlying inflation". There is no single measure of inflation that consistently indicates the appropriate stance of monetary policy. Monetary policy acts with a lag and is normally focused on achieving the inflation target within a two-year period. The two-year time horizon also provides scope for taking fluctuations in the real economy into consideration. The Riksbank routinely takes into consideration changes in asset prices and other variables […]."[14]

As it was outlined by Svensson [2003], instrument rules like the Taylor [1993] rule are not appropriate to describe monetary policy for three main reasons: first, they are overly simple and mechanic, and therefore deny the necessary flexibility; second, they do not consider the fact that in reality, when setting the interest rate, central banks make use of a lot more information than just the inflation rate and the output gap; finally, the parameters of instrument rules estimated using for example the approach in Clarida et al. [1998] are not structural, in the sense that they are convolutions of structural and preference parameters, and estimation of a simple instrument rule would leave such parameters unidentified (see Favero and Rovelli [2003]).

For the reasons outlined so far, in order to compare the policy rules coming from alternative monetary policy frameworks, we will proceed to derive optimal monetary policy reaction

[13] The inflation target was formulated in January 1993, when the transition to the new monetary regime – after the collapse of ERM – began. However, it formally began to apply in January 1995 (see Giavazzi and Mishkin [2007]).

[14] Sveriges Riksbank, "*Monetary Policy in Sweden 2008*", p. 5

functions using the approach introduced by Svensson [1997, 1999, 2000 and 2003] and also applied in Favero and Rovelli [2003] and extend it to the open economy, with a focus on fear of floating as an alternative to "honest" Inflation Targeting.

Svensson [1997] has shown how the optimal policy reaction function can be derived for both strict and flexible Inflation Targeting in a closed economy[15]. Let us consider a very simple (backward-looking) model for a closed economy which is described by the following equations:

$$\pi_{t+1} = \pi_t + \alpha_y y_t + \epsilon_{t+1} \tag{4.1}$$

$$y_{t+1} = \beta_y y_t - \beta_r (i_t - \pi_t - r) + \eta_{t+1} \tag{4.2}$$

equation (4.1) is an accelerationist Phillips curve, where the change in inflation is increasing in lagged output[16]. Equation (4.2) is an aggregate demand curve, where the output gap y is increasing in last period's output gap, and decreasing in the (ex-post) real interest rate. ε and η are zero-mean i.i.d. shocks (which can be labelled respectively as a cost-push shock and a demand shock) that are not observable at the beginning of the period. Equations (4.1) and (4.2) are the same as in Svensson [1997] and [1999] , and are quite standard in the literature. These functions are in general derived from optimization of consumers and firms in New Keynesian macro models with imperfect competition and sticky prices[17].

The policy interest rate affects output with a one-period lag, and inflation with a two-period lag; in fact:

$$\pi_{t+1} = \pi_t + \alpha_y (\beta_y y_{t-1} - \beta_r (i_{t-1} - \pi_{t-1} - r) + \eta_t) + \epsilon_{t+1} \tag{4.3}$$

Let us assume that the inflation target is π, and the objective of the central bank is to choose a sequence of policy rates i to minimize the loss function:

$$\sum_{i=0}^{\infty} \delta^i L_{t+i|t} \tag{4.4}$$

where L is the period loss and , under strict inflation targeting, it is given by:

$$L_t = \frac{1}{2} \left[(\pi_t - \pi)^2 \right] \tag{4.5}$$

in other words, the central bank chooses the policy interest rate in order to minimize the expected deviation of inflation from target. Since inflation stabilization is the only goal of

15 The rest of the section draws on Svensson [1997], § 2 and 6.

16 Svensson [1997] also includes a vector of exogenous variables, but we disregard that here for simplicity.

17 See, for example, Clarida, Gali and Gertler [1999].

monetary policy in this context, and the policy rate influences inflation only with two lags, the objective function can be written as:

$$\min_{i_t} \delta^2 \frac{1}{2}[(\pi_{t+2|t} - \pi)] \tag{4.6}$$

The FOC is given by setting the derivative of (4.6) with respect to i_t equal to zero:

$$\frac{\partial \delta^2 L_{t+2|t}}{\partial i_t} = \left[- \delta^2 \alpha_x \beta_r \left(\pi_{t+2|t} - \pi \right) \right] = 0$$

$$\pi_{t+2|t} = \pi \tag{4.7}$$

The policy rate has to be set so that the two-period-ahead inflation forecast is equal to the target. To find an explicit formula for the interest rate, rewrite (4.3) in t+2 and substitute the terms in t+1 with the respective equation (4.1) or (4.2):

$$\pi_{t+2} = \pi_t + \alpha_y y_t + \epsilon_{t+1} + \alpha_y (\beta_y y_t - \beta_r (i_t - \pi_t - r) + \eta_{t+1}) + \epsilon_{t+2}$$

$$\pi = \pi_{t+2|t} = (1 + \alpha_y \beta_r) \pi_t + \alpha_y (1 + \beta_y) y_t - \alpha_y \beta_r i_t + \alpha_y \beta_r r$$

from which we obtain an expression for the repo rate:

$$i_t = r + \pi_t + \frac{1}{\alpha_y \beta_r} (\pi_t - \pi) + \frac{1 + \beta_y}{\beta_r} y_t \tag{4.8}$$

This is very similar to the Taylor rule, except that the coefficients of the Taylor rule are here explicitated as convolutions of the structural parameters from the AD and Phillips curves. Moreover, we notice that even if the central bank is pursuing strict inflation targeting, the output gap will appear in the policy rule: not because it is one of the targets of monetary policy, but because it is a predictor of future inflation.

Let us now move to the more complex case of flexible inflation targeting. In this case, the period loss function (4.5) becomes:

$$L_t = \frac{1}{2} \left[(\pi_t - \pi)^2 + \lambda y_t^2 \right] \tag{4.9}$$

where λ is the weight attached on output stabilization relative to inflation. For the sake of brevity, we only report the results shown in Svensson [1997], where the equations describing the economy are the same as (4.1), (4.2) and (4.9). The FOC is:

$$\pi_{t+2|t} - \pi = - \frac{\lambda}{\delta \alpha_y k} y_{t+1|t}$$

where k is a function of λ, δ and α_π ; this FOC tells us that the inflation forecast should equal the inflation target only if the expected output gap is zero; expected inflation shall be higher than the target if output is expected to be below the natural rate. The reaction function

(Svensson [1997], p. 1133) is:

$$i_t = r + \pi_t + \frac{\delta \alpha_y k}{\beta_r (\lambda + \delta \alpha_y^2 k)} (\pi_t - \pi) + \frac{1}{\beta_r} \left(\frac{\delta \alpha_y^2 k}{(\lambda + \delta \alpha_y^2 k)} + \beta_y \right) y_t \tag{4.10}$$

The adjustment to the inflation target will be gradual, and it will be slower the higher the weight on output stabilization. This is due to the fact that the more rapid the adjustment to the target, the higher the fluctuations in output this will cause and, as long as the central bank cares for output stabilization, it will avoid excessive interest rate variability.

5. Derivation of interest rate rules in an Open Economy

The objective of this section is to move from the closed to the open economy case and, within this framework, to show how the Central Bank's optimal reaction function changes when the policy objectives change, within different Monetary Policy frameworks.

More precisely, we want to find alternative interest rate rules that are suitable for estimation, in order to find which one characterizes best the behaviour of the Sveriges Riksbank. The empirical literature has generally estimated monetary policy reaction functions (in the form of forward-looking Taylor [1993] rules) using a GMM approach[18] (see, for example, Clarida et al. [1998] and [2000]); however, as it was pointed out in Favero and Rovelli [2003], since Euler equations are the natural object of the GMM approach, it would be more natural to use first order conditions, derived from the Central Bank's optimization, to estimate the policy rule.

The model outlined in Section 4, when we consider a small open economy, becomes somehow more complex: we need to augment the aggregate supply and demand relations to take care of the effect of the external sector. Let us assume that the aggregate demand in a small open economy is given by:

$$y_{t+1} = \beta_y y_t - \beta_r (i_t - \pi_t - r) + \beta_q q_t + \nu_{t+1} \tag{5.1}$$

where q is the deviation of the real exchange rate, defined as domestic output per unit of foreign output, from PPP, so that when $q = 0$ the PPP holds and when q increases we have a real depreciation; therefore, the coefficient β_q is positive. For simplicity, unlike Svensson

[18] To be precise, the GMM approach is used when official forecasts for the inflation rate are not available, and therefore least squares estimation of a forward-looking Taylor Rule setting $E_t \pi_{t+k} = \pi_{t+k}$ would result in an endogenous error term. When the Central Bank's inflation forecasts are available, however, (nonlinear) least squares are suited for the estimation of a forward-looking Taylor Rule with interest rate smoothing (see Castelnuovo [2007] and De Aurelio [2005]).

