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by

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# The Choice of Monetary Policy Regime for Small Open Economies*

Kai Leitemo and Øistein Røisland[†]

July 2000

**Abstract**

The paper analyses alternative monetary policy regimes within a simple, estimated macroeconomic model with a traded and a non-traded sector. Two general classes of regimes are considered, inflation targeting and exchange rate targeting, where the latter also includes monetary union. By analysing monetary policy rules within a disaggregated model, the paper adds new insights to the literature on optimal monetary policy rules for open economies. The results suggest that flexible inflation targeting gives lower nominal and real variability than exchange rate targeting or monetary union. The main reason for this is that targeting the nominal exchange rate gives rise to persistent oscillations in the real interest rate and the real exchange rate due to the 'Walter's effect'. Contrary to conventional wisdom, the results suggest that the traded sector is more stable under flexible inflation targeting than under exchange rate targeting.

**Keywords**: Inflation targeting, exchange rate targeting, monetary policy, small open economy.

**JEL Codes**: E42, E61, E32.

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## 1. Introduction

There has been a tendency in recent years to abandon intermediate targets and steer monetary policy directly to its ultimate goal of price stability, in the meaning of low and stable inflation.[1] Since central banks have imperfect control over inflation, there is then a less direct relationship between monetary policy decisions and the target variable. This has triggered a renewed interest in monetary policy rules as guidelines for monetary policy. A small, but growing part of the literature considers open-economy models.[2] There are important differences between the monetary policy transmission mechanism in closed and open economies. In closed economies, monetary policy affects inflation mainly indirectly through its effect on aggregate demand. In open economies, however, there is an additional direct channel through which monetary policy affects inflation, namely through its effect on the exchange rate and thereby on the price of imported goods. Moreover, it is important to make a distinction between traded and non-traded sectors when considering the transmission of monetary policy. The interest rate and the exchange rate affect the two sectors differently. Even if the central bank was only concerned about aggregate output variability, and not about variability in each sector, it should respond differently to disturbances in each sector separately when setting the interest rate. It may be argued, however, that in addition to price stability and aggregate output and employment stability, sector-specific stability also contributes to welfare. The relevance of sectoral stability could be motivated by considering the following stylized example: Suppose there are two policy rules that have the same stabilizing effect on aggregate output, but where one of the rules stabilizes both traded and non-traded output separately, whereas the other produces large fluctuations in both sectors. Most economists would agree that the former rule is preferable to the latter. One reason for this might be the cost of adjustments in production. Then, aggregate stability might conceal considerable variability at the sectoral level. Second, there may be reasons to believe that the cost of transferring resources may be higher between sectors than within each sector.

This paper analyzes the stabilizing properties of alternative monetary policy regimes using a small, estimated open-economy model with a traded, a non-traded and a foreign sector. The model may be viewed as an open-economy extension to the models

[1] See Bernanke and Mishkin (1997) for an overview.

[2] E.g. Svensson (2000), Batini and Haldane (1999) and McCallum and Nelson (1999).

developed by Svensson (1997) and Rudebusch and Svensson (1999). In the growing literature on inflation targeting, we are aware of only a few papers that focus on traded and non-traded sectors. Røisland and Torvik (1999) compare exchange rate targeting and inflation targeting within a simple theoretical model with a traded and a non-traded sector. They find that some earlier results from aggregated models are turned around in a two-sectoral model. For instance, a demand shock may induce higher aggregate output fluctuations under inflation targeting than under exchange rate targeting, which is in contrast to the conventional wisdom. However, their model is kept overly simple, particularly in its dynamic structure, in order to focus on the new mechanism brought about by the two-sectoral structure. Holden (1998) also compares exchange rate targeting and inflation targeting in a model with a traded and a non-traded sector. He focuses, however, on equilibrium unemployment and not on the alternative regimes' stabilizing properties. Chapple (1994) focuses solely on output stability in the traded sector and discusses the optimal weights attached to traded and non-traded goods in the target price index. He finds that targeting traded goods prices provides the highest output stability in the traded sector when the economy faces shocks to demand. Bharucha and Kent (1998) compare aggregate inflation targeting and non-traded inflation targeting within a calibrated dynamic two-sectoral model, much like ours. They find that monetary policy should be more active in response to exchange rate shocks under (flexible) aggregate inflation targeting than under (flexible) non-traded inflation targeting, whereas it should be more active in response to supply and demand shocks under non-traded inflation targeting. They focus, however, on stability in the non-traded sector and do not consider traded sector stability.

It may be argued that in practice there are only two alternative monetary policy regimes for small open economies. First, the country can link its currency to another country's currency, either through exchange rate targeting, as in Denmark and Norway[3], or through abondoning its national currency and entering a monetary union, as the EMU countries. Second, the country can conduct some form of independent inflation targeting, as in Sweden, the United Kingdom and (recently) Switzerland. This paper considers both strict and flexible versions of exchange rate targeting, where the former

[3]The strategy of exchange rate targeting is, however, different in the two countries. Denmark has within a target zone a fixed exchange rate against the euro, while Norway conducts exchange rate targeting in a floating exchange rate regime.

may be interpreted as being part of a monetary union, and strict and flexible versions of inflation targeting. For reasons of comparison, we also consider monetary policy based on the Taylor (1993) rule.

This paper is organized as follows: In Section 2, we present a theoretical open-economy model with a traded and a non-traded sector and estimate the model using Norwegian data. In Section 3, we evaluate the performance of alternative regimes by considering the effects of the various regimes on the stability of inflation, output, real exchange rates and interest rates. We also consider how the performance of the regimes may by improved by a more active use of fiscal policy. Section 4 summarizes the results, and some technical issues regarding the solution procedure are described in an appendix.

## 2. Theoretical framework

We consider a small open economy that consists of two sectors, a traded and a non-traded sector. All variables (except the interest rate) are measured in logs as deviations from steady state. We assume for simplicity that labour is the only variable factor of production and that the wage rate is the same in each sector.[4] There is an equilibrium rate of unemployment, assumed independent of the monetary policy regime, but unemployment can due to nominal inertia be temporarily increased or decreased by economic policy or by shocks. Firms in the traded sectors are price takers on the international markets. Aggregate production in the traded sector is given by

$$y_{t+1}^{T} = \rho_T(L) y_t^T + \kappa \left(p^T - w\right)_{t+1|t} + \varepsilon_{t+1}^{T}, \tag{2.1}$$

where $y_t^T$ is traded sector output in period $t$, $\rho_T(L)$ is a polynomial of lag operators; $p^T$ is the producer price of traded goods, measured in domestic currency; $w_t$ is the nominal wage rate, and $\varepsilon_{t+1}^{T}$ is a white noise supply shock. There is a planning horizon of one period, so that actual production in period $t+1$ is decided in period $t$ based on the expected production real wage in period $t+1$, where the subscript $t+1|t$ denotes the (rational) expectation of a variable at period $t+1$ based on information at period $t$. When estimating the model (see subsection 2.1), we will interpret a 'period' as a quarter. The degree of persistence in production, determined by $\rho_T(L)$, is motivated by cost of

[4] It may be interpreted as centralized wage setting in a unionized economy.

adjustment. Since firms in the traded sector face a perfectly elastic world demand, traded output is determined by the supply side.

The domestic currency producer price of traded goods is given by

$$p_t^T = p_t^* + s_t, \tag{2.2}$$

where $p_t^*$ is the foreign price and $s_t$ is the price of the foreign currency in terms of domestic currency units. There is a slow and imperfect pass-through from producer prices of traded goods to the corresponding consumer prices, which we denote 'imported goods prices', $p^i$. Equalization of imported goods prices and traded goods prices is assumed to be an intermediate run phenomenon. Specifically, we assume, as in Naug and Nymoen (1996), that imported price inflation is given by an equilibrium correction mechanism (ECM):

$$\Delta p_t^i = \tau(L)\Delta s_t + \upsilon(L)\Delta p_{t-1}^i - \mu(L)(p^i - s - p^*)_{t-1}, \tag{2.3}$$

where $s_t$ is the nominal exchange rate and $\Delta$ is the difference operator.

Firms in the non-traded sector face only domestic demand, which is given by

$$y_{t+1}^N = \rho_N(L)y_t^N - \alpha(L)r_t + \beta(L)e_t + \varepsilon_{t+1}^N, \tag{2.4}$$

where $r$ is the real interest rate; $e_t \equiv s_t + p_t^* - p_t$ is the real exchange rate, defined as the relative price of traded goods to non-traded goods, and $\varepsilon_{t+1}^N$ is a shock to non-traded demand. The real interest rate is assumed to have a negative effect on non-traded sector demand due to intertemporal substitution effects, while the real exchange rate is assumed to have a positive effect due to intra-temporal substitution effects between traded and non-traded goods.

There is monopolistic competition in the domestic economy, which implies that firms set prices as a mark-up on costs. We assume, for simplicity, that the mark-up is independent of the level of activity, i.e.,

$$p_t = w_t, \tag{2.5}$$

where $p_t$ is the price of non-traded goods.

Aggregate production is a weighted average of production in the two sectors, i.e.

$$y_t \equiv \eta y_t^T + (1-\eta) y_t^N, \tag{2.6}$$

where $\eta$ is the share of traded production in steady state, $0 < \eta < 1$.

