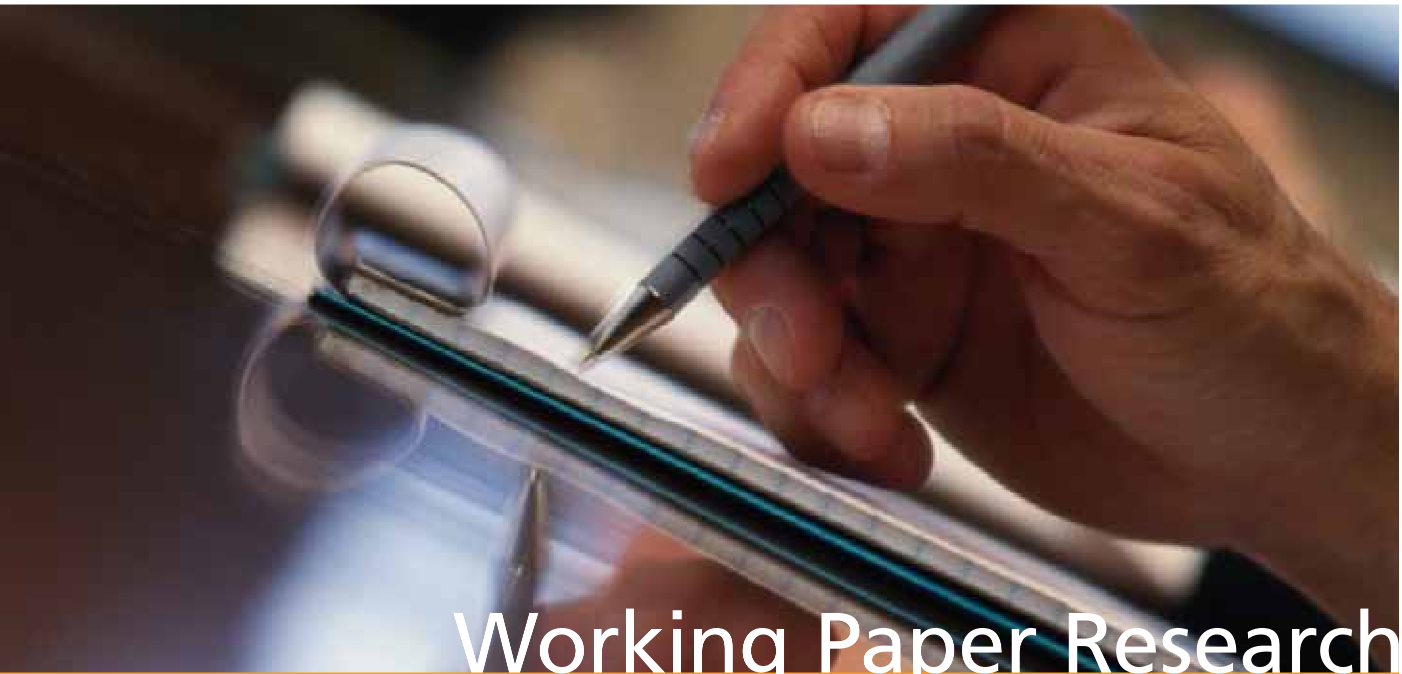
Estimation of monetary policy preferences in a forward-looking model : a Bayesian approach



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Abstract

In this paper we adopt a Bayesian approach towards the estimation of the monetary policy preference parameters in a general equilibrium framework. We start from the model presented by Smets and Wouters (2003) for the euro area where, in the original set up, monetary policy behaviour is described by an empirical Taylor rule. We abandon this way of representing monetary policy behaviour and assume, instead, that monetary policy authorities optimize an intertemporal quadratic loss function under commitment. We consider two alternative specifications for the loss function. The first specification includes inflation, output gap and difference in the interest rate as target variables. The second loss function includes an additional wage inflation target. The weights assigned to the target variables in the loss functions, i.e. the preferences of monetary policy, are estimated jointly with the structural parameters in the model. The results imply that inflation variability remains the main concern of optimal monetary policy. In addition, interest rate smoothing and the output gap appear to be, to a lesser extent, important target variables as well. Comparing the marginal likelihood of the original Smets and Wouters (2003) model to our specification with optimal monetary policy indicates that the latter performs only slightly worse. Since we are faced with the time-inconsistency problem under commitment, we initialize our estimates by considering a presample period of 40 quarters. This allows us to approach, empirically, the timeless perspective framework.

JEL-code : E42, E52, E58, E61

Key-words: optimal monetary policy, commitment, central bank preferences, euro area monetary policy.

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1 Introduction

Correct knowledge of the variables that are of main concern for monetary policy is an important asset since knowing the alternative monetary policy targets and their relative importance with respect to each other will have an effect on the formation of private sector expectations. Given the importance of these expectations and the role they play in stabilizing the economy, it is desirable for monetary policy makers to provide the private agents with sufficient information concerning the relative importance of each target variable. The value attached to a particular target variable, for example the inflation target, by monetary authorities can be described by the relative weight assigned to this target in the loss function that the Central Bank aims to minimize over the infinite horizon. The relative weights therefore generally reflect the preferences of monetary policy makers with respect to the corresponding target variables.

In order to infer the monetary policy preferences, one could analyze empirical monetary policy reaction functions and study the behaviour of monetary policy makers. This kind of approach, however, has often been criticised (Svensson, 2002a, 2003 and Dennis, 2000, 2002, 2003, 2005 and 2006). The argument is based on the idea that, while an estimated reaction function gives a good description of monetary policy behaviour, the intertemporal loss function is a more appropriate measure of (changes in) monetary policy objectives. In the context of optimal monetary policy, a reaction function is only a reduced form and results from a complex optimization problem of the Central Bank. Hence the variables entering the reaction function mainly play a role in providing monetary policy with information needed to achieve the policy objectives. These variables are therefore not necessarily equal to the target variables that appear in the loss function and cannot be attributed directly to the monetary policy objectives. In addition, the implied explicit interest rate reaction function from the optimization problem under certain policy objectives will typically contain more information by including the complete state vector, whereas a prespecified estimated reaction function is restricted to respond to only a subset of the state variables. A more theoretical justification for assuming a single representative monetary policy maker that systematically optimizes an intertemporal loss function, as in Svensson (1999) and Woodford (2003), is that this approach towards monetary policy will bring monetary policy behaviour in line with the behaviour of private agents. Hence we adopt a general equilibrium framework with rational and optimizing agents, where all structural equations result from optimal decisions made by private agents as well as monetary policy makers. This framework would also make it possible to detect changes in the monetary policy objectives over time and to derive the targeted value of inflation (Dennis, 2004).