[2000], we have assumed that the foreign output gap does not influence the domestic business cycle. Finally, ν_{t+1} is a zero-mean i.i.d. demand shock.

The Phillips curve is given by:

$$\pi_{t+1}=\pi_t+\alpha_y y_t+\alpha_q q_t+\xi_{t+1} \qquad (5.2)$$

where $\alpha_q > 0$; a depreciation of the exchange rate has both a direct inflationary effect, since imported goods become more expensive, and an indirect effect through resource utilization which kicks with a two-period lag. Ξ_{t+1} is a zero-mean i.i.d. cost-push shock, similar to ε defined in (4.1).

Since we are dealing with an open economy, with respect to the previous section we have to define an equilibrium relation for the exchange rate. For a small open economy, with free capital mobility, uncovered interest parity should hold. We can write it for the nominal exchange rate as:

$$e_t=i_t^f-i_t+e_{t+1|t}+\phi_t \qquad (5.3)$$ [19]

where φ is a stationary i.i.d. disturbance which we will label the risk premium. The exchange rate tends to be higher (i.e. weaker) when it is expected to increase in the next period and when foreign interest rates are higher than domestic interest rates. Notice that the real exchange rate is defined as:

$$Q_t=e_t+p_t^f-p_t$$

When the PPP holds, $Q_t = 1$, and thus the deviation from PPP is $q_t = Q_t - 1$. Plugging this in the UIP (5.3) above, we can rewrite it as:

$$q_t=q_{t+1|t}-i_t+i_t^f-\pi_t^f+\pi_t-\phi_t \qquad (5.4)$$

which is the real interest parity, expressed in deviation from PPP.

Finally, we make an assumption on the evolution of the real exchange rate. When PPP holds, Q_t is stationary and therefore shocks to this variable do not have permanent effects. More generally, we can assume that q_t gradually adjusts to the PPP, i.e. it gradually goes to zero, according to the following rule:

$$\Delta q_t=-\gamma q_{t-1}+\omega_t$$

[19] Notice that here we do not model the dynamics of foreign country variables, i.e. we do not specify a rule for the foreign interest rate. This, for example, implies that we disregard the impact of foreign monetary policy on foreign inflation. This choice is due to the need of keeping things simple so that we can analytically find the interest rate reaction functions, but the drawback is that it rules out one channel for the transmission of international shocks. This is evident in the Central Bank of Denmark's statement of Monetary Policy: "*The main objective of the monetary policy in the euro area is to maintain price stability, i.e. to avoid inflation. By keeping the krone stable vis-à-vis the euro, a basis for low inflation is also created in Denmark.*" (see Danmarks Nationalbank's *Introduction to Monetary and Foreign Exchange Policy*).

or, equivalently,

$$q_t = (1-\gamma) q_{t-1} + \omega_t \tag{5.5}$$

which is a simple error correction mechanism suggesting that, *ceteris paribus*, in each period Q_t converges to PPP (i.e. to its long-run constant value of 1) by γ, where $0 < \gamma < 1$ is called the adjustment coefficient. ω_t is a zero-mean i.i.d. disturbance, representing temporary shocks affecting the exchange rate that disturb its convergence to the long-run equilibrium.

The targeting rules analysis will be applied to four alternative scenarios: (i) exchange rate targeting; (ii) strict inflation targeting, (iii) flexible inflation targeting and (iv) "fear of floating", that in this case describes a country that is pursuing inflation targeting with some weight on exchange rate stabilization (here we do not care whether such exchange rate smoothing happens only de facto or also in official terms).

5.1. Exchange Rate Targeting

The simplest case is that of pure exchange rate targeting. We can describe exchange rate targeting in our framework as the central bank choosing the interest rate path that minimizes the loss function:

$$\min_{i_t} E_t \sum_{\tau=0}^{\infty} \delta^{\tau} L_{t+\tau}$$

where L is the period loss function, which in this case is:

$$L_t = \frac{1}{2} (e_t - \bar{e})^2 \tag{5.6}$$

subject to (5.4): we assume that the central bank manages to keep the exchange rate at the announced target and, at the same time, imposes no capital controls[20] and therefore the UIP holds, up to a stationary risk premium. We can show that the monetary policy strategy is very straightforward and intuitive in this case. Since exchange rate stabilization is the only objective of monetary policy, and the central bank influences the exchange rate immediately by changing the interest rate, while current policy decisions do not affect future values of the exchange rate (because $e_{t+1|t}$ is equal to the exchange rate target) , the first order condition is:

$$\frac{\partial L_t}{\partial i_t} = -(e_t - \bar{e}) = 0 \quad \Rightarrow \quad e_t = \bar{e}$$

i.e. in each period, the interest rate has to be set so that the exchange rate stays at the official

[20] This is the framework that characterizes, for example, ERM II in Europe.

target. Therefore, since the exchange rate is fixed, the expected rate of depreciation is zero and, from (5.1), the policy rule is simply:

$$i_t = i_t^f + \phi_t$$

i.e. the domestic repo rate has to be always equal to the foreign rate (plus the risk premium). This kind of rule currently characterizes, for example, the monetary policy of Danmarks Nationalbank:

> "The monetary policy is designed to keep the krone stable vis-à-vis the euro, and other aspects than the exchange rate […] are not considered in relation to monetary policy.[...] Danmarks Nationalbank can influence the krone rate by changing its monetary policy interest rates. When the exchange-rate market is stable, DNB normally changes its interest rates in step with the changes of the European Central Bank's minimum bid rate […]. In a situation with upward or downward pressure on the krone or a sustained inflow or outflow of foreign currency, DNB indipendently changes its interest rates in order to stabilize the krone." [21]

5.2 Strict inflation targeting

When the Central Bank pursues *strict* inflation targeting, its objective is to reach the target within a pre-specified period, generally 1-2 years. Assume that *t* in our model is equal to 3 quarters as in Svensson [2000]. We know from equations (5.1)-(5.4) that, when it changes the interest rate at time *t*, the Central Bank immediately affects *q*; in *t*+1 it affects the output gap via the direct interest rate channel and the real exchange rate channel, and inflation via the exchange rate pass through (measured by α_q). In *t*+2, the interest rate intervention affects inflation via the output gap. When the central bank is pursuing strict inflation targeting, we can write the objective function as:

$$\min_{i_t} \sum_{j=0}^{\infty} \delta^j \frac{1}{2} \left(\pi_{t+j|t} - \pi \right)^2 \qquad (5.7)$$

In order to keep things simple and obtain an analytical solution for all alternative regimes, we will assume, as in Svennson [1999], that the Central Bank adopts a period-by-period optimization: the monetary authority takes last year's policy decision as given, but disregards the fact that today's instrument setting will affect next year's loss function. While this simplification is not free from drawbacks, it allows us to understand how alternative objective functions translate into different interest rate rules[22].

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21 Danmarks Nationalbank (2003), *Monetary Policy in Denmark*, p. 22-24.

22 The approach of "period-by-period optimization" is drawn from Svensson [1999] who applies it to interest rate smoothing. When the lagged interest rate enters the loss function, as he argues, the standard linear-quadratic optimal control problem requires a numerical solution since the number of state variables goes up to three; for the same reason, we will use this approach also for the anaysis of the other regimes.

Moreover, if we want to describe the behaviour of a real IT central bank such as the Swedish Riksbank, this hypothesis is not overly restrictive: it is compatible, for example, with the Swedish Riksbank's policy statement that monetary policy is "normally focused on achieving the inflation target within two years".

In sum, in this case the objective function simplifies to:

$$\min_{i_t} \delta^2 \frac{1}{2}\left(\pi_{t+2|t}-\pi\right)^2$$

Since the target has to be reached within 2 years, and the Central Bank influences inflation via the repo rate, today's setting of the interest rate is such that, given the Central Bank's models to forecast the inflation rate, constant-interest-rate two-years-ahead expected inflation is equal to the target, i.e. $\pi_{t+2|t}=\pi$. The FOC with respect to i_t is simply:

$$\frac{\partial L}{\partial i_t}=(\pi_{t+2|t}-\pi)\frac{\partial \pi_{t+2|t}}{\partial i_t}=0$$

$$(\pi_{t+2|t}-\pi)(-\alpha_q(1-\gamma)-\alpha_x\beta_q-\alpha_x\beta_r)=0$$

which becomes:

$$\pi_{t+2|t}=\pi \tag{5.8}$$

Rewrite the AS curve in t+2 and after substituting we have:

$$\pi_{t+2|t}=\pi_t+\alpha_y(1+\beta_y)y_t+\left(\alpha_q+\alpha_y\beta_q\right)q_t-\alpha_y\beta_r(i_t-\pi_t-r)+\alpha_q q_{t+1|t} \tag{5.9}$$