Aggregate consumer price (CPI), $p_t^c$, is given by a weighted average of imported goods prices and non-traded goods prices:

$$p_t^c = \theta p_t^i + (1-\theta) p_t, \tag{2.7}$$

and we denote $\pi_t^c \equiv p_t^c - p_{t-1}^c$.

Wages are set according to a standard wage curve relationship (Blanchard and Katz, 1999), specified as an equilibrium correcting model, as in Bårdsen et al. (1999), i.e.

$$\Delta w_{t+1} = \rho_\pi(L)\pi_t^c + \gamma y_t - \lambda(L)(w_t - p_t^c) + \varepsilon_t^w, \tag{2.8}$$

where $\pi_t^c \equiv p_t^c - p_{t-1}^c$ is quarterly consumer price inflation, and the equilibrium correcting mechanism is captured by the last term.

The exchange rate is determined by uncovered interest rate parity (UIP), i.e.

$$s_t = s_{t+1|t} - .25(i_t - i_t^*) + u_t, \tag{2.9}$$

where $i_t$ and $i_t^*$ are the domestic and world nominal interest rate respectively, and $u_t$ is a stochastic risk premium which follows the process $u_t = \phi u_{t-1} + \varepsilon_t^u$, where $\varepsilon_t^u$ is white noise. The coefficient of 0.25 on the interest rate differential is due to quarterly annualization. Due to the assumption of a small open economy, the world economy can be treated as exogenous to the domestic economy. World inflation is for simplicity assumed to be given by the following Phillips curve relationship:

$$\Delta p_{t+1}^* = \rho_{p*}(L)\Delta p_t^* + \gamma y_t^* + \varepsilon_t^{p*}, \tag{2.10}$$

where $\Delta p_{t+1}^*$ is world inflation, defined by the change in the foreign currency price of traded goods, $\rho_{p*}(L)$ is a polynomial of lag operators which represents inflation persistence; $y_t^*$ is the world output gap, and $\varepsilon_t^{p*}$ is a shock to world inflation. Aggregate world demand is negatively affected by the world real interest rate $r^*$, i.e.

$$y^*_{t+1} = \rho_{p*}(L)y^*_t - a(L)r^*_t + \varepsilon^{y*}_t. \tag{2.11}$$

It is assumed that the world monetary policy is characterized by flexible inflation targeting. Specifically, the world interest rate is found by solving the following minimization problem[5]:

$$\min_{i^*_t} E_0 \sum_{s=0}^{\infty} [(\Delta p^*)^2 + .5{y^*_t}^2 + .5(\Delta i^*_t)^2]. \tag{2.12}$$

The solution to the problem gives an implicit rule where the interest rate depends on lagged interests rates, on current and lagged inflation rates and on current and lagged output, i.e.

$$i^*_t = i(L)i^*_{t-1} + j(L)\Delta p^*_t + k(L)y^*_t. \tag{2.13}$$

The two-sector structure allows for a more detailed description of the monetary policy transmission mechanism than the standard one-sector open economy models. Monetary policy impulses are transmitted to inflation through four channels, one of them due to a change in the interest rate and three to a change in the exchange rate. First, there is a conventional real interest rate channel, working through non-traded output (and thereby aggregate output) and then onto wage and price inflation. Second, a change in the interest rate also affects the exchange rate. The exchange rate affects output in the traded sectors and, although to a lesser extent, output in the non-traded sector, which thereby affects wage and price inflation. Third, a change in the exchange rate has a direct effect on inflation through prices of imported goods. This is the fastest channel through which monetary policy affects inflation. Fourth, a change in the exchange rate also affects wage inflation in a more direct way than the first two channels. Nominal wage increases depend partly on realized CPI inflation, which is directly affected by the exchange rate through the third channel.

[5]See the appendix for description of the optimization procedure.

### 2.1. Estimation

The equations in the model are estimated using Norwegian data. We have used OLS if not otherwise stated[6]. Due to a large petroleum sector, Norway is somewhat different from most small open economies within the group of industrialised countries. However, one would expect that the mainland economy (i.e. excluding the petroleum and shipping sectors) provides a reasonably representative example of a small open economy. The estimated model is shown in Table 2.1. All variables, except the interest rates, are log-transformed. Variables are detrended using a Hodrick-Prescott-filter with a (standard) smoothing coefficient of 1600, allowing for possible varying trends. We have followed a general-to-specific estimation strategy throughout, letting data determine the number of lags needed to produce a seemingly good econometric specification of the different processes.

It is assumed in the model that there is a sharp distinction between the traded and non-traded sectors. In practice, there are various degrees of foreign competition in product markets. The distinction between traded and non-traded sectors thus relates to a continuum rather than a dichotomy. However, in order to operationalise the distinction, we used manufacturing output as a proxy for the traded sector output and the rest of GDP (excl. petroleum sector) as non-traded sector production.[7] The real product price was proxied by the detrended series of the real exchange rate, defined as the effective exchange rate corrected for the CPI inflation differential between Norway and its trading partners. Production in the traded sector is based on the expected production real wage one quarter ahead. The traded sector supply curve is estimated using the instrumental variable method with the real exchange rate instrumented by five lags of the seasonally adjusted unemployment rate, five lags of the detrended real exchange rate and three (remaining) lags of the independent variable.

As a measure of the real interest rate, we used the detrended series of the four-quarter moving average of the difference between the 3-month NIBOR interest rate and

[6] Constants and seasonal dummies were included in the set of regressors, but not reported.

[7] The equilibrium share of traded goods output to aggregat output where set to $\eta = 0.15$, which approximately reflects the manufacturing output average share during the 1990's.

**Table 2.1**
**Model estimates**

**Traded sector output**

$$y^T_{t+1} = \underset{(.12)}{.48} y^T_t + \underset{(.12)}{.23} y^T_{t-1} + \underset{(.11)}{.23} \left(p^T - w\right)_{t+1|t} + \varepsilon^T_{t+1}$$

$$\sigma = 1.51\% \quad DW = 1.96 \quad Sample : 1980 : 2 - 1999 : 2$$

**Non-traded sector demand**

$$y^N_{t+1} = \underset{(.09)}{.41} y^N_t - \underset{(.09)}{.18} y^N_{t-2} + \underset{(.09)}{.20} y^N_{t-3} - \underset{(.13)}{.26} \overline{r}_t + \underset{(.07)}{.16} e_{t-1} + \varepsilon^T_{t+1}$$

$$\sigma = 1.09\% \quad DW = 2.19 \quad Sample : 1981 : 2 - 1999 : 2$$

**Wage curve**

$$\Delta w_{t+1} = \underset{(-)}{.59} \pi^c_t + \underset{(.12)}{.41} \pi^c_{t-1} + \underset{(.05)}{.125} y_t - \underset{(.03)}{.05} (w - p^c)_{t-1} + \varepsilon^w_{t+1}$$

$$\sigma = 1.26\% \quad AR\ 1-5\ F(5,106) = 2.14[.07] \quad Sample : 1966 : 4 - 1996 : 4$$

**Imported price inflation**

$$\Delta p^i_t = \underset{(.16)}{.34} \Delta s_t + \underset{(.10)}{.18} \Delta p^i_{t-1} - \underset{(.06)}{.26} (p^i - s - p^*)_{t-1} + \varepsilon^{pi}_t$$

$$\sigma = 2.67\% \quad DW = 1.97 \quad Sample : 1972 : 1 - 1998 : 3$$

**Foreign inflation process**

$$\Delta p^*_{t+1} = \underset{(-)}{.627} \Delta p^*_t + \underset{(.12)}{.039} \Delta p^*_{t-1} + \underset{(.095)}{.281} \Delta p^*_{t-2} + \underset{(.028)}{.054} y^*_{t-2} + \varepsilon^{p*}_{t+1}$$

$$\sigma = 0.23\% \quad AR\ 1-5\ F(5,61) = .99[.43] \quad Sample : 1980 : 2 - 1999 : 1$$

**Foreign output process**

$$y^*_{t+1} = \underset{(.052)}{.816} y^*_t - \underset{(.058)}{.238} \overline{r}^*_t + \varepsilon^{y*}_{t+1}$$

$$\sigma = 0.39\% \quad DW = 2.08 \quad Sample : 1976 : 3 - 1998 : 4$$

**Risk premium**

$$u_{t+1} = \underset{(.13)}{.33} u_t + \varepsilon^u_{t+1}$$

$$\sigma = 0.95\% \quad AR\ 1-4\ F(4,54) = 1.72[.16] \quad Sample : 1981 : 2 - 1996 : 4$$

Standard errors in parentheses.
Constants, seasonal and other dummies are not reported in this table.

the quarterly change in the consumer price index in annual terms, i.e.

$$\bar{r}_t = \frac{1}{4}\sum_{j=0}^{3}(i_{t-j} - 4\pi^c_{t-j}).$$

Equation (2.4) is estimated using (mainland) GDP minus manufacturing production as the left hand side variable.[8] The coefficient on the real exchange rate was somewhat higher than what one might expect. This may reflect the lack of a clear-cut distinction between traded and non-traded sectors, so that our proxy for the non-traded sector may include sectors that face some foreign competition.