An extensive amount of studies in the literature has recently focused attention on the estimation or calibration of preferences of optimizing monetary policy authorities, which is analogous to estimating the weights assigned to the target variables in the intertemporal optimization problem of the Central Bank. Many of these estimation exercises in the context of forward-looking models consider the case of discretionary monetary policy where optimization occurs every period and private sector expectations are treated as constants, as in Dennis (2000, 2003), Söderström et al. (2003) and Castelnuovo (2004) for the US economy and Lippi and Neri (2005) for the euro area economy[1]. The case of full commitment as in Söderlind (1999) or commitment to a simple rule of the kind adopted by Salemi (2001) for the US economy has, to our knowledge, not been applied to the euro area economy. This is probably due to the time-inconsistency problem one has to deal with under commitment. The aim of this paper is to study the case of monetary policy that systematically minimizes an intertemporal quadratic loss function under full commitment in a forward-looking model for the euro area. A commitment strategy, if credible, enables the Central Bank to control the expectations of private agents and provides it with an additional stabilization tool. We consider the Smets and Wouters (henceforth SW) (2003) model for the euro area as the benchmark model, where we drop the estimated Taylor rule and replace it by monetary policy that minimizes an intertemporal loss function under commitment subject to the structural model of the economy. This enables us to estimate the preference parameters of the monetary policy objective function jointly with the structural parameters of the model economy. The estimations are performed using Bayesian methods, considering alternative forms of monetary policy objective functions that differ in their assumptions about the number and type of the target variables. We use the values of the preference parameters obtained from the estimations to derive the optimal Taylor rule within the benchmark SW (2003) model and look to which extent the optimized feedback coefficients differ from the estimated coefficients of the Taylor rule in the original SW (2003) set up. In addition, we compare the results for the structural parameters obtained from the modified model with optimal monetary policy to the results of the original SW (2003) model, assigning differences to the alternative ways that monetary policy is described. This comparison is based on the marginal likelihood values and impulse response analysis. We make an attempt to overcome, empirically, the time-inconsistency problem that comes along with optimization under commitment by considering an initialization period that is

[1] Dennis (2006) and Ozlale (2003) perform a similar exercise for the US in the context of the Rudebusch and Svensson (1999) model, which is a purely backward-looking model and hence avoids time inconsistency issues.

long enough to reduce the effect of the initial values on the estimation results. This way, we are able to implement the timeless perspective framework of Woodford (1999).

This paper is organized as follows. In the next part we outline the theoretical framework adopted in this paper. We start from the SW (2003) model and describe the assumed structural behaviour of the private agents in the economy, followed by the introduction of optimal monetary policy, which leads to a set of Euler equations that can be estimated accordingly. In introducing optimal monetary policy we consider two types of loss functions that appear to perform best among a large set of alternative specifications. The first loss function includes inflation, the model-consistent output gap and the interest rate differential as target variables, whereas the second loss function considers an additional wage inflation target. The third part explains the methodology adopted and the data set used in the estimation procedure, followed by a discussion of the results. We compare alternative models based on their marginal likelihood and discuss the impulse responses obtained under the best performing model that is characterized by optimal policy with respect to the benchmark impulse responses of SW (2003) in part four. In part five we derive the unrestricted optimal commitment rule and the optimal coefficients of the Taylor rule, which we compare to the estimated Taylor rule of SW (2003). Accordingly, we refer to the potential time-inconsistency problem due to our commitment framework and show how we circumvent this issue by adopting the concept of timeless perspective policy of Woodford (1999) in part six. Finally, part seven concludes.

2 Theoretical Framework

The structural behaviour of the euro area economy is assumed to be described by the model developed by Smets and Wouters (2003). In this type of micro-founded framework private agents base their individual decisions on optimizing behaviour. This results in aggregate structural equations of which the parameters reflect deep preferences of the agents. However, instead of capturing the behaviour of the monetary policy authorities by an empirical Taylor rule as is done in the original set up of the SW (2003) model, we will assume that monetary policy is performed optimally under commitment. This will ensure that monetary authorities behave more consistently and in analogy with the private agents[2]. Moreover, this approach will allow us to estimate the preferences of monetary policy makers over the target variables. Following the arguments outlined in e.g. Svensson (2002a, 2003), Dennis (2000, 2003) and Lippi and Neri

[2] An argument in this direction is also made by Svensson (2002a) in his discussion of the SW (2003) paper.

(2005)[3], estimating the policy preferences rather than the monetary policy reaction function is more desirable since the latter is only a function of the former. Describing the behaviour of monetary policy authorities in terms of their preferences yields therefore more and better information about their incentives underlying their actions in response to economic developments than estimated interest rate reaction functions. In the following we present a brief summary of the linearized SW (2003) model for the euro area and introduce the optimizing monetary policy authorities. The resulting model, that takes into account optimal monetary policy behaviour under commitment, can accordingly be estimated with euro area data. Our main intention is to compare these results to those obtained under the original SW (2003) specification of the model.

2.1 The Smets and Wouters model for the Euro Area

The Dynamic Stochastic General Equilibrium (DSGE) framework presented in SW (2003) for the euro area consists of a household sector that supplies a differentiated type of labour, leading to nominal rigidities in the labour markets. The goods markets are characterized by intermediate and final goods producers. The former type of agents are monopolistically competitive and produce a differentiated type of intermediate goods, leading to nominal rigidities in the goods markets. The latter type of agents operate in a perfectly competitive market and produce one final good used for consumption and investment by the households.

Next to these nominal rigidities in the goods and labour markets, the model also features real rigidities like habit formation, costs of adjustment in capital accumulation and variable capital utilization. There are many similarities with the model presented in Christiano, Eichenbaum and Evans (CEE) (2001). However, the SW (2003) model includes an additional number of structural shocks, partial indexation to past inflation in the labour and the goods markets and is estimated using (Bayesian) estimation methods. The linearized rational expectations equations that result from private sector optimizing behaviour are summarized next, where the same notation as in SW (2003) is adopted and where all variables are expressed as log deviations from their steady state levels denoted by $\wedge$, i.e. $\hat{x} = \log\left(\frac{x}{x*}\right)$.[4]

The consumption Euler equation includes an external habit variable that leads to a backward-

[3] These studies assume, in contrast to our approach, that monetary policy is conducted under discretion. Lippi and Neri (2005) also consider the euro area and incorporate the case of imperfect information in their estimation procedures.

[4] For a detailed description of the individual parameters and the optimizing behaviour of the agents that lead to the linearized version of the model, we refer to the original SW (2003) paper.

looking component to capture habit persistence:

$$\hat{C}_t = \frac{h}{1+h}\hat{C}_{t-1} + \frac{1}{1+h}E_t\hat{C}_{t+1} - \frac{1-h}{(1+h)\,\sigma_c}\left(\hat{R}_t - E_t\hat{\pi}_{t+1}\right) + \frac{1-h}{(1+h)\,\sigma_c}\left(\hat{\varepsilon}_t^b - E_t\hat{\varepsilon}_{t+1}^b\right) \quad (1)$$

with $\hat{\varepsilon}_t^b$ an AR(1) preference shock to the discount rate with an i.i.d. normal error term. Nominal wages are set by households according to a Calvo (1983) type of scheme. Households that cannot reoptimize will adjust their nominal wages partially to past inflation with a degree $0 \leq \gamma_w \leq 1$, leading to the following real wage equation:

$$\begin{aligned}\hat{w}_t &= \frac{\beta}{1+\beta}E_t\hat{w}_{t+1} + \frac{1}{1+\beta}\hat{w}_{t-1} + \frac{\beta}{1+\beta}E_t\hat{\pi}_{t+1} - \frac{1+\beta\gamma_w}{1+\beta}\hat{\pi}_t + \frac{\gamma_w}{1+\beta}\hat{\pi}_{t-1} \\ &\quad - \frac{1}{1+\beta}\frac{(1-\beta\xi_w)(1-\xi_w)}{(\frac{\lambda_w+(1+\lambda_w)\sigma_L}{\lambda_w})\xi_w}\left[\hat{w}_t - \sigma_L\hat{L}_t - \frac{\sigma_c}{1-h}(\hat{C}_t - h\hat{C}_{t-1}) - \hat{\varepsilon}_t^L - \eta_t^w\right] \quad (2)\end{aligned}$$

where λ_w is a constant in $\lambda_{w,t} = \lambda_w + \eta_t^w$ with $\lambda_{w,t}$ a shock to the wage mark-up assumed to be i.i.d. normal around the constant term and $\hat{\varepsilon}_t^L$ a shock to labour supply assumed to follow an AR(1) process with an i.i.d. normal error term. The investment equation, characterized by adjustment costs depending on the size of investments, is described as follows:

$$\hat{I}_t = \frac{1}{1+\beta}\hat{I}_{t-1} + \frac{\beta}{1+\beta}E_t\hat{I}_{t+1} + \frac{\varphi}{1+\beta}\hat{Q}_t + \frac{\beta E_t\hat{\varepsilon}_{t+1}^I - \hat{\varepsilon}_t^I}{1+\beta} \quad (3)$$

with $\hat{\varepsilon}_t^I$ an AR(1) shock to investment costs with an i.i.d. normal error term. The real value of capital is represented by:

$$\hat{Q}_t = -(\hat{R}_t - \hat{\pi}_{t+1}) + \frac{1-\tau}{1-\tau+\bar{r}^k}E_t\hat{Q}_{t+1} + \frac{\bar{r}^k}{1-\tau+\bar{r}^k}E_t\hat{r}_{t+1}^k + \eta_t^Q \quad (4)$$

with η_t^Q an i.i.d. normal shock that captures changes in the external finance premium due to informational frictions. The capital accumulation equation fulfills[5]:

$$\hat{K}_t = (1-\tau)\,\hat{K}_{t-1} + \tau\hat{I}_t \quad (5)$$

As in the case of wage setting by households, the intermediate goods producers set their prices in line with Calvo (1983). Firms that are not able to reoptimize adjust their price partially to past inflation with a degree $0 \leq \gamma_p \leq 1$, leading to the following New-Keynesian Phillips curve:

$$\begin{aligned}\hat{\pi}_t &= \frac{\beta}{1+\beta\gamma_p}E_t\hat{\pi}_{t+1} + \frac{\gamma_p}{1+\beta\gamma_p}\hat{\pi}_{t-1} \quad (6) \\ &\quad + \frac{1}{1+\beta\gamma_p}\frac{\left(1-\beta\xi_p\right)\left(1-\xi_p\right)}{\xi_p}\left[\alpha\hat{r}_t^k + (1-\alpha)\,\hat{w}_t - \hat{\varepsilon}_t^a + \eta_t^p\right]\end{aligned}$$

[5] Note that we correct for a typo in SW (2003) by replacing lagged investment by its current value. In addition, we include in equation (8) the cost of capital adjustment component (last term) in the first line, which is omitted in SW (2003).

where $\hat{\varepsilon}_t^a$ is an AR(1) productivity shock with i.i.d. normal error term. The final term in square brackets represents the real marginal costs augmented with an i.i.d. (cost-push) shock η_t^p to the mark-up in the goods market, i.e. $\lambda_{p,t} = \lambda_p + \eta_t^p$. The labour demand equation for a given capital stock is given by:

$$\hat{L}_t = -\hat{w}_t + (1 + \mathbf{\Psi})\,\hat{r}_t^k + \hat{K}_{t-1} \tag{7}$$

Finally, the goods market equilibrium condition is represented by the following expression where total output equals total demand for output by households and the government (first line) and total supply of output by the firms (second line):

$$\begin{aligned} \hat{Y}_t &= c_y \hat{C}_t + g_y \varepsilon_t^G + \tau k_y \hat{I}_t + \bar{r}^k k_y \mathbf{\Psi} \hat{r}_t^k \\ &= \phi(\hat{\varepsilon}_t^a + \alpha \hat{K}_t + \alpha \mathbf{\Psi} \hat{r}_t^k + (1-\alpha)\,\hat{L}_t) \end{aligned} \tag{8}$$

where ε_t^G is an AR(1) government spending shock with i.i.d. normal error term.

In order to complete the model we introduce optimizing monetary policy authorities, discussed in the next section, which distinguishes our model from the original SW (2003) specification where monetary policy is described by a generalized empirical Taylor rule of the following type[6]:

$$\begin{aligned} \hat{R}_t &= \rho \hat{R}_{t-1} + (1-\rho)\left\{ \bar{\pi}_t + r_\pi(\hat{\pi}_{t-1} - \bar{\pi}_t) + r_y(\hat{Y}_{t-1} - \hat{Y}_{t-1}^p) \right\} \\ & +r_{\Delta\pi}(\hat{\pi}_t - \hat{\pi}_{t-1}) + r_{\Delta y}((\hat{Y}_t - \hat{Y}_t^p) - (\hat{Y}_{t-1} - \hat{Y}_{t-1}^p)) + \eta_t^R \end{aligned} \tag{9}$$

where ρ is the monetary authorities' smoothing parameter and η_t^R an i.i.d. monetary policy shock. In addition to the one-period difference in inflation and the output gap, a gradual response to lagged inflation and lagged output gap is assumed. Since the main difference between the two models is the way monetary policy is described, i.e. optimizing vs. empirical reaction function, we will be able to attribute differences in estimation results under both models to the specific assumptions made about monetary policy behaviour[7].

2.2 Optimal Monetary Policy

Monetary policy authorities are assumed to minimize a discounted intertemporal quadratic loss function of the following type:

$$E_t \sum_{i=0}^{\infty} \delta^i [y_{t+i}' W y_{t+i}], \qquad 0 < \delta < 1 \tag{10}$$

[6] Note that we correct a typo in SW (2003) in the first line of the rule where the lag of the output gap appears instead of the current output gap.

[7] Note that we also do not include the inflation objective shock, $\bar{\pi}_t$, in the model with optimal policy. This shock does not play a significant role in the estimation outcomes of SW (2003).

with δ the discount factor and E_t the expectations operator conditional on information available at time t. This type of quadratic loss function is commonly adopted in the literature, as in Rudebusch and Svensson (1998), Giannoni and Woodford (2003), Söderlind (1999) and Dennis (2005). The vector $y_t = [x_t' \;\; u_t']'$ contains the $n \times 1$ endogenous variables and AR(1) exogenous variables in the model included in x_t and the $p \times 1$ vector of control variables included in u_t. Since we assume only one control variable, i.e. the interest rate, u_t is in our case a scalar with $u_t = \hat{R}_t$. W is a time-invariant symmetric, positive semi-definite matrix of policy weights which reflect the monetary policy preferences of the Central Bank over the target variables. An alternative and theoretically more justifiable approach towards monetary policy would be to derive the approximated welfare based loss function, where the target variables and their weights in the loss function are determined by the utility of the households. However, this is not an easy task given the presence of variable capital utilization and investment dynamics in the model. Therefore we will assume a quadratic ad hoc loss function in this study[8].