Consider again equation (5.9) and plug (5.5) in it:

$$\pi_{t+2|t}=\pi_t+\alpha_y(1+\beta_y)y_t+\left(\alpha_q+\alpha_y\beta_q\right)q_t-\alpha_y\beta_r(i_t-\pi_t-r)+\alpha_q\left(1-\gamma\right)q_t$$

Merging this with FOC (5.8) and rearranging, we obtain the interest rate rule when the central bank pursues strict inflation targeting:

$$i_t=\pi_t+r+\frac{1}{\alpha_y\beta_r}\left(\pi_t-\pi\right)+\frac{1+\beta_y}{\beta_r}y_t+\frac{\alpha_q(2-\gamma)+\alpha_y\beta_q}{\alpha_y\beta_r}q_t$$

The peculiarity of this interest rate rule is that, due to the real interest parity (5.4), q_t will automatically respond to interest rate movements; in order to avoid the problem of endogeneity of q_t due to its contemporaneity with i_t, we substitute q_t with (5.5)[23]:

$$i_t=\pi_t+r+\frac{1}{\alpha_y\beta_r}\left(\pi_t-\pi\right)+\frac{1+\beta_y}{\beta_r}y_t+\frac{\alpha_q(2-\gamma)+\alpha_y\beta_q}{\alpha_y\beta_r}(1-\gamma)q_{t-1} \tag{5.10}$$

Equation (5.10) is the policy rule in strict IT: the interest rate is raised when inflation is above

[23] This is equivalent to saying that the central bank responds with a lag to shocks to the exchange rate, and knowing the adjustment mechanism of the real exchange rate it assumes that, over the current period, the deviation of the real exchange rate from PPP will be $(1-\gamma)$ times that of the previous period.

target but, although the actual monetary policy strategy is strict inflation targeting, the policy rate is also influenced by the output gap and the real exchange rate deviation from PPP. Therefore, when the real exchange rate is weak, the central bank increases the repo rate to cool down the inflationary pressure and bring q_t back to its long-run equilibrium faster than it would otherwise go.

We can therefore see that an interest rate rule for inflation targeting in an open economy has the output gap and the real exchange rate in it *even if* the central bank is pursuing strict inflation targeting. The reason is that both q_t and y_t are predictors of future inflation, and therefore their role in the monetary policy rule is "indirect".

The coefficient of the real exchange rate in the interest rate rule is higher the lower the adjustment factor γ, suggesting that when real exchange rate shocks are persistent the policy rate will exhibit higher variability. Interest rate rule (5.10) encompasses two extreme cases, that is when shocks to q_t are not absorbed and there is no adjustment to the PPP (i.e. $\gamma=0$ and $q_{t+1|t} = q_t$) and when shocks are immediately absorbed (i.e. $\gamma=1$ and $q_{t+1|t} = 1$).

In the former case, equation (5.10) becomes:

$$i_t = r + \pi_t + \frac{1}{\alpha_y \beta_r}(\pi_t - \pi) + \frac{(1+\beta_y)}{\beta_r} y_t + \frac{2\alpha_q + \alpha_y \beta_q}{\alpha_y \beta_r} q_t \tag{5.11}$$

while, when convergence to PPP occurs within one period, equation (8) becomes:

$$i_t = r + \pi_t + \frac{1}{\alpha_y \beta_r}(\pi_t - \pi) + \frac{(1+\beta_y)}{\beta_r} y_t \tag{5.12}$$

The difference with respect to (5.11) is that the policy rate is not sensitive to exchange rate fluctuations; this result is intuitive: if q_t rapidly goes back to equilibrium, shocks to it will have no effect on future inflation.

Within the simple case of strict IT it is easy to consider the effect of the time horizion of the monetary authority on the interest rate rule. In particular, we ask to ourselves: what happens if the target horizon of the central bank is longer? In this case, the more persistent real exchange rate fluctuations, the higher will be the weight of this variable in the interest rate rule.

Let us assume that the Central Bank wants to reach the target in three periods. The objective function becomes:

$$\min_{i_t} \delta^3 \frac{1}{2}(\pi_{t+3|t} - \pi)^2 \tag{5.13}$$

and therefore the FOC is the same as in the previous case, moved one period further ahead:

$$\frac{\partial L}{\partial i_t} = (\pi_{t+3} - \pi) \frac{\partial \pi_{t+3}}{\partial i_t} = 0$$

which is simply: $\pi_{t+3|t} = \pi$. Three-periods-ahead expected inflation is:

$$\pi_{t+3|t} = \pi_{t+2|t} + \alpha_y y_{t+2|t} + \alpha_q q_{t+2|t}$$

If we assume that the RER adjusts to the PPP according to (5.5) and that forecasts of inflation and output gap are made at a constant interest rate [24], after some algebra we obtain the interest rate reaction function, which we write as:

$$i_t = r + \pi_t + \frac{1}{\alpha_x \beta_r (2+\beta_x)} (\pi_t - \pi) + \frac{1 + (1+\beta_x)\beta_x + \alpha_x \beta_r}{\beta_r (2+\beta_x)} x_t + \frac{a(1-\gamma)}{\alpha_x \beta_r (2+\beta_x)} q_{t-1} \qquad (5.14)$$

where $a = \alpha_q \left(\alpha_x \beta_r + 3 - \gamma + (1-\gamma)^2 \right) + \alpha_x \beta_q (2 - \gamma + \beta_x)$. Notice that, with respect to equation (5.10), the coefficient on current inflation is lower, the coefficient on the output gap is lower and the coefficient on q_t is higher. The results stemming from this section are summarized in Proposition 1 below.

> Proposition 1.
> In an open economy, the interest rate rule of a Central Bank pursuing strict Inflation Targeting will have a role for y_t and q_t, other than for ($\pi_t - \pi$). Other things equal, the interest rate reactivity to real exchange rate shocks will be larger when the target horizon is longer, when shocks to q_t are more persistent (i.e. $\gamma \rightarrow 0$) and when the exchange rate pass-through (captured by α_q) is larger.

5.3. Flexible inflation targeting

With respect to the closed economy case, we assume a more general framework for flexible IT: the flexibility comes both from a positive weight on output stabilization and a weight put on interest rate stabilization and smoothing[25], similar to Svensson [1999]:

$$\min_{i_t} \sum_{j=0}^{\infty} \delta^j \frac{1}{2} \left[\left(\pi_{t+j|t} - \pi \right)^2 + \lambda_i (i_t - i_{t-1})^2 + \lambda_r (i_t - \pi_t - r)^2 + \lambda_y y_{t+j|t}^2 \right] \qquad (5.15)$$

subject to (5.1), (5.2), (5.4), where the weight on inflation is normalized to 1 and $\lambda_i, \lambda_r, \lambda_y \geq 0$ are respectively the relative weight put on interest rate smoothing (i.e. the central bank wants to avoid excessive interest rate variability), on interest rate stabilization around the target real rate, and on output stabilization.

Assuming a period-by-period optimization as in the previous case, the problem to be solved by the Central Bank becomes:

[24] Most IT Central Banks which target expected inflation develop inflation forecasts under the assumption of constant interest rates.

[25] In Section 7, when we take these interest rate rules to the data, we will also consider these cases separately.

$$\min_{i_t} \frac{1}{2}\delta^2\left[\left(\pi_{t+2|t}-\pi\right)^2+\lambda_i(i_t-i_{t-1})^2+\lambda_r(i_t-\pi_t-r)^2+\lambda_y y_{t+1|t}^2\right] \quad (5.16)$$

and thus the monetary authority takes last year's policy decision as given, but disregards the fact that today's instrument setting will affect next year's loss function. When $\lambda_i = \lambda_r = \lambda_y = 0$, this problem is equivalent to the intertemporal problem analysed for the case of strict inflation targeting.

Notice that in objective function (5.16) the central bank sets the interest rate to minimize the two-period-ahead inflation gap and the *one*-period-ahead output gap. In principle, there is no fundamental reason why the time horizon for the output gap and inflation gap objectives should be the same; in (5.16) the difference is due to the fact that, given the dynamical structure of our simple model, the central bank can affect output via the policy rate after one period, while it takes two periods for inflation to be influenced by monetary policy. In any case, even if the output gap appeared in t+2, the results would qualitatively be the same.