In the estimation of the wage curve, we draw heavily on Bårdsen et al. (1999) for the precise functional form. Dynamic homogeneity in inflation was accepted by data with $\chi^2(1) = .23[.63]$ and henced imposed. The consumer real wage, $(w - p^c)$, is measured as deviations from the equilibrium real consumer wage, which is given by the level of productivity. As a measure for the (aggregate) output gap, we use the detrended series of aggregate mainland production.[9]

The estimation of the import price equation, (2.3), we impose complete long-run pass-through from foreign prices (trade-weighted export prices) in domestic currency units onto imported goods prices.[10] Our estimated coefficients suggest a pass-through from the exchange rate to import prices of about 88 percent after one year and a pass-through from foreign prices of about 78 percent.

In order to model the foreign sector, we use available data for Norway's trading partners. Foreign output is proxied by the trade-weighted GDP, foreign prices are measured by a trade-weighted consumer price index and the short-run interest rate is measured as the trade-weighted 3-month interest rate. The measure for the real interest rate was constructed as explained above. Dynamic homogeneity was accepted by data with $\chi^2(1) = 3.46[.06]$ in the CPI inflation regression.[11]

[8] Dummies were included for the following periods: 1982:1, 1985:4, 1986:2, 1987:4 and 1997:2.

[9] The regression also included the series of employers' tax rate and the indirect (VAT) tax rate in order to control for the effect of these taxes on wage growth. Since the study of these fiscal decision variables are not central to our study, the effects of these tax rates were not included in the subsequent model.

[10] A Norwegian study by Akram (1999) finds support for a cointegrating relationship between imported manufacturing goods prices and foreign export prices in Norwegian data.

[11] Dummies for the 1979:2 and 1980:2 quarters were included in the foreign output regression and for 1991:1 and 1985:2 in the foreign inflation regression.

In order to construct a series of deviation from the uncovered interest rate parity condition[12] - defined here as the risk premium - we first regressed the log of the effective nominal exchange rate on six lags of the foreign interest rate, the domestic interest rate, the output gap, the nominal effective exchange rate and the detrended series of the real exchange rate. The fitted values ($\widehat{s}_{t+1|t}$) from this regression were then assumed to be a proxy for the expected nominal exchange rate given one-period lagged information. The risk premium was then calculated as:

$$u_t = 0.25(i_t - i_t^*) - (\widehat{s}_{t+1|t} - s_t).$$

We modelled the risk premium as an autoregressive disturbance process where no *a priori* restrictions were placed on the order of the process. We found that a simple AR(1) process fit the data reasonably well over the period 1981:2 to 1996:4, and additional lags had no significant effect. We used the residuals from this regression equation as a measure of the risk premium shocks hitting the economy.

In order to obtain estimates of the distribution for the remaining structural shocks, we constructed a structural vector autoregression model[13] with contemporaneously recursive structure and estimated it over the period 1980:2 to 1996:4. The model contained foreign output (as defined above), foreign inflation, foreign trade-weighted 3-month interest rate, manufacturing output, non-manufacturing output (less petroleum production), the short 3-month domestic interest rate, hourly aggregate wages, the nominal exchange rate and imported goods prices in the order stated. The variance-covariance matrix was constructed for the shocks to the variables included in our model, i.e. foreign output, foreign inflation, manufacturing output, non-manufacturing output, wages, imported goods

[12] We impose uncovered interest rate parity, adjusted for an autoregressive risk premium. We tested these restrictions by regressing the effective nominal interest rate onto the fitted values of the nominal exchange rate from the above regression (but excluding the one-period lagged nominal and real exchange rate as instruments in order to avoid simultaneity problems) and the domestic and foreign interest rates and allowing for autoregression of order one using autoregressive least squares, and obtained for the period 1983:1-1996:4,

$$s_t = \psi_s \hat{s}_{t+1} - \psi_i i_t + \psi_{i*} i_t^* + .19\widehat{u}_{t-1} + \widehat{u}_t,$$

where $\psi_s = .97, \psi_i = .15$ and $\psi_{i*} = .05$. The restrictions $\psi_s = 1; \psi_i = \psi_{i*} = .25$ were accepted by data at $\chi^2(3) = 2.76[0.43]$.

[13] Alternatively, we could have proceeded by using the residuals from the regression equation as measures of the structural shocks. However, these residuals are critically dependent on the possibly controversial parameter restrictions imposed in the estimation of the model. It is possible that our chosen approach is less likely to be criticised since it is less dependent on a restrictive model.

prices and the risk premium.

Although numerical models may be viewed as special cases, and the choice of parameter values may always be questioned, we believe that our parameter estimates are not *a priori* unreasonable. In addition, the parameter estimates are broadly consistent with other comparable models.

## 3. Monetary policy regimes

As argued in the introduction, there are in practice two alternative monetary policy regimes for small open economies: The country may either link its currency to another currency (or basket of currencies) or it may steer monetary policy more directly to its ultimate goal(s). Within the first group, there is a continuum of variants ranging from adopting another country's (or group of countries') currency, via traditional fixed exchange rate regimes to more flexible variants of exchange rate targeting. Within the second general group of regimes, there is a continuum of variants that differ with regard to the weights attached to variables other than inflation when deciding the interest rate. We have chosen to consider two sub-groups of each group, a strict version of the regime and a flexible version. In the strict versions of the regimes, the sole objective is to minimize variability of the primary target variable. Under flexible targeting there could be several other secondary variables that are targeted in addition to the primary variable, denoted by the regime name. There is, in principle, an infinite number of flexible regimes, depending on the weights attached to variables in the loss function. However, we only consider one type of flexibility, namely that the monetary authority attaches weight to aggregate output and nominal interest rate smoothing in addition to the main target variable.

We assume that the target(s) for monetary policy, whether ultimate or intermediate, are decided by the government. The central bank is assumed to be instrument independent, so that the bank sets the interest rate in order to achieve the target(s). Such a definition of a monetary policy regime describes the institutional arrangements for monetary policy in many countries today, although some central banks (e.g. the European Central Bank and Sveriges Riksbank) have 'narrow' goal independence, which means that they are free to specify the more general goals given by the political authorities.

The distinction between goal independence and instrument independence becomes less important, however, when the central bank is given a mandate to hold the exchange rate fixed, since there is little room for manoeuvring in the instrument setting.

The above definition of a monetary policy regime is consistent to what Svensson calls 'targeting rules' (see e.g., Svensson, 1999, 2000). In addition to considering such 'targeting rules', we consider monetary policy based on a Taylor rule in order to compare the results from 'targeting rules' with an 'instrument rule' that has received considerable attention in the literature.

### 3.1. Characterization of regimes

A targeting rule can be defined by the following optimization problem:

$$\min_{i_t} E_0 \sum_{t=0}^{\infty} L_t, \tag{3.1}$$

where $L_t$ is a function of the target variables and the nominal interest rate, $i$ is the monetary policy instrument. As is common in the literature, we assume that the loss function is linear-quadratic. Specifically, we consider the following loss function:

$$L_t = a_\pi (\pi_t^c)^2 + a_s s_t^2 + a_y y_t^2 + a_{\Delta i} (\Delta i_t)^2. \tag{3.2}$$

Based on this loss function, we characterize the regimes as follows:

**1.a Strict inflation targeting:** $a_\pi = 1, a_s = 0, a_y = 0, a_{\Delta i} = 0$

**1.b Flexible inflation targeting:** $a_\pi = 1, a_s = 0, a_y = .5, a_{\Delta i} = .5$

**2.a Strict exchange rate targeting:** $a_\pi = 0, a_s = 1, a_y = 0, a_{\Delta i} = 0$

**2.b Flexible exchange rate targeting:** $a_\pi = o, a_s = 1, a_y = .5, a_{\Delta i} = .5$

In the strict versions of the regimes, only the primary target variable enters the loss function. Under strict inflation/exchange rate targeting, the interest rate is set so as to minimize the expected sum of deviations of the inflation/exchange rate from the target. In the flexible versions of the regimes, the central bank also attaches weights to output and to the change in the interest rate. The weight attached to $\Delta i_t$ represents 'interest rate smoothing', which seems to be an important feature of monetary policy in practice (Froyen and Waud, 1995; Goodhart, 1996). In our model, it is not obvious that $\Delta i_t$

should enter as a separate argument in the loss function. However, it can be argued that in a larger model with a financial sector explicitly modelled, interest volatility may have significant costs and should therefore be included. Another reason for interest rate smoothing is that the central bank is uncertain about the true economic model. A cautionary strategy, implied by interest rate smoothing, may have attractive features, as shown by Brainard (1967). It turns out that interest rate smoothing may also in some circumstances have a positive effect on the discretionary equilibrium, leading to lower variability of the targeted variables (see Woodford, 1999; Leitemo and Røisland, 1999). An additional reason for interest rate smoothing is that central banks may find it costly in terms of loss of public prestige if they reverse a change in the interest rate. Several small steps may therefore be preferable to one large step. In our analysis, the weights attached to $\Delta i_t$ as well as to $y_t$ are somewhat arbitrarily set to .5.

Although we argued in the introduction that there are reasons to include sectoral output variability in the loss function, in addition to aggregate output variability, we do not include each sector separately in the loss functions representing flexible targeting. The reason for this is that we have not found any evidence that sectoral considerations play any significant role in practice when central banks set the interest rate.[14]

A formal treatment of the optimization procedure is given in Appendix A. The procedure calculates the rational expectations solution for a given policy rule and iterates on the policy rule to produce the minimum loss. Because we have a forward-looking variable in the model, i.e. the exchange rate, there is a difference between the discretionary solution and the commitment solution of the optimization procedure. We assume that the central bank does not possess the commitment technologies to make the commitment solution credible, and, therefore, we focus on the discretionary, time-consistent solution (see Backus and Driffill, 1986).