We follow standard practice in the literature[9] in assuming that the one-period ad hoc loss function for (10) reflects the fact that monetary policy targets inflation, a measure of the output gap and a smoothing component for the policy instrument which is described by the interest rate:

$$L_t = \overset{\wedge}{\pi}_t^{\,2} + q_y(\hat{Y}_t - \hat{Y}{}_t^p)^2 + q_r(\hat{R}_t - \hat{R}_{t-1})^2 \qquad (11)$$

As explained in the next part, the dataset used in the estimation procedure contains series on (detrended) inflation considered in deviation from its sample mean. Since we normalize the inflation target in (11) to zero, this implies that monetary policy aims to stabilize inflation around the sample mean. Hence the sample mean is considered to be the inflation target, which is a known constant[10]. The inclusion of the term $\hat{R}_t - \hat{R}_{t-1}$ in the loss function, as in Rudebusch and Svensson (1998) and Giannoni and Woodford (2003), can be justified by concerns about financial stability or in order to take into account the observed inertial behaviour in the policy instrument, which suggests a gradualist monetary policy approach[11]. The output gap

[8] See Onatski and Williams (2004) for an exercise on welfare based approximation to the loss function in the SW (2003) model and Levin et al. (2005) for a similar study.

[9] See e.g. Rudebusch and Svensson (1998), Giannoni and Woodford (2003), Dennis (2003), Söderström et al. (2003), Lippi and Neri (2005) and Castelnuovo (2004).

[10] One could criticise this approach and alternatively consider the inflation target as an additional parameter to be estimated. We would like to consider this apporach as an extension to this paper in the near future. Conditions under which the inflation target can be identified and estimated are provided by Dennis (2003,2004).

[11] In our estimation exercises performed in the next part, we replace this final term by the interest rate level, i.e. $\hat{R}{}_t^2$, a case studied by e.g. Giannoni and Woodford (2002), Woodford (2003) and Onatski and Williams (2004). The results in terms of marginal likelihood suggest that the data prefers the loss function specification of type (11).

considered here is the one implied by the model, i.e. the deviation of output from its natural level, the latter being the level of the output in total absence of nominal rigidities and the three i.i.d. cost-push shocks $(\eta_t^Q, \eta_t^p, \eta_t^w)$[12]. As is done in most applications in the literature, the weight assigned to inflation in the above loss function is normalized to one[13]. Hence the weights corresponding to the output gap and the interest rate smoothing component, i.e. q_y and q_r, respectively, are to be interpreted as relative weights with respect to the inflation target variable. We will estimate the preferences of monetary policy reflected by these parameters along with the structural parameters of the economy, which will provide us with values for the weights in the loss function over the estimation period. These values will be accordingly used in the optimal monetary policy evaluation exercises performed in part five.

Since the structural model of the economy outlined above is characterized by nominal wage rigidities, it is appealing from a theoretical point of view to investigate also the case where monetary policy is concerned about stabilizing nominal wage inflation in addition to the target variables in (11). A case for a nominal wage inflation target is provided by Erceg et al. (1998, 1999) where, as in Kollmann (1997) and Woodford (2003), a dynamic general equilibrium model featuring staggered wage and price setting is developed and where the authors show that rigidities in these both markets at the same time make the Pareto optimal equilibrium unattainable for monetary policy. Hence there is a tradeoff between price, wage and output gap stabilization. Moreover, Erceg et al. (1999) derive a social welfare function under the circumstances of nominal wage and price rigidities and show that there are high welfare costs attached to targeting price inflation only and ignoring wage inflation stabilization. In the welfare based loss function derived for the SW (2003) model by Onatski and Williams (2004), a term for wage inflation is also included[14]. Therefore, we will analyze also the following alternative specification of the loss function, where monetary policy aims to target nominal wage inflation as well:

$$L_t = \hat{\pi}_t^2 + q_y(\hat{Y}_t - \hat{Y}_t^p)^2 + q_r(\hat{R}_t - \hat{R}_{t-1})^2 + q_w(\hat{W}_t - \hat{W}_{t-1} + \hat{\pi}_t)^2 \tag{12}$$

[12] Although it is more common in empirical applications that deviations of output from a linear trend are used as an approximation to the output gap, we prefer to adopt the theoretical concept of the output gap. To support this choice, we experiment with alternative definitions of the output gap in the next part which yield less favourable results in terms of the marginal likelihood.

[13] Examples can be found in Rotemberg and Woodford (1998), Rudebusch and Svensson (1998), Dennis (2003) and Woodford (2003).

[14] In addition, Onatski and Williams (2004) include a positive weight on the capital stock and the covariance between inflation and wages. This results in an approximated loss function of the type $L_t = \hat{\pi}_t^2 + 0.21K_{t-1}^2 - 0.51\hat{\pi}_t\hat{\pi}_{t-1} + 0.24(\hat{W}_t + \hat{\pi}_t)(\hat{W}_t - \hat{W}_{t-1})$. We consider this specification also in the next part, where the corresponding weights are estimated. The results however, which we do not report or analyze further, appear to be worse than under (11) and (12). Moreover, we cannot provide an intuitive explanation for the inclusion of the capital stock in the context of standard loss functions we wish to focus on in this study.

The specification of the one period loss function in (11) can be considered as a special case of (12) where q_w is set to 0. We will estimate the model under both specifications of the loss function, by treating the case under each one of the two specifications as a separate model. Therefore, we will refer to the case where $q_w = 0$, i.e. period loss function (11), as model $M1$ and consider the case where nominal wage inflation is an additional target variable as model $M2$. We then use the corresponding marginal likelihood values in order to rank the two models and assess to which extent monetary policy has been concerned about nominal wage inflation stabilization over the sample period[15].

The Central Bank minimizes the intertemporal loss function (10), the one-period loss function of which is given by either (11) or (12), under commitment subject to the structural equations of the economy (1) - (8) augmented by their flexible price versions, written and represented by the following second order form:

$$Ax_t = BE_t x_{t+1} + Fx_{t-1} + Gu_t + Dz_t, \qquad z_t \sim iid[0, \Sigma_{zz}] \tag{13}$$

with z_t an $n \times 1$ vector of stochastic innovations to the variables in x_t, having mean zero and variance-covariance matrix Σ_{zz}.

Under commitment the central bank optimizes only once in the initial period t_0, ignoring past promises but tying its hands by promising at t_0 to follow the resulting policy rule forever[16]. The resulting equilibrium is not time consistent and past commitments will be respected only in the future periods to come after t_0, therefore making policy history dependent only from t_0 on. This is reflected by the presence of the Lagrange multipliers in the optimal reaction function[17].

We follow the optimization routine for commitment suggested by Dennis (2005) where, in contrast to e.g. Söderlind (1999), no classification of the variables in a predetermined and a non-predetermined block is needed. We further adopt the definition of rational expectations as proposed by Sims (2002), i.e.

$$E_t x_{t+1} + \eta^x_{t+1} = x_{t+1} \tag{14}$$

[15] We admit that in this study we make the strong assumption that the monetary policy regime has been unchanged in the euro area throughout the sample period. This might be doubtful given the separate monetary policy strategies adopted in the individual countries before the introduction of the Euro. However, the transition period towards the Euro and the restrictions imposed by the Maastricht treaty justify our assumption that the policy regimes were more likely to have been in line rather than divergent.