Minimizing (5.16) with respect to i_t yields the following FOC:

$$-(\pi_{t+2|t}-\pi)(\alpha_q(2-\gamma)+\alpha_y(\beta_r+\beta_q))-\lambda_y(\beta_r+\beta_q)\,y_{t+1|t}+\lambda_i(i_t-i_{t-1})+\lambda_r(i_t-\pi_t-r)=0 \quad (5.17)$$

This is the targeting rule of the central bank, showing that when the policy rule is flexible inflation targeting, with respect to strict IT, the adjustment towards the target will be slower due to interest rate smoothing. After some algebra, the interest rate rule is:

$$\begin{aligned} i_t= & \frac{\lambda_i}{\lambda_i+\lambda_r+b_2\beta_r}i_{t-1}+\frac{b_2\beta_r+\lambda_r+b_1\alpha_y\beta_r}{\lambda_i+\lambda_r+b_2\beta_r}(\pi_t+r)+\frac{b_1}{\lambda_i+\lambda_r+b_2\beta_r}(\pi_t-\pi) \\ & +\frac{b_1\alpha_y(1+\beta_y+b_2\beta_y)}{\lambda_i+\lambda_r+b_2\beta_r}y_t+\frac{(b_2\beta_q+b_1(\alpha_q(2-\gamma)+\alpha_y\beta_q))(1-\gamma)}{\lambda_i+\lambda_r+b_2\beta_r}q_{t-1} \end{aligned} \quad (5.18)$$

where $b_1=\alpha_q(2-\gamma)+\alpha_y(\beta_r+\beta_q)$ and $b_2=\lambda_y(\beta_r+\beta_q)$.

Two things are worth noticing. First of all, as in the strict IT case, although the monetary authority does not have a target for the real exchange rate, it will respond to its fluctuations since it affects expected inflation and the expected output gap. The second result which is worth noticing is that the coefficients of the "Taylor Rule" (5.18) are convolutions of structural parameters and the preference parameters λ_i, λ_r, λ_y. When λ_i and λ_r are different from zero, interest rate variability is lower with respect to the case of strict IT.

Finally, when $\lambda_y > 0$, the monetary authority's reaction to output and real exchange rate fluctuations will be larger, and that to inflation smaller, than in strict IT. The results on flexible inflation targeting are summarized in Proposition 2.

Proposition 2.
The interest rate rule of a Central Bank pursuing flexible Inflation Targeting will have coefficients on (π_t - π) , y_t and q_t that are convolutions of structural parameters and the preference parameters $\lambda_x = [\lambda_y , \lambda_i , \lambda_r]$. If $\lambda_x = 0$ we go back to the strict IT case. Other things equal, the larger any element in λ_x , the lower the response to inflation fluctuations, and the larger the response to fluctuations in y_t and q_t . As in strict IT, other things equal, the interest rate reactivity to shocks to q_t will be larger when $\gamma \rightarrow 0$.

5.4. Fear of Floating

Let us now move to the case of "Fear of Floating" or exchange rate smoothing. In order to concentrate on the role of the exchange rate, we will assume here that the weight on interest rate smoothing and output stabilization is zero, i.e. $\lambda_i = \lambda_r = \lambda_y = 0$. The loss function becomes:

$$L(\pi_t, e_t - e_{t-1}) = \frac{1}{2}\left[(\pi_t - \pi)^2 + \lambda_e (e_t - e_{t-1})^2\right]$$

and thus we allow for a weight $\lambda_e \geq 0$ for exchange rate smoothing, that is, for a separate exchange rate objective in the monetary policy. In order to keep things simple, as it was stated above (see fn. 14) we will assume here that the Central Bank adopts a period-by-period optimization as we did above. This, other than being an acceptable restriction as we explained in section 5.3, will simplify matters and we will not have to resort to a numerical solution, while still being able to understand the consequences of fear of floating on the interest rate rule.

The objective function of the Central Bank therefore becomes:

$$\min_{i_t} \frac{1}{2}\left[\delta^2 (\pi_{t+2|t} - \pi)^2 + \lambda_e (e_t - e_{t-1})^2\right] \tag{5.19}$$

subject to

$$\pi_{t+2} = \pi_{t+1} + \alpha_y y_{t+1} + \alpha_q q_{t+1} + \xi_{t+2}$$

Recall that expected two-period-ahead inflation was written in (5.9) as:

$$\pi_{t+2|t} = \pi_t + \alpha_y (1+\beta_y) y_t + (\alpha_q (2-\gamma) + \alpha_y \beta_q) q_t - \alpha_y \beta_r (i_t - \pi_t - r)$$

The FOC for minimizing (18) with respect to the repo rate is:

$$\pi_{t+2|t} = \pi - \frac{\lambda_e}{\delta^2 (\alpha_y \beta_q + \alpha_q (2-\gamma) + \alpha_y \beta_r)} (e_t - e_{t-1}) \tag{5.20}$$

We can compare (5.20) with the FOC in the strict IT case: with fear of floating, expected inflation two periods ahead is equal to the target only if the exchange rate is stable. If the exchange rate in the current period is weak compared to the previous period, i.e. $e_t > e_{t-1}$, then the interest rate is kept at a level higher than what would ensure that the inflation target is reached in t+2, and therefore $\pi_{t+2} < \pi$. The opposite holds when the exchange rate is falling. The deviation from the target will be higher the larger is γ, that is, the faster the real exchange rate tends to converge to PPP. In other words, when PPP holds it is harder to control the exchange rate via interest rate intervention and thus more costly in terms of deviation of inflation from the Central Bank's target.

Plug this FOC in (5.9) and we get:

$$\pi_t+\alpha_y(1+\beta_y)y_t+\left(\alpha_q(2-\gamma)+\alpha_y\beta_q\right)q_t-\alpha_y\beta_r(i_t-\pi_t-r)=\pi-\frac{\lambda_e}{c_1}(e_t-e_{t-1})$$

where $c_1=\delta^2\left(\alpha_y\beta_q+\alpha_q(2-\gamma)+\alpha_y\beta_r\right)$.

We can therefore derive the interest rate rule in fear of floating as:

$$i_t=\pi_t+r+\frac{1}{\alpha_y\beta_r}(\pi_t-\pi)+\frac{(1+\beta_y)}{\beta_r}y_t+\frac{\alpha_q(2-\gamma)+\alpha_y\beta_q}{\alpha_y\beta_r}q_t+\frac{\lambda_e}{c_1\alpha_y\beta_r}\left(e_t-e_{t-1}\right) \quad (5.21)$$

using the definition of real exchange rate in (5.21), we can rewrite it as:

$$i_t=\pi_t+r+\frac{1}{\alpha_y\beta_r}(\pi_t-\pi)+\frac{1+\beta_y}{\beta_r}y_t+\frac{c_2}{\alpha_y\beta_r}(\pi_t-\pi_t^f)+\frac{c_3}{\alpha_y\beta_r}q_{t-1} \quad (5.22)$$

where the c_i coefficients are defined as:

$$c_2=\frac{\lambda_e}{c_1};\; c_3=\left(\alpha_q(2-\gamma)+\alpha_y\beta_q\right)(1-\gamma)+\frac{\lambda_e\gamma}{c_1}.$$

Apart from the analytical complexity of the coefficients, we can see from (5.22) that, with fear of floating, the interest rate response to shocks to inflation and the real exchange rate will be stronger than in strict and flexible inflation targeting, since b_1 is positive. Moreover, as in the previous case, the lower the adjustment coefficient γ, the stronger its role in the interest rate rule. The results of the case of Fear of Floating are summarized in Proposition 3 below.

> Proposition 3.
> The interest rate rule of a Central Bank with fear of floating and zero weight on output stabilization will feature larger reaction coefficients for shocks to π_t and q_t with respect to strict and flexible IT. Such coefficients are convolutions of structural parameters and the preference parameter λ_e. The interest rate response to exchange rate fluctuations will be larger when $\gamma \rightarrow 0$. All other conclusions drawn in Proposition 1 are confirmed.

The results obtained in sections 5.1 – 5.4 are summarized in Table 5.1, which classifies the policy rules according to the interest rate reactivity to shocks of different nature[26].

[26] This table is an attempt to “bridge the gap” between the literature on inflation targeting and exchange rate regime classification, and is similar to Table 1 in Levy-Yeyati and Sturzenegger [2005]; the difference is that our results were derived from an optimization process of the central bank, while in their case they are *a priori* definitions.

Table 5.1. Interest rate reactions to different shocks

	π	x	q	i^f
Exchange Rate Targeting	Nil	Nil	High	High
Strict Inflation Targeting	Medium	Low	Low	Low
Flexible Inflation Targeting	Low	Medium	Medium	Low
Fear of Floating	High	Medium	High	High

The definitions "low", "medium" and "high" should be interpreted as relative with respect to the other three regimes included in the analysis; in order to say anything on the magnitude of the coefficients, we need parameter values from the structural model.

6. A stylized model of the Swedish economy

The first step in the empirical analysis is the estimation of a small model for the Swedish economy. This will allow us to obtain the empirical counterparts of the theoretical model in Section 5.

Depending on the chosen specification[27], the literature seems to have reached a consensus on the minimal set of variables that should be present in an empirical model aimed at representing aggregate demand and supply in a small open economy; this includes domestic and foreign output (gap), price level (or inflation), short-term interest rates, the (nominal or real) exchange rate and possibly some commodity price index[28].

In our case, the "rest of the world" is proxied by the euro area, and the exchange rate is therefore the bilateral rate. This assumption is not overly restrictive; almost 60% of Swedish international trade is with the euro area, and a similar assumption is quite common in the literature on small open economies[29].