The optimal time-consistent rule, that is, the rule that minimizes the loss given by

[14] A citation from a speech by George (1999, p. 4), the Governor of the Bank of England, illustrates this: "We are concerned - as you are - with the health of every sector of the economy, we fully appreciate the interdependence of the different sectors, and we well understand the part that greater real exchange rate stability can play in promoting more balanced economic growth.[...]. But we can only hope to maintain macro-economic stability for the economy as a whole. What we cannot hope to do is to provide an equally stable environment for every sector of the economy or for every business enterprise ..."

Moreover, King (1999, p. 4), Deputy Governor, says that "...I do not offer any simple solutions to the imbalances between different parts of the British economy. [...] Interest rates cannot target both inflation and asset prices, whether the exchange rate or share prices or house prices. Nor should they. Interest rates must focus on the economy-wide inflation target."

(3.2), is in general a feedback rule where the instrument (the nominal interest rate) depends on all the state variables, i.e.

$$i_t = FX_t, \tag{3.3}$$

where $X_t$ is the vector of state variables and $F$ is a vector of response coefficients. These specific, implicit rules associated with the alternative regimes, are reported in Table 3.1. As illustrated by the table, implicit instrument rules like (3.3) are generally rather complex in models with reasonably rich dynamics. Moreover, optimal rules are model dependent, and one rule that is optimal within one specific model may give poor results in other models. For these reasons, there has been increased focus in the literature on simple instrument rules that are based on a small set of state-variables. Particularly, the Taylor rule, where the interest rate is a function only of the inflation rate and the output gap, has received considerable attention (see e.g., Taylor, 1999). It is therefore of interest to analyse the performance of the Taylor rule in this model of a small open economy and to compare it with the monetary policy regimes specified above. Since the variables in our models are measured as deviations from their equilibria, the Taylor rule may be written as

$$i_t = 1.5\pi_t^c + .5y_t. \tag{3.4}$$

Note that neither of the right-hand side variables in the Taylor rule enter the optimal, implicit rule (3.3). This reflects that the sub-components in the aggregate variables $\pi_t^c$ and $y_t$ should in general enter separately in the optimal rule when the determination of prices and output in the two sectors is different.

### 3.2. Performance of alternative regimes

Ideally, a comparison of the performance of alternative monetary policy regimes should be carried out in the context of an indisputable welfare criterion. Unfortunately, such a welfare criterion does not as yet exist. It has, however, become customary to consider welfare implications by the use of a (linear-quadratic) loss function where only inflation and aggregate output enter as arguments. There are, however, two disadvantages to this

**Table 3.1**
**Implicit interest reaction functions**

| State variables, $X_t$ | Strict $s$-targ | Flex $s$-targ. | Strict $\overline{\pi}^c$-targ. | Flex $\overline{\pi}^c$-targ. |
|---|---|---|---|---|
| $y_t^*$ | .68 | .45 | .68 | .29 |
| $y_{t-1}^*$ | .13 | .09 | .13 | .04 |
| $y_{t-2}^*$ | .15 | .10 | .15 | .04 |
| $\pi_t^*$ | 3.03 | 1.95 | $-.02$ | .83 |
| $\pi_{t-1}^*$ | 1.27 | .81 | 1.27 | .45 |
| $\pi_{t-2}^*$ | 1.09 | .68 | 1.09 | .35 |
| $\pi_{t-3}^*$ | .17 | .08 | .17 | .08 |
| $i_{t-1}^*$ | .41 | $-.020$ | .41 | $-.08$ |
| $i_{t-2}^*$ | $-.08$ | $-.054$ | $-.08$ | $-.04$ |
| $i_{t-3}^*$ | $-.04$ | $-.027$ | $-.04$ | $-.02$ |
| $e_{t-1}$ | – | 0.00 | $-.72$ | $-.02$ |
| $p_t$ | – | 0.19 | 12.83 | .75 |
| $p_{t-1}$ | – | $-.06$ | $-.33$ | $-.27$ |
| $p_{t-2}$ | – | $-.05$ | 5.60 | $-.23$ |
| $p_{t-3}$ | – | $-.02$ | 14.02 | $-.08$ |
| $p_{t-4}$ | – | $-.01$ | $-32.44$ | $-.06$ |
| $y_t^T$ | – | .012 | $-.33$ | .02 |
| $y_{t-1}^T$ | – | .003 | $-.00$ | .00 |
| $y_t^N$ | – | .034 | $-1.85$ | .09 |
| $y_{t-1}^N$ | – | $-.01$ | $-.01$ | $-.01$ |
| $y_{t-2}^N$ | – | .01 | .01 | .01 |
| $y_{t-3}^N$ | – | .01 | $-.01$ | .02 |
| $p_{t-1}^{IM}$ | – | .06 | 11.00 | .24 |
| $p_{t-2}^{IM}$ | – | $-.06$ | 1.68 | $-.26$ |
| $p_{t-3}^{IM}$ | – | $-.01$ | 9.35 | $-.06$ |
| $p_{t-4}^{IM}$ | – | $-.01$ | $-21.62$ | $-.04$ |
| $u_t$ | 4 | .73 | 3.97 | .30 |
| $i_{t-1}$ | – | .48 | .01 | .59 |
| $i_{t-2}$ | – | $-.04$ | .00 | $-.02$ |
| $i_{t-3}$ | – | $-.01$ | .00 | $-.01$ |
| $\varepsilon_t^{im}$ | – | .11 | 8.93 | .49 |

The reaction function under strict exchange rate targeting is equal to the foreign reaction function except for the response to the risk premium. Hence, $i_t = i_t^* + 4u_t$.

**Table 3.2**
**Stabilization properties. Standard deviations in percent.**

| $\bar{\pi}^c$ | $y^T$ | $y^N$ | $y$ | $s$ | $e$ | $i$ | $\Delta i$ |
|---|---|---|---|---|---|---|---|
| *Strict inflation targeting* | | | | | | | |
| 0.00 | 3.19 | 4.69 | 4.08 | $\infty$ | 6.95 | 14.78 | 16.79 |
| *Flexible inflation targeting* | | | | | | | |
| 1.66 | 1.94 | 1.27 | 1.26 | $\infty$ | 3.08 | 2.41 | 0.99 |
| *Strict exchange rate targeting* | | | | | | | |
| 2.68 | 3.67 | 2.03 | 2.05 | 0.00 | 5.29 | 4.26 | 4.58 |
| *Flexible exchange rate targeting* | | | | | | | |
| 2.33 | 2.95 | 1.46 | 1.55 | 1.30 | 4.29 | 1.72 | 0.88 |
| *Taylor rule* | | | | | | | |
| 2.07 | 2.75 | 1.85 | 1.79 | $\infty$ | 4.08 | 3.48 | 1.98 |
| $EMU_{\frac{1}{2}}$ | | | | | | | |
| 2.63 | 3.54 | 1.81 | 1.88 | 0.00 | 5.10 | 2.60 | 2.35 |
| $EMU_0$ | | | | | | | |
| 2.60 | 3.49 | 1.71 | 1.81 | 0.00 | 5.02 | 1.68 | 0.60 |

approach. First, the relative weight attached to output in the welfare loss function is difficult to calibrate. Second, and more importantly, there might be additional variables entering the true welfare loss function. For example, it may be argued that, in small open economies, exchange rate variability affects welfare directly, in addition to its effect on CPI inflation variability, due to the role of the exchange rate in international trade and financial stability. In addition, as argued in the introduction, disaggregated (sectoral) stability may be considered important in addition to aggregate stability. Thus, due to the arbitrariness of measuring the performance of the alternative monetary policy regimes in terms of a single welfare criterion, we have chosen to compare the regimes in terms of the variability of each variable separately.

The unconditional standard deviations of the variables under the alternative regimes are summarized in Table 3.2. Note that the unconditional standard deviation of the nominal exchange rate is infinite under inflation targeting and under the Taylor rule. The reason is that these regimes imply base drift in the differential between the domestic and foreign price level, so that the nominal exchange rate becomes non-stationary. It may, however, be argued that it is the variability of the *real* exchange rate, as opposed to the nominal exchange rate, that may have a potential welfare cost in small open economies. Thus, the variability of the nominal exchange rate could be disregarded when discussing the performance of alternative regimes.

Not surprisingly, strict inflation targeting leads to the lowest CPI inflation variability of the alternative regimes. However, as also illustrated in Figures 3.1 - 3.3, which show the effects on the key variables of a cost-push shock, a non-traded demand shock and a risk premium shock to several key variables, strict inflation targeting leads to large variability in all the other variables, and in particular the interest rate. The reason is that strict inflation targeting implies an aggressive monetary policy, where the direct exchange rate channel is used extensively in order to keep the inflation rate perfectly stable. The aggressive policy results in large fluctuations in the real variables. This result thus confirms the theoretical results of Svensson (2000) and Ball (1999).