[16] Past promises are ignored by setting initial values of the Lagrange multipliers equal to zero.

[17] However, we will make an attempt to overcome this time-inconsistency problem in our estimation procedure, by incorporating the philosophy of optimization from a timeless perspective of Woodford (2003). This boils down to setting the initial values of the Lagrange multipliers of forward-looking variables to nonzero, which does lead to a time consistent equilibrium.

and partition the matrix of weights W in (10) as follows:

$$E_t \sum_{i=0}^{\infty} \delta^i [x'_{t+i} Q x_{t+i} + u'_{t+i} \Theta u_{t+i}], \qquad 0 < \delta < 1 \tag{15}$$

where we express the loss function in terms of the variables x_t and u_t. Accordingly, we obtain the Euler equations of the monetary policy optimization problem, which can be represented in the following second order form:

$$A1^* \Upsilon_t = B1^* E_t \Upsilon_{t+1} + C1^* \Upsilon_{t-1} + D1^* z_t \tag{16}$$

with:

$$\begin{aligned} A1^* &= \begin{bmatrix} Q & 0 & A' \\ 0 & \Theta & -G' \\ A & -G & 0 \end{bmatrix} \qquad B1^* = \begin{bmatrix} 0 & 0 & \delta F' \\ 0 & 0 & 0 \\ B & 0 & 0 \end{bmatrix} \\ C1^* &= \begin{bmatrix} 0 & 0 & \frac{1}{\delta} B' \\ 0 & 0 & 0 \\ F & 0 & 0 \end{bmatrix} \qquad D1^* = \begin{bmatrix} 0 \\ 0 \\ D \end{bmatrix} \qquad \text{and } \Upsilon_t = \begin{bmatrix} x_t \\ u_t \\ \rho_t \end{bmatrix} = \begin{bmatrix} y_t \\ \rho_t \end{bmatrix} \end{aligned} \tag{17}$$

and the final term in Υ_t, ρ_t, the vector of Lagrange multipliers. It is clear from the system of Euler equations (17) that the economy's law of motion (13), which reappears in the last line in (17), is augmented by the set of first order conditions with respect to x_t and u_t, through which the (leads and lags of the) Lagrange multipliers ρ_t enter into the system and the matrices $A1^*, B1^*, C1^*$ have dimension $(2n + p) \times (2n + p)$[18]. In the next part, we will estimate the Euler equations resulting from the optimization procedure outlined above, i.e. the system (16), by applying Bayesian estimation techniques.

3 Estimation

In this part we discuss the dataset used and the methodology followed in estimating the system (16), which yields estimates of the structural parameters resulting from optimizing private agents and policy preferences of optimizing monetary policy authorities. Next, we present the results under $M1$ and $M2$ and compare them to each other and to the estimates obtained from the benchmark model in SW (2003).

3.1 Data

We use the same dataset as the one used by SW (2003) for the euro area, i.e. constructed by Fagan, Henry and Mestre (2001). The dataset contains observed series on real GDP, real

[18] A more detailed illustration of the state space expansion and the inclsuion of the leads and lags of the Lagrange multipliers can be found in Juillard and Pelgrin (2005).

consumption, real investment, GDP deflator, real wages, employment and the nominal interest rate. The series range over the period 1980:2 - 1999:4, preceded by an initialization period of 40 quarters in order to initialize the estimates. The reason why we opt to end the observation period in the last quarter of 1999 is for comparison of the estimation results to those obtained under the original specification of the model in SW (2003), where monetary policy is assumed to follow a generalized Taylor rule. Furthermore, as in SW (2003), all variables are considered in deviations from their sample means. Inflation and nominal interest rates are detrended by the inflation trend, whereas the remaining variables in the dataset are detrended separately by a linear trend. As explained in SW (2003), we introduce an additional equation for employment to correct for the use of data on employment instead of the unobserved data on aggregate hours worked in the euro area:

$$\hat{E}_t - \hat{E}_{t-1} = \hat{E}_{t+1} - \hat{E}_t + \frac{(1-\beta\xi_e)(1-\xi_e)}{\xi_e}\left(\hat{L}_t - \hat{E}_t\right) \tag{18}$$

We further introduce an i.i.d. measurement error ϵ_t^R to take account for mismeasurement in the observed series of the nominal interest rate ($\hat{R}_t^{obs}$), leading to the following relation between the observed and the non-observed policy instrument rate[19]:

$$\hat{R}_t^{obs} = \hat{R}_t^{nobs} + \epsilon_t^R \tag{19}$$

As opposed to SW (2003), the two monetary policy shocks that appear in the generalized Taylor rule, i.e. a shock to the inflation objective and an interest rate shock, are absent from the models $M1$ and $M2$[20]. As in SW (2003), identification is obtained through the assumption that all shocks are uncorrelated, that the three cost-push shocks together with the measurement error follow a white noise process and that the remaining shocks related to preferences and technology are AR(1). In order to compare our results to those obtained by SW (2003), we use the same prior specifications for those parameters that correspond to the parameters in the original model. Therefore, we fix the following parameters: the discount factor β is set equal to 0.99, implying an annual real interest rate of 4 percent. The annual depreciation rate on capital is assumed to be 10 percent, i.e. $\tau = 0.025$. The income share of labour in total output is assumed to be 0.7 in the steady state, i.e. $\alpha = 0.3$. The share of consumption and investment in total output is 0.6 and 0.22 in the steady state, respectively. Finally, λ_w is calibrated to be 0.5, for reasons of

[19] This measurement error could be compared to a monetary policy shock, since it takes account for the observed difference between the actual interest rate and the systematic movements in the interest rate as implied by the model. Although the interpretation of this measurement error, in contrast to the monetary policy shock in the original SW (2003) model, is not a structural one.

[20] As a result, we end up with nine shocks, instead of the original ten shocks.

identification. In the next section we outline the methodology adopted in the estimation of the remaining parameters.

3.2 Methodology

We apply Bayesian estimation techniques in order to estimate the parameters of the alternative models[21]. After solving for the linear rational expectations solution of the model in (16), we derive the following state transition equation:

$$\Upsilon_t = \Gamma_Y \Upsilon_{t-1} + \Gamma_z z_t \tag{20}$$

and the measurement equation that links the state variables Υ_t linearly to the vector of observables Ω_t,

$$\Omega_t = \Lambda_Y \Upsilon_t \tag{21}$$

We use the Kalman filter to calculate the likelihood function of the observables recursively, starting from initial values of the state vector $\Upsilon_0 = 0$ and the unconditional variances[22]. Next, the posterior density distribution is derived by combining the prior distribution with the likelihood function obtained from the previous step. We proceed until the parameters that maximize the posterior distribution are found, i.e. until convergence around the mode is achieved. After maximizing the posterior mode, we use the Metropolis-Hastings algorithm to generate draws from the posterior distribution in order to approximate the moments of the distribution, calculate the modified harmonic mean and construct the Bayesian impulse responses[23]. In discussing the estimation results, however, we will focus on the maximized posterior mode and the Hessian-based standard errors.