As far as the sample period is concerned, we only consider data from the inflation targeting era, i.e. from 1995 on. This will help us to avoid the risk of including different regimes while maintaining a sufficient number of observations: in fact, Sweden was a member of the ERM from 1986 to 1992, then abandoned it because of speculative attacks to the Krona. Between

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27 i.e., whether the one at hand is a model with stationary or cointegrated variables.

28 See, for example, Eichembaum and Evans [1995], Jacobson et al. [2001]; Kim and Roubini [1997] also include a commodity price index, while Betts et al. [1996] augment the system with a (domestic and foreign) monetary aggregate.

29 Betts et al. [1996], for example, in a Cointegration analysis for Canada, use the U.S. as a proxy for the rest of the world.

1992:4 and 1994:4, Sweden suffered from a severe economic downturn and financial crisis, while on the other hand, the inflation targeting regime, coupled with a flexible exchange rate, was being put in place. Inflation targeting was not, however, adopted officially until January 1995; moreover, Sweden entered the European Union in the same month and, although its economy was already well integrated with the rest of Europe, it is plausible that this fostered further economic integration. For this reason, we will restrict ourselves to the period from 1995 to 2008.

There are several alternative empirical strategies to identify a set of equations that could be interpreted as a small structural model for the Swedish economy. Two alternative approaches are VAR (Vector Autoregressive) models and structural econometric models. VAR models are the most general, a-theoretical models to describe the macroeconomy. Once the choice on the set of variables and the number of lags (on the basis of information criteria and likelihood ratio tests) is made, the researcher "lets the data speak" and, given an empirically congruent representation of the DGP, imposes restrictions to identify long-run (in Cointegrated VARs - CVARs) relations among the variables or structural shocks (in Structural VARs - SVARs). The main drawback of VARs, however, is that they are very demanding in terms of data needed. As the number of variables and lags increases, the number of parameters increases quickly, raising the so-called problem of "vanishing degrees of freedom" of VARs, not to mention the fact that, in the case of CVARs, tables for the rank test have been developed only for models with up to 11 variables[30].

On the other hand, structural econometric models are identified by imposing restrictions on the parameters of the models; they are more parsimonious than VARs and therefore more reliable when the number of observations is limited; finally, all restrictions imposed on the system are testable, while the same is not true for SVARs, identified using recursive and/or sign restictions. For these reasons, we will stick to structural econometric models. Since we do not know what the "true" data generating process (DGP) is, we will start from specifying a statistical model which should be general enough to deliver a congruent representation of the true DGP. In other words, in the first stage we will estimate regression equations similar to (5.1) – (5.4) specified as general polynomial lags models[31]:

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[30] For a discussion, see Johnston, DiNardo [1997], Chp. 9.

[31] The empirical model here is similar to Golinelli and Rovelli [2005], although unlike them we do not include a Taylor Rule, since it will be estimated separately in the next section.

$$y_t = d_0 + d_1(L) y_{t-1} - d_2(L)(i_{t-1} - \pi_{t-1}) + d_3(L) q_{t-1} + d_4(L) \Delta w_t + \epsilon_t^y \quad (6.1)$$

$$\pi_t = f_0 + f_1(L) \pi_{t-1} + f_2(L) y_{t-1} + f_3(L) \pi_{t-1}^f + f_4(L) q_{t-1} + f_5(L) \Delta_4 C_t + \epsilon_t^\pi \quad (6.2)$$

$$q_t = g_0 + g_1(L) q_{t-1} + \epsilon_t^q \quad (6.3)$$

Equations (6.1) – (6.3) represent our empirical model; the identification assumptions embodied in this model are quite standard in the literature and resemble the (simpler) theoretical model in section 5: first, Monetary Policy cannot affect output and prices immediately; the setting of interest rates affects the real exchange rate immediately and output with some lag; this will, in turn, affect inflation. Second, the foreign (i.e. "large") economy variables and commodity inflation are exogenous; thus, shocks originating in the domestic economy (Sweden) have no impact on Europe and on commodity prices. Equation 6.1 is an Aggregate Demand equation normalized on the domestic output gap; output depends on its past values, on the real interest rate, the growth in world demand (proxied by euro area output growth, Δw[32]) and the real exchange rate. The presence of the contemporaneous foreign growth rate allows for synchronized shocks to output. Equation (6.2) is an aggregate supply equation, where inflation is determined by past inflation, imported inflation (i.e. the euro area inflation rate), resource utilization (the past output gap), convergence to the purchasing power parity and commodity price inflation, $\Delta_4 C_t$. Equation (6.3) is just a more general representation of (5.5)[33] and shows how the real exchange rate corrects to the PPP; when $\Sigma g_{1l} < 1$ the real exchange rate is stationary.

We will further test the validity of the real interest parity, that was included in the theoretical model of section 5. The RIP shows how q is immediately affected by monetary policy shocks (i.e. changes in the interest rate).

The first step will be to estimate the model equation by equation, in order to impose restrictions on the dynamics of each regression. Equations (6.1) to (6.3) are thus estimated by OLS[34]. Once each equation is estimated and passes all specification tests, we simplify the dynamic structure by dropping the parameters which are not significant at 5%, following a limited information approach and making sure that the parsimonious model residuals are

[32] The analysis was however robust to a different definition of w, i.e. a weighted average of Sweden's main trade partners (EMU, USA, Norway, UK and Denmark).

[33] According to (5.5), $q_t = (1 - \gamma)\, q_{t-1} + \omega_t$

[34] An alternative specification of the AD curve shows the output gap responding to the *expected* real interest rate. In this case, the equation should be estimated by 2SLS. We have performed this exercise and the estimates are very close to OLS estimates with the realized interest rate. However, there might be a problem of weak instruments.

white noise. Finally, we re-estimate the simultaneous equations model, with further restrictions, by Constrained Full Information Maximum Likelihood (CFIML).

Inflation is measured as the annual change in the CPI[35]; the real exchange rate is defined as: $q_t = e_t + p_t^* - p_t$ where p is the (log) swedish price level and p^* is the european CPI; e is the nominal bilateral SEK/Euro exchange rate; commodity prices are measured using the IMF index for all commodities; finally, the output gap is taken from the OECD Economic Outlook 84[36]. Data are seasonally and working day adjusted.

As a starting point, we chose L=3 lags for each equation (6.1) – (6.3). Table 6.1 shows specification tests for the three equations; notice that the restricted regression equations are well specified as the residuals are white noise. Moreover, even when the variables included in the system are nonstationary, regression is valid as long as the regressors are cointegrated (see Hsiao [1997]).

Nonstationarity of interest rates and inflation is an issue in the present dataset; the fact that these variables have a unit root might be disturbing from a theoretical point of view but it has been widely discussed in the empirical literature[37].

The AD curve shows that the real interest rate affects output with three lags; output also responds to real exchange rate changes and foreign output growth (robust standard errors in parenthesis):

$$y_t = \underset{(0.001)}{-0.002} + \underset{(0.044)}{0.803}\, y_{t-1} - \underset{(0.031)}{0.079}\,(i_{t-3} - \pi_{t-3}) + \underset{(0.019)}{0.043}\,(q_{t-2} - q_{t-3}) + \underset{(0.037)}{0.215}\,\Delta w_t + \epsilon_t^y \qquad (6.6)$$

The negative (and significant) constant is in line with Hjelm and Jönsson [2010] who state that an estimation of the Swedish output gap starting in the beginning of the 1990s necessarily yields an output gap which is negative on average due to the consequences of the financial crisis of the '90s.

35 There is some debate on whether it is more appropriate to use the annual rate or the annualized quarterly inflation. Lindé [2003], on Sweden, discusses how this may be not relevant for a large economy, but it is for small open economies such as Sweden. The annualized quarterly rate adds variability that cannot be explained by the model nor additional variables. Moreover, the Riksbank defines inflation in its policy rule as the annual change in the CPI.

36 The OECD measures the output gap using the production function approach. The estimation was robust to the use of a different measure of output gap (obtained using the HP filter), although the coefficient on y was larger.

37 The argument that inflation is I(1) and therefore prices are I(2), which leads to the empirical finding of the failure of the PPP and the UIP to hold, has been thoroughly investigated and discussed by Juselius [2006] and Johansen et a. [2009], just to name a couple (see also fn. 45).

Table 6.1. Specification Tests [38]

		ε^Y	ε^π	ε^q
Normality		0.783	0.589	0.320
Autocorrelation	Ljung_Box (4)	0.504	0.111	0.246
ARCH	LM(4)	0.995	0.501	0.330
		Output Gap	*Inflation*	*Real Exch. Rate*
R^2		0.939	0.848	0.999

Moreover, the same authors state that when prices, as well as wages, react more to positive gaps than to negative gaps, as it is the case for Sweden[39], the output gap will be negative on average.