A more surprising result is perhaps the relative attractiveness of flexible inflation targeting, as indicated by the simulation results. Of all the regimes considered, flexible inflation targeting provides the lowest variability in all the real variables, including the real exchange rate. In addition, its effect on inflation stability is only outperformed by strict inflation targeting. Why does flexible inflation targeting provide a more stable real exchange rate than exchange rate targeting does? As indicated by the figures, exchange rate targeting generates more noticeable oscillations in the variables and slower convergence to equilibrium. The reason for this lies in the 'Walter's effect' (Walters, 1986). In the case of strict exchange rate targeting, the domestic interest rate must follow the foreign interest rate, adjusted for risk premium shocks. A shock that affects domestic inflation thus affects the real interest rate and thereby the real exchange rate. The mechanism may be explained as follows: Increased domestic inflation, due e.g., to a cost-push shock or a positive non-traded demand shock, reduces the real interest rate, which reinforces the increase in inflation and thereby the decrease in the real interest rate. Since the nominal exchange rate is constant under strict exchange rate targeting, the increased inflation leads to a gradual real exchange rate appreciation. Eventually, the dampening effect of the real appreciation more than offsets the expansionary effect of a lower real interest rate, and the cycle turns. Inflation will then start to decrease, which increases the real interest rate, and the cycle will turn again when the expansionary effect of a real exchange rate depreciation due to low inflation more than offsets the dampening effect of a higher real interest rate. Although a shock will generate such oscillations in the key variables, the estimated coefficients in the model ensures stability, so that the oscillations diminish. Flexible exchange rate targeting will generate less pronounced responses, but the same type of oscillations.

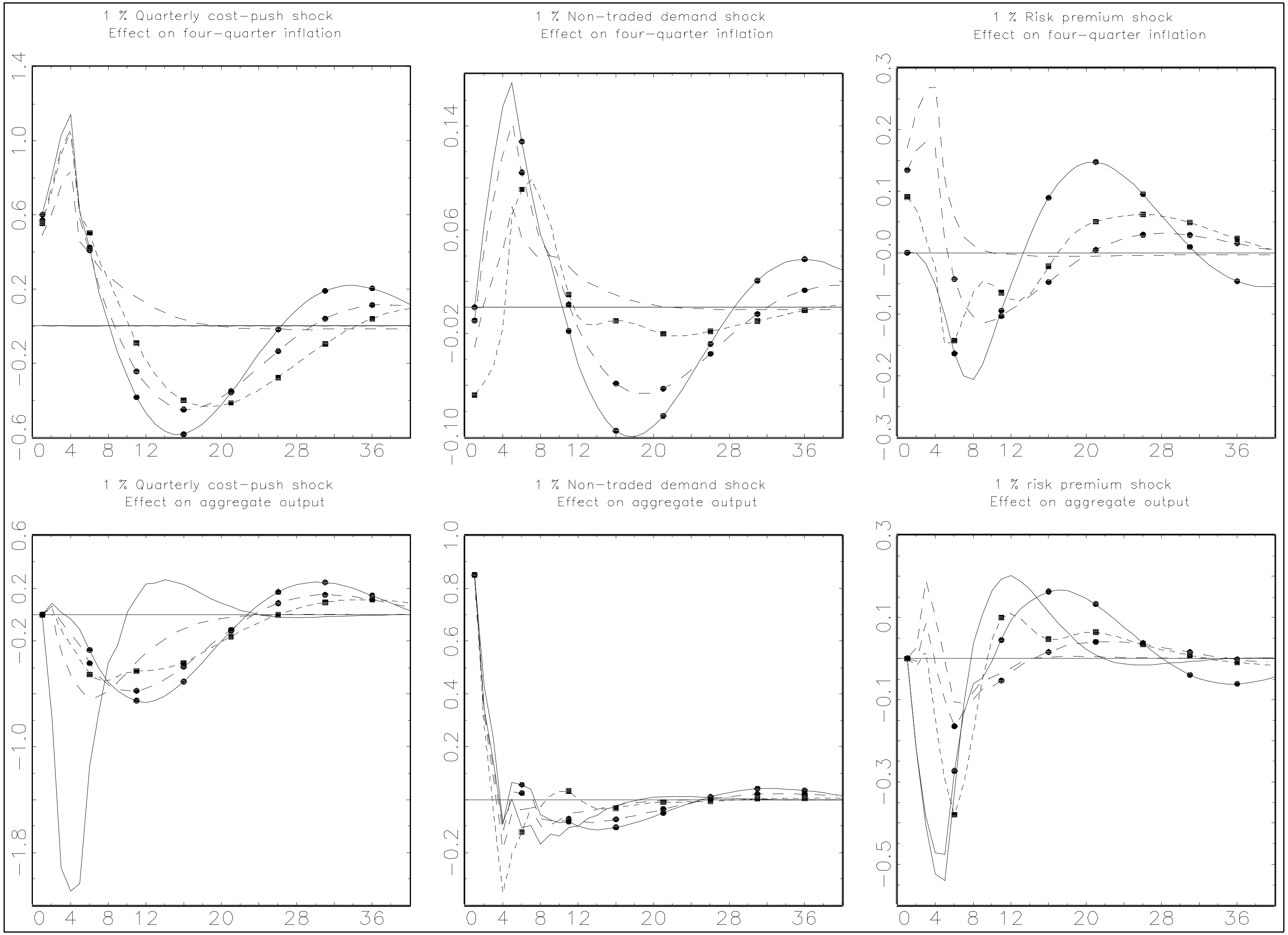


Figure 3.1: **Impulse responses on inflation and aggregate output.**
**A solid (dashed) line denotes a strict (flexible) targeting regime. Circles denote an exchange rate targeting regime, and squares the Taylor rule.**

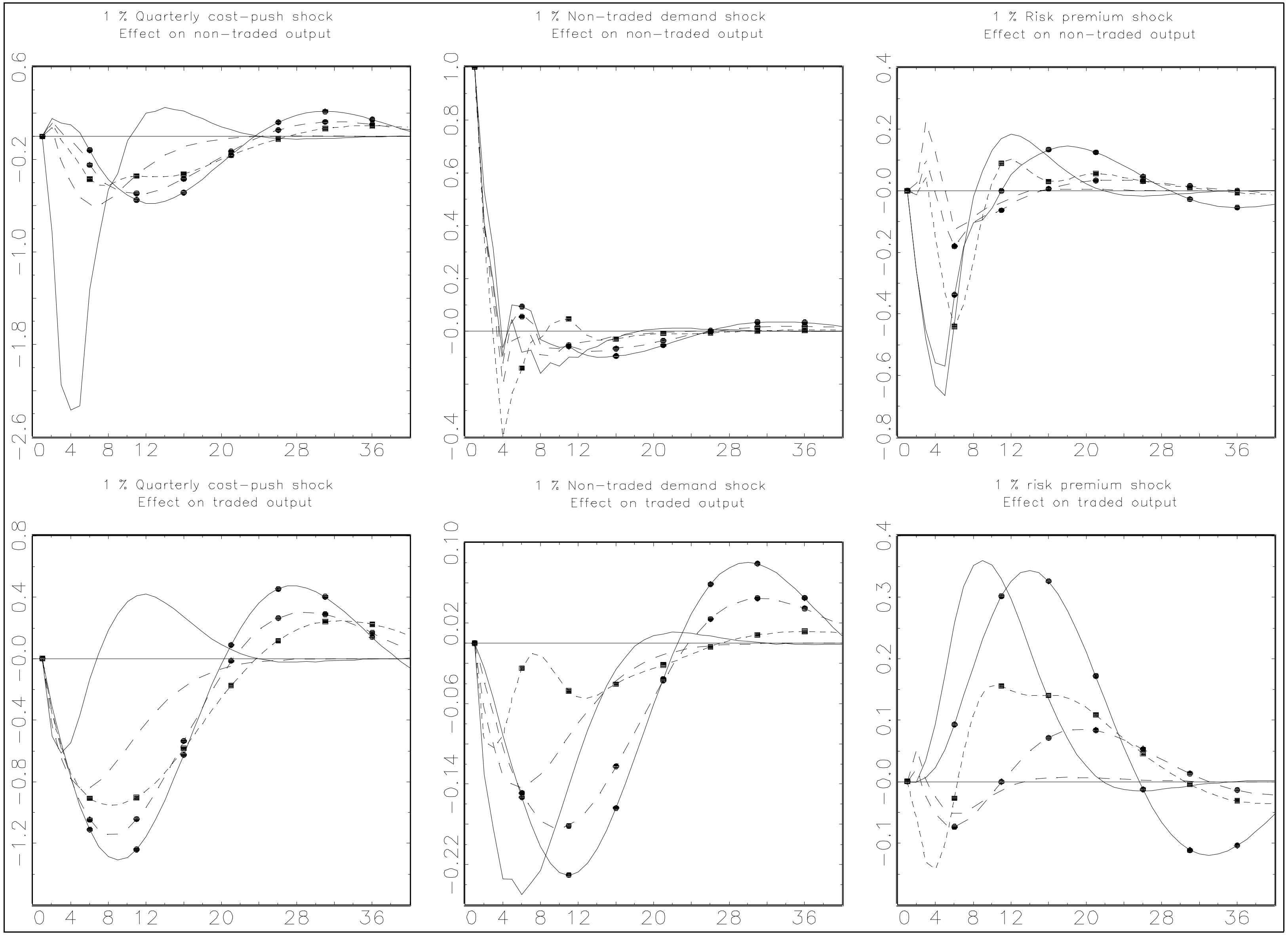


Figure 3.2: **Impulse responses on traded and non-traded output.**
**A solid (dashed) line denotes a strict (flexible) targeting regime. Circles denote an exchange rate targeting regime, and squares the Taylor rule.**