In Table 1 the first three columns show the details of the prior distributions for the shock processes, i.e. the standard errors σ of all nine shocks and the AR(1) coefficients ρ of the five preference shocks. The type of the prior distributions, the prior means and the prior standard errors are identical to the assumptions made in SW (2003) and are kept constant throughout the estimation processes for both models $M1$ and $M2$. All variances of the shocks are assumed to have an inverted gamma distribution with 2 degrees of freedom, except for the measurement error which we assume to be gamma distributed with a prior mean of 0.05 and standard error of

[21] For a detailed discussion in favour of Bayesian estimation of DSGE models, we refer to SW (2003-2005), Schorfheide (2006) and An and Schorfheide (2006).

[22] As discussed next, we experiment also with initial values at nonzero for certain lagrange multipliers in order to incorporate the concept of optimal policy under the "timeless perspective".

[23] All estimations are performed using Michel Juillard's software dynare, which can be downloaded from the website *www.dsge.net*.

0.025. The five AR(1) coefficients are assumed to have a beta distribution with a prior mean of 0.85 and a strict prior standard error of 0.1 in order to distinguish the persistent shocks clearly from the i.i.d. shocks. Table 1 also reports the results obtained from the posterior maximization, i.e. the posterior mode and the (Hessian-based) standard errors for the models $M1$, $M2$ and the original SW (2003) model. These results are discussed and compared in the next section. The results for the structural parameters are reported in Table 2, together with the SW (2003) results. The prior specifications and the estimates of the monetary policy preference parameters, i.e. the weights assigned to the target variables q_y, q_r and q_w are reported in the bottom part of the table. These parameters are assumed to be normally distributed with 0.5 prior mean and 0.2 prior standard error.

3.3 Results

As mentioned before, we report and discuss only the estimation results obtained for $M1$ and $M2$ because under these two types of the loss function highest marginal likelihoods were obtained[24]. We also re-estimate the SW (2003) model[25] which will serve as a benchmark for the results obtained under models $M1$ and $M2$ with optimal monetary policy.

3.3.1 Structural Shocks and Private Sector Parameters

Turning to the results concerning the structural shocks reported in Table 1, the estimated parameters and their corresponding standard errors under our specification $M1$ of the model are similar to those under $M2$. A few remarks are worth making when we compare the results under both models to our estimates of the benchmark SW (2003) model. The estimates of the labour supply shock σ_l and the equity premium shock σ_Q are considerably lower under the models $M1$ and $M2$, compared to SW (2003). In addition, the labour supply shock turns out to be more persistent under $M1$ and $M2$ than under SW (2003). A higher persistence is also estimated for the productivity shock. The wage mark-up shock σ_W is higher under $M1$ and $M2$ than the SW (2003) estimate.

Comparing the SW (2003) estimates for the structural parameters to these obtained under $M1$ and $M2$, which are reported in Table 2, yields the following conclusions. The investment

[24]In our experiments we consider alternative loss functions where we replace the interest rate smoothing term by the interest rate level, or the output gap by the differences in output. We also studied the case where we used simply output deviations from a linear trend instead of the model-consistent output gap. We examined loss functions including a difference in the output gap, a difference in the inflation rate or of the welfare approximated type presented by Onatski and Williams (2004) as well. None of these cases, however, could yield better outcomes in terms of their corresponding marginal likelihoods.

[25]These results appear to be very similar to those reported in the original SW (2003). However, mainly due to corrections for very small errors in the original version, the results are not identical.

Table 1: Prior specifications and estimates of the shocks, with the standard errors followed by the AR(1) coefficients. Both specifications are compared to the results obtained in SW (2003)

Parameter	Prior Specification		
	Distribution Type	Prior Mean	Prior se
σ_a productivity shock	Inverse gamma	0.4	2
σ_b preference shock	Inverse gamma	0.2	2
σ_G government spending shock	Inverse gamma	0.3	2
σ_l labour supply shock	Inverse gamma	1	2
σ_I investment shock	Inverse gamma	0.1	2
σ_Q equity premium shock	Inverse gamma	0.4	2
σ_P price mark-up shock	Inverse gamma	0.15	2
σ_W wage mark-up shock	Inverse gamma	0.25	2
σ_π inflation objective shock (only SW (2003))	Inverse gamma	0.02	2
σ_{MP} monetary policy shock (only SW (2003))	Inverse gamma	0.1	2
σ_R measurement error (only $M1$ and $M2$)	Gamma	0.05	0.025
ρ_π inflation objective shock (only SW (2003))	Beta	0.85	0.1
ρ_a productivity shock	Beta	0.85	0.1
ρ_b preference shock	Beta	0.85	0.1
ρ_G government spending shock	Beta	0.85	0.1
ρ_L labour supply shock	Beta	0.85	0.1
ρ_I investment shock	Beta	0.85	0.1

Parameter	Results from Posterior Maximization $M1$ ($q_w = 0$)		Results from Posterior Maximization $M2$ ($q_w \neq 0$)		Results SW (2003) (re-estimated)	
	Mode	se (Hessian)	Mode	se (Hessian)	Mode	se (Hessian)
σ_a	0.5252	0.0771	0.5366	0.0806	0.6051	0.1097
σ_b	0.2031	0.0475	0.1909	0.0465	0.2577	0.0805
σ_G	0.3236	0.0256	0.3234	0.0255	0.3225	0.0254
σ_l	1.8033	0.3533	1.8406	0.3629	4.1880	1.4832
σ_I	0.0498	0.0159	0.0523	0.0174	0.0639	0.0177
σ_Q	0.4907	0.0602	0.4862	0.0615	0.5984	0.0594
σ_P	0.1595	0.0152	0.1578	0.015	0.1576	0.015
σ_W	0.3423	0.0289	0.3428	0.0292	0.2881	0.0266
σ_π	–	–	–	–	0.0092	0.0038
σ_{MP}	–	–	–	–	0.0562	0.0252
σ_R	0.0354	0.0082	0.0351	0.0085	–	–
ρ_π	–	–	–	–	0.9221	0.0863
ρ_a	0.8686	0.042	0.8774	0.043	0.8075	0.0601
ρ_b	0.8606	0.0345	0.8651	0.0359	0.8856	0.0327
ρ_G	0.9311	0.028	0.9328	0.0281	0.9464	0.0279
ρ_L	0.9776	0.0102	0.978	0.0102	0.8556	0.0728
ρ_I	0.9455	0.0259	0.9433	0.0265	0.9527	0.0226

Table 2: Prior specifications and estimates of the structural parameters. The results for both models are compared to those obtained in SW (2003)

Parameter	Prior Specification		
	Distribution Type	Prior Mean	Prior se
$S"(.)$ investment adjustment cost	Normal	4	1.5
σ_c consumption utility	Normal	1	0.375
h consumption habit	Beta	0.7	0.1
ξ_w calvo wages	Beta	0.75	0.05
σ_L labour utility	Normal	2	0.75
ξ_p calvo prices	Beta	0.75	0.05
ξ_e calvo employment	Beta	0.5	0.15
γ_w indexation wages	Beta	0.75	0.15
γ_p indexation prices	Beta	0.75	0.15
capital utiliz. adjustment cost	Normal	0.2	0.075
ϕ fixed cost	Normal	1.45	0.125
ρ smoothing parameter empirical Taylor rule	Beta	0.8	0.1
r_π lagged inflation parameter	Normal	1.7	0.1
r_y lagged output gap parameter	Normal	0.125	0.05
$r_{\Delta\pi}$ inflation differential	Normal	0.3	0.1
$r_{\Delta y}$ output gap differential	Normal	0.0625	0.05
q_r interest smoothing preference	Normal	0.5	0.2
q_y output gap preference	Normal	0.5	0.2
q_w wage inflation preference	Normal	0.5	0.2