The Aggregate Supply curve shows that the inflation rate is positively affected by past inflation, the output gap two periods before, commodity price inflation and the real exchange rate:

$$\pi_t = \pi_{t-1} + \underset{(0.047)}{0.112}\, y_{t-2} + \underset{(0.020)}{0.085}\,(q_{t-1} - q_{t-3}) + \underset{(0.006)}{0.018}\,(\Delta_4 C_t - \Delta_4 C_{t-1}) + \epsilon_t^\pi \qquad (6.7)$$

The coefficient on inflation was restricted to 1, and this restriction, together with the restrictions on the coefficients on q and ΔC could not be rejected with a p-value of 0.104. The restriction on past inflation is also present in theoretical macro models that have been cited in the present work such as Svensson [1997]. This is equivalent to finding that expectations are backward-looking and therefore, in the Phillips Curve, $\pi^e_t = \pi_{t-1}$[40]; thus we can re-write (6.7) as:

$$\Delta \pi_t = \underset{(0.047)}{0.112}\, y_{t-2} + \underset{(0.020)}{0.085}\,(q_{t-1} - q_{t-3}) + \underset{(0.006)}{0.018}\,(\Delta_4 C_t - \Delta_4 C_{t-1}) + \epsilon_t^\pi$$

Finally, the real exchange rate is represented here as an AR(1) process: if the real exchange rate is stationary, as it should occur if purchasing power parity holds, then it should be mean-reverting and its coefficient significantly lower than one. In our case, we have:

$$q_t = \underset{(na)}{1.00}\, q_{t-1} + \epsilon_t^q \qquad (6.8)$$

The real exchange rate was found to be nonstationary, i.e. purchasing power parity does not hold The restriction that $g_1 = 1$ could not be rejected with a p-value of 0.510.

[38] Other single-equation tests were performed which are not reported here and show that the model is well-specified and no parameter instability seems to be present.

[39] See also Eliasson [2001].

[40] See Bagliano et al. [2001], Taylor [1999] and Rudebusch and Svensson [1999].

Table 6.2. Real Interest Parity

$q_t = q_{t+1\|t} - i_t + i_t^f - \pi_t^f + \pi_t + \phi_t$	where	$\phi_t = \underset{(0.004)}{0.003} + \underset{(0.133)}{0.645}\,\phi_{t-1} + \epsilon_t^{\phi}$
ADF test on φ with a constant and no trend		τ = -2.008 ; p-value 0.040

While this might sound puzzling from a theoretical point of view, the fact that the PPP does not hold (if not over very long time horizons) has been documented in many empirical papers[41]. In other words, since the coefficient on q_{t-1} is exactly equal to 1, $\gamma = 0$ in (5.5) and the real exchange rate exhibits a unit root. We have also checked for possible level shifts at significant dates which might have determined the nonstationarity of q_t but no significant break was found. Apparently, q_t has been steadily depreciating over the sample period, since Sweden had a lower average inflation rate than the Euro Area, with the nominal exchange rate not correcting for the imbalance. The overidentified structure of the system could not be rejected, with a p-value of 0.065[42]. Table 6.2 shows the real interest parity equation, which was estimated by 2SLS, and the risk premium. As it is clear from the table, the risk premium is stationary, with a positive but insignificant contant term.

Summing up, monetary policy affects inflation indirectly, through different channels: the real exchange rate channel, with a lag of 1 quarter, and the interest rate channel via the output gap, after 5 quarters, i.e. 1 year and three months.

7. The Identification of Central Bank Preferences

We can identify Central Bank preferences by assigning the Central Bank a loss function to be minimized, as we did in the theoretical model of Section 5, subject to the constraint given by the structure of the economy that was estimated in Section 6. Once the relevant first order conditions have been derived, we will estimate them and compare the results we obtain under alternative policy regimes like those we outlined in Section 5 with the actual policy adopted by the Riksbank. The general problem is the following. The Central bank chooses i_t to minimize the loss function:

[41] See for example Juselius and McDonald [2004 and 2007] and Juselius [2006] who have thoroughly investigated the so-called PPP puzzle, and this results seem to support the so-called Imperfect Knowledge Economics theory by Frydman and Goldberg [2007] as opposed to the mainstream Rational Expectations theory.

[42] The complete statistics as well as vector specification tests are available on request.

$$E_t \sum_{k=0}^{\tau} \delta^k \left[\lambda_\pi (\pi_{t+k} - \pi)^2 + \lambda_y y_{t+k}^2 + \lambda_i (i_{t+k} - i_{t+k-1})^2 + \lambda_r (i_{t+k} - \pi_{t+k} - r)^2 + \lambda_e (e_{t+k} - e_{t+k-1})^2 \right] \qquad (7.1)$$

where λ_x, x = [π, y, i, r, e] are the weights attached to the various goals of monetary policy in the present setup; the terms ($i_t - i_{t-1}$) and ($i_t - \pi_t - r$) are added to the theoretical setup of Section 5 to allow for the case of interest rate stabilization and smoothing[43].

The loss function is minimized with respect to i_t subject to the structure of the economy:

$$\pi_{t+k} = \alpha_0 \pi_{t+k-1} + \alpha_1 y_{t+k-2} + \alpha_2 q_{t+k-1} - \alpha_3 q_{t+k-3} + \alpha_4 \Delta_4 C_{t+k} - \alpha_5 \Delta_4 C_{t+k-1} + \epsilon_{t+k}^{\pi} \qquad (7.2)$$

$$y_{t+k} = \beta_0 + \beta_1 y_{t+k-1} - \beta_2 (i_{t+k-3} - \pi_{t+k-3}) + \beta_3 (q_{t+k-2} - q_{t+k-3}) + \beta_4 \Delta w_{t+k} + \epsilon_{t+k}^{y} \qquad (7.3)$$

$$q_{t+k} = q_{t+k+1|t} - i_{t+k} + i_{t+k}^{f} - \pi_{t+k}^{f} + \pi_{t+k} - \phi_{t+k} \qquad (7.4)$$

$$q_{t+k+1|t} = (1-\gamma) q_{t+k} + \epsilon_{t+k+1}^{q} \qquad (7.5)$$

The structure defined in equations (7.2) – (7.5) is derived from the empirical model estimated in Section 6; the estimated α_i and β_i coefficients are reported in table 7.1. Notice that, given the model in Section 6, real interest parity holds, up to a stationary risk premium; q_t is a random walk, since $\gamma = 0$.

The five alternative monetary policy strategies are defined by different weights λ_x as described in table 7.2: these are precisely the coefficients we want to estimate within out framework. To this end, we also set a numerical value for the discount factor. In particular, we set δ = 0.984 which corresponds to a discount rate of around 1.6%; this figure is equal to the average real interest rate in Sweden over the period we are considering. The cited works of Favero and Rovelli [2003] and Collins and Siklos [2004] adopted different approaches to defining δ. The former sets δ = 0.975, while the latter chooses, for each country, a level of δ consistent with the average interest rate over the sample period. We therefore follow Collins and Siklos; however, our results are robust to a (marginally) different choice of δ.

As in Section 5, rather than assuming a "timeless perspective" for the central bank, we consider a finite-time horizon, so that we are able to derive analytically the first order conditions for all regimes. As far as the length of the horizon *k* is concerned, that depends on the monetary policy regime. In the case of exchange rate targeting, we know from Section 5 that it is optimal for the Central Bank to passively follow foreign monetary policy, so the horizon is one period.

[43] See also Svensson [1997].

Table 7.1. Estimated Structural Coefficients

α_0	1.000	α_4	0.018	β_2	0.079
α_1	0.112	α_5	0.018	β_3	0.043
α_2	0.085	β_0	-0.002	β_4	0.215
α_3	0.085	β_1	0.803	γ	0

Table 7.2. Preference parameters and monetary policy regimes.

Regimes *weights*	λ_π[44]	λ_y	λ_i	λ_r	λ_e
1. Exchange Rate Targeting	0	0	0	0	1
2. Strict Inflation Targeting	1	0	0	0	0
3. Interest Rate Smoothing	1	0	> 0	> 0	0
4. Flexible Inflation Targeting	1	> 0	≥ 0	≥ 0	0
5. Fear of Floating	1	≥ 0	≥ 0	≥ 0	> 0

Within strict inflation targeting, the Central Bank only has the concern of stabilizing inflation at its target; since, in the present case, we have seen that the interest rate channel kicks in after 5 quarters, then k=5.

The remaining three regimes are extensions of strict inflation targeting where the Central Bank wants to minimize fluctuations in output, the interest rate and/or the exchange rate. Here we set k=8 to be consistent with the monetary policy statement of the Riksbank[45]:

> "(...) Monetary Policy is normally focused on achieving the inflation target within two years. One reason for that is that the effects of monetary policy appear with a lag. Another reason is that the Riksbank, by aiming at this horizon, can contribute to dampening fluctuations in the real economy(...)"