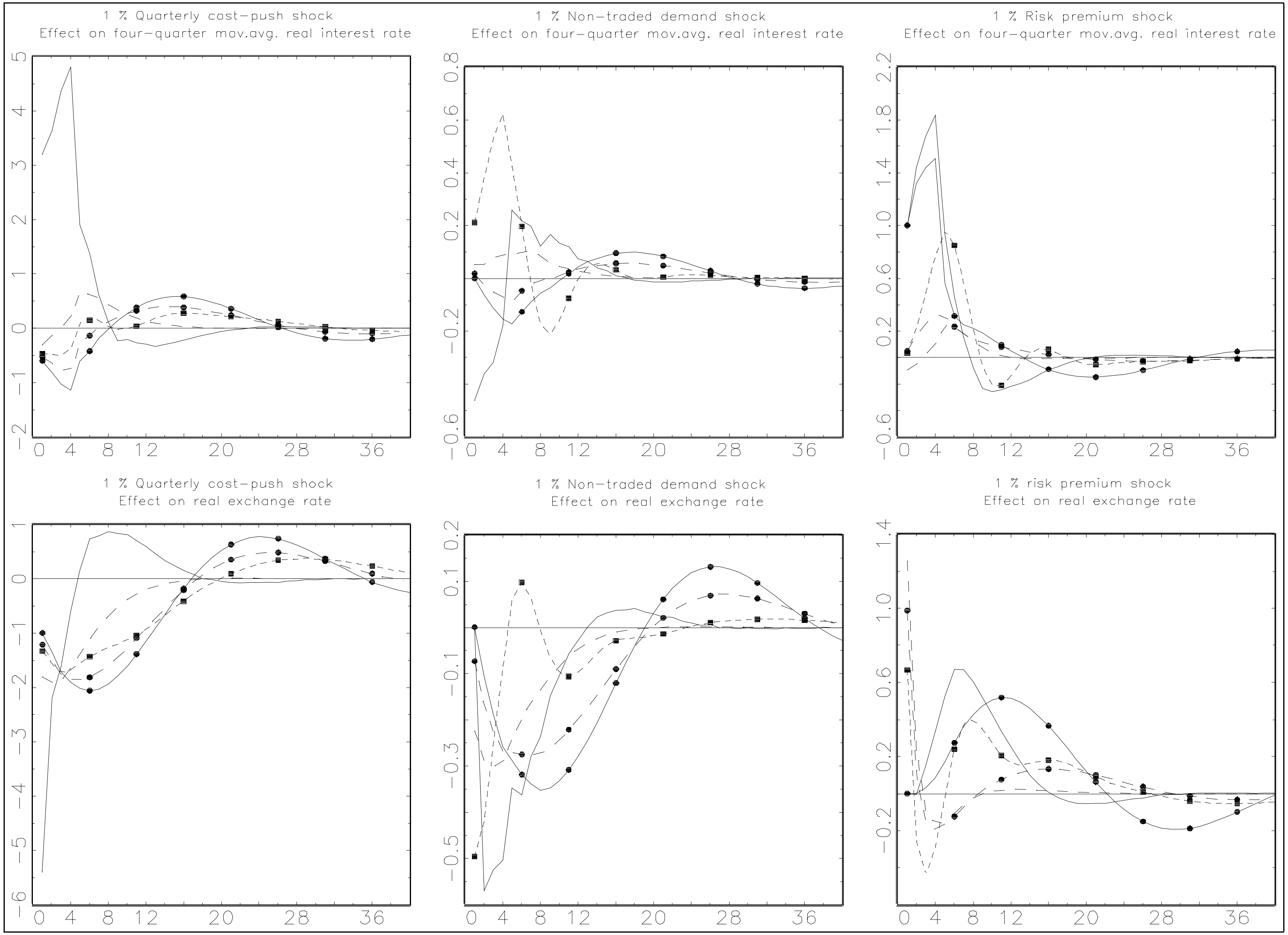


Figure 3.3: **Impulse responses on real interest rate and real exchange rate. A solid (dashed) line denotes a strict (flexible) targeting regime. Circles denote an exchange rate targeting regime, and squares the Taylor rule.**

Another reason for the relatively poor performance in terms of output and inflation variability of exchange rate targeting compared with flexible inflation targeting, is related to the distinction between targeting the price level and targeting the inflation rate. A target for the level of the nominal exchange rate may be thought of as an implicit long-run price level target, where the domestic price level must over time have a constant relation to the foreign price level in order to achieve consistency between the equilibrium real exchange rate and the nominal exchange rate target. If domestic inflation increases, it is thus not sufficient to bring the inflation rate down to the same level as the world rate of inflation. A period with a lower inflation rate than the world rate is required to achieve the noted consistency. This requires a period with a negative output gap.

A third reason for the relatively high degree of inflation and output variability under exchange rate targeting is that the central bank must respond more vigorously to risk premium shocks than is the case under inflation targeting. Under strict exchange rate targeting, there is a one-to-one relationship between the interest rate and the annualized risk premium.

An alternative to keeping the domestic currency in a fixed relation to a foreign currency is adopting the foreign currency by joining a monetary union. One advantage of a monetary union compared to pegging the exchange rate is that the risk premium between the domestic currency and the union currency is removed. The average risk premium of the domestic currency relative to the trade partners' currencies is thus reduced. The larger the share of trade with the union, the more the trade-weighted risk premium is reduced. A full analysis of a monetary union would require a three-country framework with the home country, the union and the 'rest of the world'. A full specification would be particularly important if one analyses game situations between the countries. This paper focuses, however, on the choice of monetary policy regime for a small open economy, and international game situations therefore have a limited role. The simplest way to discuss the alternative of joining a monetary union in our model is simply to consider the regime of strict exchange rate targeting, but with a lower risk premium.[15] We have considered two cases, one in which the standard deviation of the trade-weighted risk premium is

[15] A monetary union is likely to have other more fundamental effects than reflected in our analysis. It can be argued that the main reasons for joining a monetary union are of a microeconomic origin, i.e., in the reduction of barriers to trade. These changes would most likely affect the economic structure and hence the propagation of policy behaviour and structural shocks. Our results with regard to monetary union should therefore be interpreted with caution.

reduced by one-half - denoted by "$EMU_{1/2}$" - and one extreme case where the whole risk premium is removed - denoted by "$EMU_0$".

Comparing the "$EMU$" regimes with the strict exchange rate targeting regime shows that the most noticeable difference is the reduction of the variability in the nominal interest rate. Since strict exchange rate targeting implies that the interest rate should fully offset a change in the risk premium, reducing the risk premium gives considerably lower variability in the interest rate. However, a reduction in the risk premium has relatively modest effects on inflation variability and output variability. Comparing the "$EMU_0$" regime, where the whole risk premium is removed, and flexible inflation targeting, shows that flexible inflation targeting generates the lower variability in all variables except the interest rate. The reason is the same as for exchange rate targeting, i.e. the interest rate is not sufficiently oriented towards domestic stabilisation, so that there are oscillations in inflation and output.

The general performance of a monetary policy based on the Taylor rule lies somewhere between flexible inflation targeting and exchange rate targeting as regard the variability in nominal and real variables. It may be argued that the standard Taylor rule is more suitable for a relatively closed economy, since it does not take into account various disturbances to which small open economies are exposed, such as shocks to imported inflation, foreign exchange shocks and shocks to the world interest rate. Considering the implicit rule under flexible inflation targeting in Table 3.1, we see that such shocks play a significant role when the interest rate is set. The Taylor rule, however, gives lower real and nominal variability than exchange rate targeting, except for variability in the interest rate. The reason is indicated by Figures 3.1 - 3.3: The Taylor rule does not generate the same oscillations in the key variables as exchange rate targeting does. Since the coefficient on inflation in the Taylor rule is greater than unity, monetary policy based on the Taylor rule cannot give rise to the 'Walter's effect'. With the Taylor rule, the real interest rate increases when inflation increases, as opposed to the case of exchange rate targeting.

Except in the case of strict inflation targeting, traded sector output is generally more volatile than the non-traded sector's output. By focusing on aggregate variability, one conceals information about sectoral variability, as these may differ substantially. This confirm our prior belief that results from one-sector models potentially may disregard important elements of the effects of monetary policy and stabilization policies in general.

### 3.3. Fiscal policy stabilisation

In fixed exchange rate regimes, fiscal policy has traditionally been the main tool for macroeconomic stabilisation. If fiscal policy provides sufficient macroeconomic stability, the need for a flexible monetary policy becomes less important. It may therefore be argued that comparisons between exchange rate targeting and inflation targeting do not do justice to exchange rate targeting when it is assumed that fiscal policy is passive. However, the political and academic support for an activist fiscal policy has declined considerably during the last 20 years. The main reason for this is that many countries have experienced that activist fiscal policies tend to generate excessive government debt. Several countries have therefore adopted fiscal policy rules that are meant to provide fiscal discipline. In addition to the argument that an activist fiscal policy may generate excessive debt, several parts of the public budget can potentially lead to large welfare losses if they are changed on a cyclical basis, e.g., health care and education. Other parts are easier to change, and some parts change automatically due to cyclical patterns, e.g. tax revenues and unemployment benefits. Although there seems to be limited support for an activist fiscal policy in most countries, there is a broad consensus that as a minimum, automatic stabilisers in fiscal policy should be allowed to work.