Parameter	Results from Posterior Maximization $M1$ ($q_w = 0$)		Results from Posterior Maximization $M2$ ($q_w \neq 0$)		Results SW (2003) (re-estimated)	
	Mode	se (Hessian)	Mode	se (Hessian)	Mode	se (Hessian)
$S"(.)$	5.1667	1.0009	4.994	1.0043	6.5814	1.0918
σ_c	1.3667	0.2869	1.3637	0.2883	1.3545	0.2665
h	0.5135	0.0691	0.5165	0.07	0.5535	0.0696
ξ_w	0.8898	0.0151	0.8934	0.0149	0.7603	0.0503
σ_L	0.6961	0.3554	0.7351	0.3656	2.1097	0.6077
ξ_p	0.8819	0.0097	0.8841	0.0105	0.9088	0.0109
ξ_e	0.5595	0.05	0.5667	0.0499	0.6011	0.0472
γ_w	0.9067	0.0866	0.9126	0.0819	0.7677	0.1850
γ_p	0.3452	0.0737	0.3905	0.0764	0.4226	0.099
capital utiliz.	0.1748	0.0741	0.177	0.0743	0.1775	0.0737
ϕ	1.4887	0.1059	1.4778	0.1075	1.4365	0.1089
ρ	–	–	–	–	0.976	0.0112
r_π	–	–	–	–	1.7	0.0997
r_y	–	–	–	–	0.1265	0.0442
$r_{\Delta\pi}$	–	–	–	–	0.0977	0.0473
$r_{\Delta y}$	–	–	–	–	0.1392	0.0322
q_r	0.6309	0.1647	0.624	0.1652	–	–
q_y	0.0401	0.0147	0.04	0.015	–	–
q_w	–	–	0.269	0.1564	–	–

adjustment cost parameter is estimated to be lower (5.1667 and 4.994) than the baseline estimated value of 6.5814, whereas the standard errors are similar. This suggests a higher elasticity of investment with respect to an increase in the current price of installed capital of 1 percent under $M1$ and $M2$. A strikingly higher value is obtained under $M1$ and $M2$ for the Calvo wage parameter ξ_w than in the baseline case (0.8898 and 0.8934 vs. 0.7603). The same conclusion holds for the wage indexation parameter γ_w with 0.9067 and 0.9126 vs. 0.7677. Hence a significantly higher wage stickiness and wage indexation is present whenever monetary policy is assumed to behave optimally as is the case under $M1$ and $M2$, suggesting an average duration of wage contracts of slightly more than two years. The reverse conclusion can be drawn from estimates for the Calvo price ξ_p and the price indexation parameter γ_p. These parameters are significantly lower under the models characterized by optimizing monetary policy authorities, yielding 0.8819 and 0.8841 for ξ_p vs. the SW (2003) estimate of 0.9088 and 0.3452 and 0.3905 for γ_p vs. 0.4226. The former suggests a lower degree of price stickiness in the goods markets under $M1$ and $M2$ compared to SW (2003) with an average duration of price contracts of two years, which is very close to the average duration of the wage contracts, implying a similar degree of stickiness in wages and prices under $M1$ and $M2$. The estimates of γ_p imply that price indexation is lower under $M1$ and $M2$, and in line with the findings of Gali et al. (2001) for the euro area where a low degree of backward-looking behaviour in the goods market is estimated. Finally, the estimate of the labour utility parameter σ_L is considerably lower under the models $M1$ and $M2$ (0.6961 and 0.7351) than under SW (2003) (2.1097)[26].

3.3.2 Monetary Policy Preference Parameters

Table 2 also shows the parameter estimates of our main interest, i.e. the monetary policy preferences in the two models $M1$ and $M2$[27]. The estimates of the policy preferences for the interest rate smoothing target q_r and the output gap target q_y are very similar for the two alternative specifications $M1$ and $M2$. In both cases the preference for interest rate smoothing is estimated to be higher (0.6309 and 0.624) than the preference for output gap stabilization (0.0401 and 0.04), while overall the main concern is still the inflation target whose weight is

[26] Note that, as was the case in the original SW (2003), our estimates of this parameter did not appear to be robust across specifications either...

[27] Since inflation and the interest rates, both target variables, are measured on a quartely basis and the literature occasionally considers target variables on a yearly frequency, the weights obtained from the estimates have to be adjusted in order to make the results comparable to those in the literature which base their results on yearly data. Therefore, from the viewpoint of these studies, the weight assigned to the output gap q_y is not as small as it seems at first sight. Taking this into account boils down to multiplying q_y by a factor of 16 and converting the inflation and the interest rate in the model to a yearly frequency . Hence, the values for q_y would become 0.6416 under $M1$ and 0.64 under $M2$.

Table 3: Model comparison based on the marginal likelihood

	$M1$ ($q_w = 0$)	$M2$ ($q_w \neq 0$)	$SW(2003)$
Laplace approximation	-280.98	-282.39	-270.76
$\log \frac{p(Q_T\|M_i)}{p(Q_T\|SW(2003))}$ $\quad i = 1,2$	-10.22	-11.63	–
Modified Harmonic Mean	-280.31	-281.68	-270.32
$\log \frac{p(Q_T\|M_i)(1970{:}2-1999{:}4)}{p(Q_T\|M_i)(1970{:}2-1980{:}2)}$ $\quad i = 1,2, SW(2003)$	-266.82	-265.98	-246.41
Laplace approximation when $q_y = 0.005$	-291.49	-290.79	–
Laplace approximation when $q_r = 0.2$	-286.15	-340.58	–

normalized to one. However, when we investigate the importance of the output gap as a target variable by calculating the marginal likelihood cost of decreasing the weight q_y from 0.0401 to e.g. 0.005, the importance attached to the output gap appears to be higher than the estimates suggest[28].

As the first line in Table 3 shows, a value of $q_y = 0.0401$ is accomodated by a higher marginal likelihood than whenever the weight is decreased to 0.005 (second last line in Table 3)[29]. In addition, the impulse response dynamics of the target variables, which are shown in figures 1 and 2 for the productivity shock and the price mark-up shock, respectively[30], is different when we set $q_y = 0.005$ (purple line) compared to the case where the weight is only slightly higher, i.e. 0.0401 as in $M1$ (dark line). In both figures, there is mainly a remarkable difference in the dynamics of the output gap, which takes a longer time to return to equilibrium when $q_y = 0.005$.

[28] It should also be noted that, in order to evaluate the relative importance of the components in the loss function, their corresponding weights should be combined with the realtive volatility of the related variables. Hence the weights per se are not sufficient to evaluate the importance of the alternative target variables, due to the fact that the output gap concept we use in this study is a theoretical one.

[29] The marginal likelihood keeps deteriorating with the decrease in q_y. For example, setting q_y equal to 0.01 brings only a slight deterioration in the marginal likelihood (-281.95). When $q_y = 0.001$ the marginal likelihood already drops to -335.96 and to -499.24 when $q_y = 0$.