It has been discussed [see Svensson, (1999)] that by smoothing the interest rate, the Central Bank might also stabilize output, as a side product. In other words, when forecasted inflation is above target, rather than immediately setting i to the level that brings inflation back to target as soon as possible given policy lags, the Central Bank gradually changes the interest rate, and in this way it minimizes output fluctuations. For this reason, the time horizon in regimes 3 to 5 is equal to 8 quarters, consistent with the Riksbank's official statements.

With a horizon of 8 periods and the dynamics given in (7.2) – (7.4), the first order conditions for regimes 2 to 5 of Table 7.1 would be particularly complicated, with many collinear terms;

[44] Except for Exchange Rate Targeting, where λ_π is set to zero, in all other alternative regimes we normalize it to 1, without loss of generality.

[45] *Monetary Policy in Sweden 2008*, p. 13.

this collinearity is an increasing function of the length of the horizon[46]. To obtain a manageable solution we consider for those regimes a period-by-period optimization, as discussed in Section 5. This, however, is not an overly strong simplifying assumption as it appears consistent with official Central Bank statements. Moreover, this approach has the advantage, on the empirical side, that it allows us to estimate policy rules relying only on official forecasts of inflation[47].

The availability of official forecasts is a serious advantage of the present analysis. Real-time forecasts are very attractive because they can be considered predetermined variables in period *t*, and consistent parameter estimates can be computed running least squares regression. In fact, since the actual forecast rather than a proxy is available, the former can be used as a regressor, and one does not need to revert to instrumental variable estimation. Empirical Taylor rules generally put a very high coefficient on monetary policy inertia[48] and this appears to be due to a weak instrument problem (see Consolo and Favero [2009]). By using real-time forecasts we can circumvent this limitation of monetary policy rules estimation, and this is another strength of the present empirical analysis.

7.1 Exchange Rate Targeting

In the case of Exchange Rate Targeting, the policy rule to be estimated is:

$$i_t = \kappa_1 i_t^f + \psi_t \qquad (7.6)$$

where we should have $\kappa_1 = 1$ and ψ_t should be stationary. The results are presented in Table 7.2. The restriction to 1 is rejected at all significance levels, and residuals are nonstationary; thus, while the two interest rates have been moving closely, a "strict exchange rate targeting" policy cannot well mirror swedish monetary policy in the last 14 years. This is not a surprise: while there is a doubt that the Riksbank *might* have put some weight on exchange rate stabilization, it is clear from both official statements and its actions that in several occasions it actually pursued an interest rate policy that did not always follow that of the ECB.

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[46] See Favero and Rovelli [2003].

[47] Over the whole sample, only forecasts at t, t+4 and t+8 are available. If we adopted a finite-time horizon, also $\pi_{t+1|t}, \dots, \pi_{t+7|t}$ and $y_{t+1|t}, \dots, y_{t+7|t}$ would appear in the FOC and they would need to be instrumented.

[48] One example is Clarida et al. [2002].

Table 7.3. Euler Equation: Exchange Rate Targeting.

Estimated Equation is (7.6). Sample: 1995Q1 - 2008Q4				
	Coefficient	Std. Error	t-Statistic	P-Value
κ_1	1.262	0.071	17.70	0.000
Restrictions: κ_1=1 F(1,55) = 13.506 p-value: 0.001				
R-squared:0.851			S.E. Of Regression:0.0166	Mean of Dep. Var.: 0.0391
φ	ADF (with constant): τ = -1.526 p-value: 0.119		$\phi_t = \underset{(0.001)}{-0.001} + \underset{(0.036)}{0.941}\phi_{t-1}$	

Estimation method: OLS. Standard Errors are HAC.

7.2 Strict Inflation Targeting

As anticipated above, in order to have a manageable solution we will assume a period-by-period optimization as discussed in Section 5.

We know from Section 6 that, in Sweden, it takes 5 quarters for monetary policy to affect the inflation rate via the interest rate channel. Minimizing equation (7.1) setting k=5[49] and λ_i, λ_y, λ_e and λ_r equal to zero we obtain the empirical counterpart of (5.10):

$$i_t = \frac{\beta_0}{\beta_2} + \bar{r} + \pi_t + \frac{1}{\alpha_1 \beta_2}(\pi_{t+4|t} - \pi) + \frac{\beta_1}{\beta_2} y_{t+2|t} + \frac{\beta_4}{\beta_2} \Delta w_{t+5|t} \qquad (7.7)$$

The corresponding unrestricted equation is:

$$i_t = k_0 + k_1 \pi_t + k_2(\pi_{t+4|t} - \pi) + k_3 y_{t+2|t} + k_4 \Delta w_{t+5|t} \qquad (7.8)$$

Notice from (7.7) that, due to the structure of the economy, the real exchange rate and the commodity price index are cancelled from the interest rate rule, since $\alpha_2 = \alpha_3$ and $\alpha_4 = \alpha_5$. In the present case, with strict inflation targeting, when the central bank is responding to *forecasted* inflation and output gap, the coefficients on *q* and commodity price inflation should thus be zero, as *q* and ΔC only have a role as predictors of future inflation.

If the Riksbank has indeed been following strict inflation targeting, the actual and optimal interest rate reaction functions should not differ too much from each other; by imposing the appropriate restrictions we should therefore reconcile (7.7) with (7.8). That is, the following restrictions should not be rejected:

$$k_1 = 1 \, ; \, k_2 = \frac{1}{\alpha_1 \beta_2} \, ; \, k_3 = \frac{\beta_1}{\beta_2} \, ; \, k_4 = \frac{\beta_4}{\beta_2}$$

[49] One might argue that it is a contradiction to set k = 5 in the Strict Inflation Targeting case while it is well known that the time horizon of the Riksbank is two years. However, the choice of k = 5 is consistent with the idea of the Central Bank only caring to bring inflation back to equilibrium. As Svensson [1997, p. 356] has pointed out, "(...) under strict IT the instrument should be adjusted such that the conditional inflation forecast for a horizon corresponding to the control lag always equals the inflation target".

Table 7.4, column 3 reports the results of the strict IT case. A Wald Test on the above restrictions rejected them at all significance levels. The estimated interest rate rule would imply a higher interest rate variability than what is observed in practice, but still it can capture the behaviour of the Swedish policy interest rates moderately well; a strict inflation targeting rule with optimal coefficients as derived from our structural model estimated in the previous section, instead, does not predict correctly the magnitude of the coefficients. Indeed, the optimal coefficients if the Riksbank had actually been pursuing strict IT would have been much larger, and the interest rate variability extremely high. This result is in line with those in Favero and Rovelli [2003] and Collins and Siklos [2004] and the prediction of the theoretical model by Svensson [2000].

7.3 Interest Rate Smoothing

In the case of interest rate stabilization and smoothing, we set λ_y and λ_e equal to zero in (7.1) and k = 8; minimizing the loss function with respect to i_t we obtain the following first order condition:

$$\delta^8(\pi_{t+8|t}-\pi)((-2\alpha_2-\alpha_1\beta_2)(1+\beta_1+\beta_1^2+\beta_1^3))+\lambda_i(i_t-i_{t-1})+\lambda_r(i_t-\pi_t-\bar{r})=0$$

For the purpose of estimation, we can rewrite it as:

$$i_t=\frac{\lambda_r}{\lambda_i+\lambda_r}\bar{r}+\frac{\lambda_r}{\lambda_i+\lambda_r}\pi_t+\frac{\lambda_i}{\lambda_i+\lambda_r}i_{t-1}+\delta^8\frac{k_5}{\lambda_i+\lambda_r}(\pi_{t+8|t}-\pi) \qquad (7.9)$$

where $k_1 = 2\alpha_2 + \alpha_1 (\beta_2 + \beta_3 \beta_1) (1 + \beta_1 + \beta_1^2 + \beta_1^3)$. Two things are worth noticing: first, output does not appear in the first order condition, i.e. the central bank responds to output only as an indicator of forecasted inflation. In other words, they are included in the forecast $\pi_{t+8\ |\ t}$ produced by the Central Bank.

The problem with (7.9) is that the coefficients are not uniquely identified. In order to achieve identification, we have to impose further restrictions, either on the target real interest rate, that we have assumed to be constant[50], or on k_5.

We choose the latter option, imposing the restriction $k_5 = 2\alpha_2 + \alpha_1 (\beta_2 + \beta_3 \beta_1) (1 + \beta_1 + \beta_1^2 + \beta_1^3)$, where α_1, α_2, β_1 and β_2 are those given in Table 7.1, while leaving the constant *r* unrestricted and then check if the estimated equation is meaningful and able to replicate the observed path of policy interest rates.