To introduce fiscal policy, we assume that the shock $\varepsilon_t^N$ consists of two elements, a shock to private demand, $\varepsilon_t^p$, and a shock to public demand, $x_t$, where $x_t$ is an indicator of the fiscal policy stance. If fiscal policy were fully flexible, one could minimize the loss function and find the optimal fiscal policy rule. However, such flexibility in fiscal policy seems unrealistic, given fiscal policy decision lags, political negotiations etc. We therefore adopt the following simple representation of an active fiscal policy:

$$x_{t+1} = \tau y_t + \varepsilon_{t+1}^x \tag{3.5}$$

Equation (3.5) may be thought of as an activist fiscal policy, where fiscal policy responds to the level of activity, represented by the aggregate output gap, by one period lag due to decision lags in fiscal policy. Alternatively, (3.5) may be thought of as a representation of a passive fiscal policy with automatic stabilization, where $\tau$ is the degree of automatic stabilization. Equation (2.4) is then replaced by

$$y_{t+1}^N = \rho_N(L)y_t^N - \alpha(L)r_t + \beta(L)e_t + x_{t+1} + \varepsilon_{t+1}^N \quad (3.6)$$

$$= \rho_N(L)y_t^N - \alpha(L)r_t + \beta(L)e_t + \tau y_t + \tilde{\varepsilon}_{t+1}^N \quad (3.7)$$

where $\tilde{\varepsilon}_t^N = \varepsilon_t^N + \varepsilon_t^x$, $\varepsilon_t^N$ and $\varepsilon_t^x$ are assumed to be independent.

An active fiscal policy that responds to the level of activity is particurlarly beneficial when monetary policy conducts either strict exchange rate targeting or strict inflation targeting. Although no central banks conduct strict inflation targeting in practice,[16] it is fruitful to consider an active fiscal policy under strict interpretations of the regimes, in order to focus on differences between an active and a passive fiscal policy. Moreover, by considering strict inflation targeting and an active fiscal policy, we are able to analyse whether fiscal policy is a substitute for monetary policy in stabilizing the real economy, so that monetary policy can focus solely on controlling inflation.

Table 3.3 shows the effects of an active fiscal policy on the unconditional standard deviations of the variables in the model. We consider three cases with different degrees of fiscal policy stabilization. First, a case where $\tau = -.5$, which represents a case with a high degree of fiscal stabilization. Second, a case with more modest stabilization; $\tau = -.2$, and third $\tau = .2$, which represents a case where fiscal policy is pro-cyclical. The third case may be interpreted as a case with a strict budget rule, where reduced government revenues during recessions must be followed by reduced government spending. We see that a counter-cyclical fiscal policy reduces the variability of output considerably, in particular under strict inflation targeting. This suggests that a fiscal policy that responds to the output gap in a rather mechanical way, as in (3.5), produces a considerably improved inflation variability/output variability trade-off. However, a regime with strict targeting and the highest counter-cyclical fiscal policy response considered here, i.e. $\tau = -.5$, generates higher output variability than a regime with flexible inflation targeting and a passive fiscal policy. Thus, for realistic degrees of fiscal policy stabilization, fiscal policy is not a perfect substitute for monetary policy in stabilizing output under inflation targeting. It is also interesting to note that in the case of strict exchange rate targeting with $\tau = -.5$, aggregate output variability is the same as in the case of flexible inflation

[16] King (1997) called central banks with strict inflation targets "inflation nutters" and argued that such central banks are not observed in practice.

**Table 3.3**
**Fiscal policy stabilization. Unconditional standard deviations in percent.**

| **Fiscal policy stabilization** ($\tau$) | $\bar{\pi}^c$ | $y^T$ | $y^N$ | $y$ | $s$ | $e$ | $i$ | $\Delta i$ |
|---|---|---|---|---|---|---|---|---|
| *Strict inflation targeting* | | | | | | | | |
| −0.5 | 0.00 | 2.37 | 2.89 | 2.55 | $\infty$ | 5.85 | 14.43 | 16.95 |
| −0.2 | 0.00 | 2.68 | 3.74 | 3.27 | $\infty$ | 6.27 | 14.58 | 16.84 |
| 0.2 | 0.00 | 4.31 | 6.46 | 5.61 | $\infty$ | 8.57 | 15.22 | 16.76 |
| *Strict exchange rate targeting* | | | | | | | | |
| −0.5 | 2.38 | 3.44 | 1.17 | 1.26 | 0.00 | 4.76 | 4.26 | 4.58 |
| −0.2 | 2.50 | 3.49 | 1.53 | 1.60 | 0.00 | 4.92 | 4.26 | 4.58 |
| 0.2 | 3.23 | 4.46 | 3.26 | 3.17 | 0.00 | 6.63 | 4.26 | 4.58 |

targeting with a passive fiscal policy. However, sectoral output variability is higher in the former case than in the latter.

The results show that fiscal policy stabilization, either in terms of an active fiscal policy or from automatic stabilization, reduces nominal and real variability under both exchange rate targeting and inflation targeting. Thus, the trade-off between nominal variability and real variability can be improved by using fiscal policy. The results also suggest that there are greater advantages to an active fiscal policy if the central bank conducts strict inflation targeting than if it conducts strict exchange rate targeting.

## 4. Summary and final remarks

This paper has analysed alternative monetary policy regimes within a small open-economy model with a traded and a non-traded sector. Two main types of regimes, or targeting rules, have been considered; inflation targeting and exchange rate targeting, where the latter regime includes either independent exchange rate targeting or entering a monetary union. These two general types of monetary policy regimes represent the realistic alternatives for monetary policy in small open economies today. The rationale for modelling the traded and the non-traded sectors separately, and not just the economy as a whole, is twofold. First, monetary policy affects traded and non-traded sectors differently, and an optimal policy should take into account all aspects of the transmission mechanism. Even if the central bank was only concerned about stabilizing inflation and aggregate output, it should respond to disturbances in each sector separately, and not just aggregate disturbances. However, there is reason to believe that sector-specific fluctuations have welfare effects that go beyond those of aggregate fluctuations. For example, the cost of adjustment in production might lead to welfare gains from stabilizing each sector if resources cannot be transferred between the sectors without cost. We therefore also have considered the effects of alternative monetary policy regimes on sectoral output variability, which has received little attention in the literature.

The performances of the alternative regimes are discussed by considering the effects on the key variables of the model. In principle, the variability of the variables could be weighted according to a welfare loss function in order to provide more precise normative results. However, it may be argued that such a precision would be arbitrary, as the weights attached to each variable in the true welfare function are unknown and therefore have to be chosen somewhat arbitrarily.

The results suggest that flexible inflation targeting, where the central bank is concerned about aggregate output and interest rate stability in addition to inflation stability, has the most advantageous properties of the regimes considered. Flexible inflation targeting leads to reasonably low variability in both nominal and real variables. Somewhat surprisingly, flexible inflation targeting gives a more stable real exchange rate than both strict and flexible exchange rate stabilization, and thereby a more stable traded sector. This is in contrast to the common view that a fixed exchange rate provides a more stable economic environment for the traded sector. Real exchange rate variability is higher under exchange rate targeting because a central bank that targets the nominal exchange rate responds less vigorously to domestic disturbances than it does under inflation targeting. Due to the 'Walter's effect', this generates persistent (although diminishing) oscillations in the real interest rate and thereby the real exchange rate. Even if the currency risk premium could be reduced or removed by entering a monetary union, flexible inflation targeting would still be preferable according to our simulations.

As would be expected, active fiscal counter-cyclical policy helps stabilize the economy in all the regimes. The strict regimes benefit in particular from counter-cyclical fiscal policy. A counter-cyclical fiscal policy seems, however, to reduce the variability in real variables particularly when the central bank conducts strict inflation targeting. Turning this result around, this suggests that an active fiscal policy makes it possible for the central bank to focus more on the inflation target without sacrifizing stability in the real economy.

It should be noted that comparing the alternative regimes within the same numerical model makes our results subject to the Lucas' critique. There is no reason to believe that the economic structure is identical when the central bank conducts independent inflation targeting or the country is a member of a monetary union. However, until more research is conducted, it is difficult to specify exactly *how* the economic structure will differ among alternative monetary regimes. It has often been argued that countries entering the EMU will experience more syncronized business cycles. This would lead to a better adjustment of the common monetary policy to economic conditions in the small periphery countries. In that case, our comparison between inflation targeting and monetary union may not do justice to the latter. However, the exercise of comparing alternative regimes within the same model still has some attractive features. For example, the results provide answers to questions like: Given that the economic structure remains the same, what are the potential costs and benefits for small open economies of abandoning an independent monetary policy and entering a monetary union?