50 Collins and Siklos [2004] – within a different macroeconomic framework – do not assume a constant target real interest rate and take it to be given by the trend from an HP filter of the observed real rate. In this case, we would have to impose the restriction that the coefficients on the (time varying) *r* and on current inflation are equal. We have already discussed in Section 6 the pitfalls related to the use of HP filters; moreover, it is not unreasonable to imagine that, when there are no regime shifts or major policy or structural changes, the target real interest rate is constant.

We estimated equation (7.9) by NLS and the estimated coefficients are reported in Table 7.4. The results suggest that the Riksbank might have been pursuing interest rate stabilization and smoothing. Given that the weight on expected inflation is normalized to 1, we estimate that the relative weight on interest rate smoothing was over 41% and the weight on interest rate stabilization close to 8%. The target real rate over the sample period was 1.46. With respect to the previous case, the fit of the regression has largely improved, with the adjusted R^2 going from 0.35 to 0.97.

7.4 Flexible Inflation Targeting

In the empirical counterpart of Section 5.3 we minimize (7.1) with respect to i_t setting $\lambda_e = 0$ and k = 8. The interest rate rule resulting when we rearrange the FOC is:

$$i_t = \frac{\lambda_r}{\lambda_i+\lambda_r}\bar{r} + \frac{\lambda_i}{\lambda_i+\lambda_r} i_{t-1} + \frac{\lambda_r}{\lambda_i+\lambda_r}\pi_t + \frac{\delta^8 k_5}{\lambda_i+\lambda_r}(\pi_{t+8|t}-\pi) + \frac{\delta^8 \lambda_y k_6}{\lambda_i+\lambda_r} y_{t+8|t} \qquad (7.10)$$

where $k_5 = (2\alpha_2 + \alpha_1(\beta_2+\beta_1\beta_3)(1+\beta_1+\beta_1^2+\beta_1^3))$; $k_6 = (\beta_1^5(\beta_1\beta_3+\beta_2))$.

Again, the real exchange rate as well as foreign output and commodity inflation do not play a direct role in the Euler Equation but, being themselves predictors of inflation and,in particular, the output gap (which is endogenous in (7.10)), they should be included as instruments. As in the previous case, in order to achieve identification, we restrict k_5 and k_6 using the parameters estimated in the structural model, and limit ourselves to the estimation of the λ's and the target real rate. Column 5 in Table 7.3 shows the results for flexible inflation targeting.

According to our estimates, the Riksbank has not been following flexible IT. The coefficient on the expected output gap is positive but not significant and this result was robust to a different choice of the time horizon for output (in particular, setting the target for the output gap to be one year). The estimated target real interest rate is up to 2%.

This result suggests that the objective of “dampening fluctuations in the real economy” as stated in the Riksbank's monetary policy statement has probably been fulfilled by smoothing the interest rate and, at the same time, choosing a horizon for the inflation target which is longer than necessary, rather than by directly responding to the output gap.

Moreover, this result is consistent to what was obtained by Favero and Rovelli [2003] on the U.S. and Collins and Siklos [2004] on Australia, Canada and New Zealand.

7.5 Fear of Floating

The case of Fear of Floating is analyzed minimizing (7.1) with respect to i_t while leaving all λ_x unrestricted and setting k = 8.

Rearranging, and using (7.5) to get rid of the endogenous contemporaneous nominal exchange rate, the equation to be estimated by GMM is:

$$i_t = \frac{\lambda_i}{\lambda_i+\lambda_r} i_{t-1} + \frac{\lambda_r}{\lambda_i+\lambda_r}(\pi_t + r) + \frac{\delta^8 k_5}{\lambda_i+\lambda_r}(\pi_{t+8|t} - \pi) + \frac{\delta^8 \lambda_y k_6}{\lambda_i+\lambda_r} y_{t+8|t} + \frac{\lambda_e}{\lambda_i+\lambda_r} \Delta e_{t-1} \qquad (7.11)$$

where k_1 and k_2 are the same as in (7.10).

Column 7 in Table 7.3 shows the results of the GMM estimation of (7.11) when we assume that the objective function of the Central Bank is (7.1); since, in the previous section, we estimated λ_y to be insignificant, we also estimated (7.11) with $\lambda_y = 0$ and Column 8 shows the results for this alternative rule.

The GMM estimation suggests that the Riksbank might indeed have put some weight on exchange rate stabilization; the relative weight in the objective function is quite small (2.6%) but significant at all levels. However, this result is not robust to the specification of the interest rate rule with $\lambda_y = 0$, since λ_e becomes insignificant. We can therefore conclude that "Fear of Floating" cannot describe the preferences of the Riksbank between 1995 and 2008 well, and thus the sources of the Krona/euro exchange rate stabilization have to be found somewhere else.

8. Conclusions

In this paper, I have proposed an approach to estimate Central Bank preferences within a small open economy starting from the monetary authority's optimization problem. When the official regime is Inflation Targeting, the issue of the role played by the exchange rate in the policy rule becomes relevant, and yet it has not received a definite answer so far. On one hand, the literature on inflation targeting suggests that the exchange rate can only play an indirect role in the interest rate rule as a predictor of inflation, because responding directly to exchange rate fluctuations would result in excessive interest rate fluctuations.

On the other hand, the literature on exchange rate regimes classification has shown that as far as the exchange rate policy is concerned, (small open economies) Central Banks' *de facto* policies often deviate from the *de jure* regime, and this ends up in a situation, for many countries with flexible exchange rates, of implicit exchange rate smoothing, that has been termed by Calvo and Reinhart [2002] "Fear of Floating".

A CPI Inflation targeting regime can, as a side product, contribute to the stabilization of the exchange rate and therefore it can be hard to distinguish it from a Fear of Floating regime just

Table 7.4 Regression results

		Estimated Equation				
	Optimal Coefficients	Strict IT	Interest Rate Smoothing	Flexible IT	Fear of Floating 1	Fear of Floating 2
k_0	-	-0.1709 (0.3713)				
k_1	1.000	1.5323[a] (0.1487)				
k_2	91.11	0.8748[a] (0.1502)				
k_3	8.041	0.1784[a] (0.0589)				
k_4	2.255	0.5440[a] (0.0624)				
k_5			0.208 (-)	0.208 (-)	0.208 (-)	0.208 (-)
k_6				0.038 (-)	0.038 (-)	
r			1.462[a] (0.309)	1.996[a] (0.106)	2.865[a] (0.186)	1.464[a] (0.315)
λ_i			0.415[a] (0.090)	0.268[a] (0.028)	0.493[a] (0.051)	0.415[a] (0.091)
λ_r			0.078[a] (0.019)	0.077[a] (0.005)	0.070[a] (0.006)	0.078[a] (0.019)
λ_y				0.220 (0.150)	0.124 (0.220)	0 (-)
λ_e					0.026[a] (0.005)	0.000 (0.010)
δ			0.984 (-)	0.984 (-)	0.984 (-)	0.984 (-)
R^2		0.360	0.967	0.958	0.953	0.953
Reg. SE		1.4117	0.325	0.361	0.382	0.382
D.W. Stat.		0.5144	1.065			1.063
J-stat.		9.6484		0.201	0.238	
Estimation Method		GMM	NLS	GMM	GMM	NLS

HAC Standard Errors in Parenthesis. Instruments used in GMM: constant; $\pi_{t-1},\ldots, \pi_{t-4}$; $y_{t-1},\ldots,y_{t-4}$; $i_{t-1},\ldots,i_{t-4}$; Δw_{t-1} , … , Δw_{t-4} ; $r^l_{t-1},\ldots, r^l_{t-4}$; $\Delta_4 C_{t-1}$, … , $\Delta_4 C_{t-4}$, Δq_{t-2}, … , Δq_{t-4}

[a] estimated coefficient is sign. at 1%, [b] estimated coefficient is sign. at 5%, [c] estimated coefficient is sign. at 10%

using the techniques suggested by the literature on exchange rate classification. By estimating Central Bank preferences using the approach suggested by Favero and Rovelli [2003] and Collins and Siklos [2004], we were able to bridge the gap between exchange rate regime classification schemes and the literature on the estimation of monetary policy rules including explicitly exchange rate smoothing in the Central Bank's objective function. At the same time, we could overcome a well-known critique on Taylor rule coefficients: since they are a convolution of structural and preference parameters, they cannot be given a structural interpretation.

Sweden was the object of the empirical analysis for two main reasons: it has a history of 15 years of Inflation Targeting and the exchange rate of its currency with the euro has shown a substantial stability in the recent years, raising the doubt that some sort of exchange rate smoothing could have been in place.

The results suggest that the Riksbank has been following a policy of Inflation Targeting with interest rate stabilization and smoothing, but not Fear of Floating.

The stabilization of the Krona/euro exchange rate might therefore be the result of the convergence of the business cycles in the two regions, which made sure that the ECB and the Riksbank have been synchronizing their interest rate decisions, and this can be the object of further research on exchange rate stabilization.

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