# Appendix

## A. The discretionary optimization procedure

The optimization procedure is described in Backus and Driffill (1986). Here we review this method with respect to our two-sectoral model. The model can be written conveniently in the following state space form:

$$X_{t+1} = AX_t + Di_t + U_{t+1} \tag{A.1}$$

Note that the $X$ matrix is ordered in such a way that the forward-looking variable, $e_t$, is at the end. Our objective function in (3.1) can be written in a more general form:

$$J_t = E_t \sum_{s=0}^{\infty} \begin{bmatrix} X'_{t+s} & i_{t+s} \end{bmatrix} \begin{bmatrix} Q_{9x9} & U_{9x1} \\ U'_{1x9} & R_{1x1} \end{bmatrix} \begin{bmatrix} X_{t+s} \\ i_{t+s} \end{bmatrix} \tag{A.2}$$

where

$$Q_{9x9} = \begin{bmatrix} T_{\pi^C} \\ T_{\pi} \\ T_{\Delta S} \\ T_S \\ T_y \\ T_{i-} \end{bmatrix}' \begin{bmatrix} a_1 & 0 & 0 & 0 & 0 & 0 \\ 0 & a_2 & 0 & 0 & 0 & 0 \\ 0 & 0 & a_3 & 0 & 0 & 0 \\ 0 & 0 & 0 & a_4 & 0 & 0 \\ 0 & 0 & 0 & 0 & a_5 & 0 \\ 0 & 0 & 0 & 0 & 0 & a_6 \end{bmatrix} \begin{bmatrix} T_{\pi^C} \\ T_{\pi} \\ T_{\Delta S} \\ T_S \\ T_y \\ T_{i-} \end{bmatrix} \tag{A.3}$$

where $T_x$ defines the relationships between the target variables $x$ and the state-variable vector $X$.

Our problem is now to minimize (A.2) given (A.1). We go on to partition the X matrix: $X_t = \begin{bmatrix} x_{1t} & e_t \end{bmatrix}'$. Since our loss function is quadratic, the value function is quadratic and the Bellman equation can then be written accordingly:

$$\begin{aligned} J_t \quad = \quad & \begin{bmatrix} x_{1t} \\ e_t \end{bmatrix}' \begin{bmatrix} Q_{11} & Q_{12} \\ Q_{21} & Q_{22} \end{bmatrix} \begin{bmatrix} x_{1t} \\ e_t \end{bmatrix} + 2x'_{1t}U_1 i_t + i'_t R i_t + \\ & \beta E_t \left[ x'_{1t} V_{t+1} x_{1t} + v_{t+1} \right] \end{aligned} \tag{A.4}$$

where $V_{t+1}$ and $v_{t+1}$ - the parameters in the value function - so far are unspecified. The $Q$ matrice are given by (A.3) and $U_1 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & -a_6 & 0 & 0 \end{bmatrix}'$.

The expectation of the forward-looking variable can be written as a linear function of the expectation of the predetermined variables:

$$e_{t+1|t} = C_{t+1} x_{t+1|t}$$

where $C_{t+1}$ is a known vector of parameters that remains to be solved for. By using this relationship and taking expectations in (A.1), we get

$$\begin{aligned}
\begin{bmatrix} x_{1t+1|t} \\ e_{t+1|t} \end{bmatrix} &= \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} x_{1t} \\ e_t \end{bmatrix} + \begin{bmatrix} D_1 \\ D_2 \end{bmatrix} i_t \\
&\Rightarrow \\
\begin{bmatrix} I \\ C_{t+1} \end{bmatrix} x_{1t+1|t} &= \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} x_{1t} \\ e_t \end{bmatrix} + \begin{bmatrix} D_1 \\ D_2 \end{bmatrix} i_t
\end{aligned}$$

and after expressing the non-predetermined variables as explicit functions of the predetermined and instrument variables, you get:

$$\begin{aligned}
\begin{bmatrix} I & -A_{12} \\ C_{t+1} & -A_{22} \end{bmatrix} \begin{bmatrix} x_{1t+1|t} \\ e_t \end{bmatrix} &= \begin{bmatrix} A_{11} \\ A_{21} \end{bmatrix} x_{1t} + \begin{bmatrix} D_1 \\ D_2 \end{bmatrix} i_t \\
&\Rightarrow \\
\begin{bmatrix} x_{1t+1|t} \\ e_t \end{bmatrix} &= \begin{bmatrix} I & -A_{12} \\ C_{t+1} & -A_{22} \end{bmatrix}^{-1} \left( \begin{bmatrix} A_{11} \\ A_{21} \end{bmatrix} x_{1t} + \begin{bmatrix} D_1 \\ D_2 \end{bmatrix} i_t \right)
\end{aligned}$$

The real exchange rate can be extracted from the above system of equations:

$$\begin{aligned}
e_t &= (A_{22} - C_{t+1}A_{12})^{-1}(C_{t+1}A_{11} - A_{21})x_{1t} + \\
&\quad (A_{22} - C_{t+1}A_{12})^{-1}(C_{t+1}D_1 - D_2)i_t \\
&= H_{1t}x_{1t} + K_{1t}i_t \qquad \text{(A.5)}
\end{aligned}$$

where $H_{1t}$ and $K_{1t}$ is defined accordingly. Now using (A.5) in (A.1) we can extract an expression for the backward looking variables:

$$\begin{aligned}
x_{1t+1} &= (A_{11} + A_{12}H_{1t})x_{1t} + (D_1 + A_{12}K_{1t})i_t + u_{1t+1} \qquad \text{(A.6)} \\
&= H_{2t}x_{1t} + K_{2t}i_t + u_{1t+1}
\end{aligned}$$

By using (A.5) in the instantaneous period $t$ loss of (A.4) and denoting this by $j_t$, it becomes:

$$\begin{aligned}
j_t &= \begin{bmatrix} x_{1t} \\ H_{1t}x_{1t} + K_{1t}i_t \end{bmatrix}' \begin{bmatrix} Q_{11} & Q_{12} \\ Q_{21} & Q_{22} \end{bmatrix} \begin{bmatrix} x_{1t} \\ H_{1t}x_{1t} + K_{1t}i_t \end{bmatrix} + 2x_{1t}'U_1 i_t + i_t' R i_t \\
&= x_{1t}' \left[Q_{11} + H_{1t}'Q_{21} + Q_{12}H_{1t} + H_{1t}'Q_{22}H_{1t}\right] x_{1t} + \\
&\quad x_{12}' \left[Q_{12}K_{1t} + H_{1t}'Q_{22}K_{1t} + U_1\right] + \\
&\quad i_t' \left[K_{1t}'Q_{21} + K_{1t}'Q_{22}H_{1t} + U_1'\right] x_{1t} + \\
&\quad i_t \left[R + K_{1t}'Q_{22}K_{1t}\right] i_t \\
&= x_{1t}'Q^* x_{1t} + 2x_{1t}'O^* i_t + i_t' R^* i_t
\end{aligned}$$

By substituting this expression into (A.4) and using (A.6) you eventually get:

$$\begin{aligned}
J_t &= x_{1t}'Q^* x_{1t} + 2x_{1t}'O^* i_t + i_t' R^* i_t + \\
&\quad \beta E_t \left[ (H_{2t}x_{1t} + K_{2t}i_t + u_{1t+1})' V_{t+1} (H_{2t}x_{1t} + K_{2t}i_t + u_{1t+1}) + v_{t+1} \right]
\end{aligned}$$

which should be minimized with respect to $i_t$. The first order condition is:

$$2(R^* + \beta K_{2t}' V_{t+1} K_{2t}) i_t + 2(O_t^{*\prime} + \beta K_{2t}' V_{t+1} H_{2t}) x_{1t} = 0$$

which means that the optimal rule for the interest rate is:

$$\begin{aligned} i_t &= -(R^* + \beta K_{2t}' V_{t+1} K_{2t})^{-1} (O_t^{*\prime} + \beta K_{2t}' V_{t+1} H_{2t}) x_{1t} \\ &= -F_t x_{1t} \end{aligned} \tag{A.7}$$

where F is defined accordingly.

We can now use (A.7) in (A.5) in order to get:

$$\begin{aligned} e_t &= H_{1t} x_{1t} + K_{1t} i_t \\ &= (H_{1t} - K_{1t} F_t) x_{1t} \end{aligned}$$

which means that $C_{t+1} = (H_{1t} - K_{1t} F_t)$. The optimal value function can now be written in terms of the predetermined state variables only, $x_{1t}$ :

$$\begin{aligned} J_t^* &= x_{1t}' Q^* x_{1t} - 2 x_{1t}' O^* F_t x_{1t} + x_{1t}' F' R^* F x_{1t} + \\ &\quad \beta E_t \left[ ((H_{2t} - K_{2t} F_t) x_{1t} + u_{1t+1})' \, V_{t+1} \left( (H_{2t} - K_{2t} F_t) x_{1t} + u_{1t+1} \right) + v_{t+1} \right] \\ &= x_{1t}' \left[ Q_t^* - O_t^* F_t - F_t' O_t^{*\prime} + F_t' R_t^* F_t + \beta (H_{2t} - K_{2t} F_t)' V_{t+1} (H_{2t} - K_{2t} F_t) \right] x_{1t} + \\ &\quad E_t u_{1t+1}' \beta V_{t+1} u_{1t+1} + \beta E_t v_{t+1} \end{aligned}$$

which gives an equation for $V_{t+1} = \left[ Q_t^* - O_t^* F_t - F_t' O_t^{*\prime} + F_t' R_t^* F_t + \beta (H_{2t} - K_{2t} F_t)' V_{t+1} (H_{2t} - K_{2t} F_t) \right]$.

The above procedure is recursive and describes an iterative process. When the process converges, we have found the path for the interest rate as well as the non-exploding path for the exchange rate:

$$\begin{bmatrix} i_t \\ e_t \end{bmatrix} = \begin{bmatrix} -F \\ C \end{bmatrix} x_{1t}$$

From (A.1) the path for the predetermined variables can also be calculated accordingly:

$$x_{1t+1} = (A_{11} + A_{12} C - B_1 F) x_{1t} + U_{t+1}$$

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20832