[30] Due to spatial limitations, we consider only the responses of the target variables to these two selected shocks.

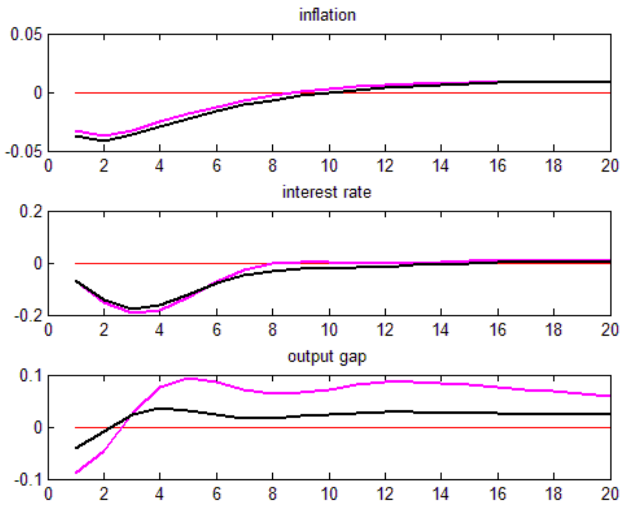


Figure 1. Impulse response to productivity shock when $q_y = 0.005$ vs. $q_y = 0.0401$ $(M1)$

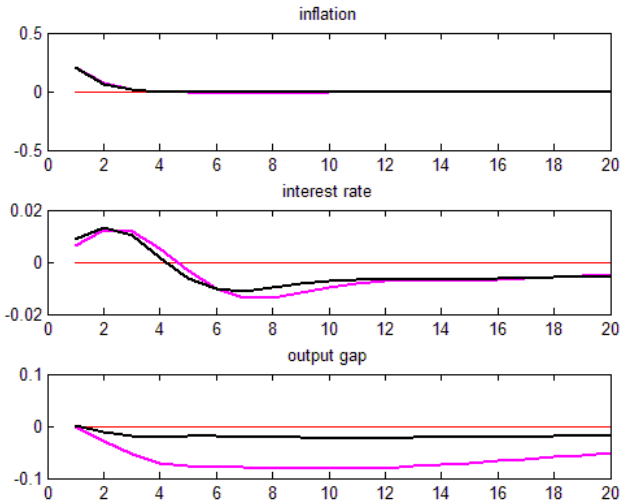


Figure 2. Impulse response to price mark-up shock when $q_y = 0.005$ vs. $q_y = 0.0401$ $(M1)$

When we decrease the weight assigned to the interest rate smoothing target (i.e. q_r) to a value of 0.2, the marginal likelihood also deteriorates as is shown in the last line of Table 3, although this worsening is smaller than in the case where we lower the weight on the output gap. Likewise, the impulse responses of the target variables to a productivity shock and a price mark-up shock shown in figures 3 and 4, respectively, do not change a lot when $q_r = 0.2$ (purple line) compared to the case where $q_r = 0.6309$ as in $M1$ (dark line). Overall, the output gap turns out to be more important as a target variable than is suggested by the estimates, since the deterioration in the marginal likelihood is worse and the dynamics of the target variables differ to a greater extent when models are re-estimated under the assumption that $q_y = 0.005$ than when $q_r = 0.2$. Therefore, although the weight on the output gap is estimated to be small, the statement that the output gap could be ignored in the loss function would be too strong given the high effect a decrease in q_y has on the marginal likelihood and the impulse responses.

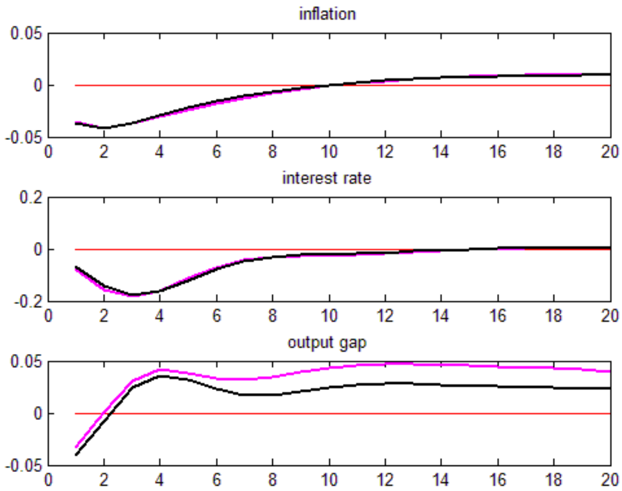


Figure 3. Impulse response to productivity shock when $q_r = 0.2$ vs. $q_r = 0.6309$ $(M1)$

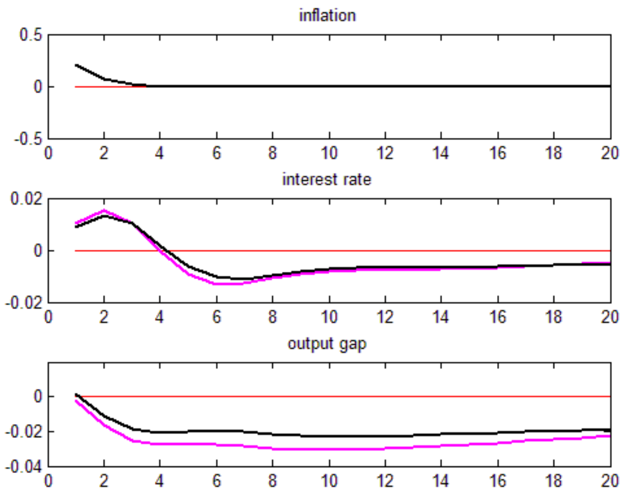


Figure 4. Impulse response to price mark-up shock when $q_r = 0.2$ vs. $q_r = 0.6309$ $(M1)$

In general, however, estimates of a small role for the output gap seem to find support in the literature. Lippi and Neri (2005) for example estimate a very low value for q_y for the euro area, although they use a different output gap concept than the one in this study[31] and assume that monetary policy is conducted under discretion, which requires some caution in comparing the results. Dennis (2003) likewise finds an ignorable weight for the output gap for the US under discretionary monetary policy, which is in analogy with Lippi and Neri (2005)[32]. Söderlind (1999), who also considers the case of commitment in estimating the policy preference parameters and therefore provides a more appropriate comparison to our results, estimates a relatively high value for q_y in the framework of a standard loss function similar to (11). However, it is important to keep in mind the fact that our output gap concept differs from the one used in the other studies, which makes direct comparison of the results a bit troublesome. While Svensson (1999, 2002b) argues for a case of gradual monetary policy where some weight should be given to stabilizing the output gap, and therefore requires a less activist policy, findings in the literature mentioned above for q_y generally do not support this concept of flexible inflation targeting. On the other hand, our experiments with the marginal likelihood costs and impulse responses do imply that somehow monetary policy has considered the output gap as an important target variable.

Lippi and Neri (2005) and Dennis (2003) estimate a weight on the interest rate smoothing component that is higher than the weight on the inflation target, indicating a higher importance attached to smoothing than to inflation[33]. This is not the case in our study. Although our estimates of q_r show that interest rate smoothing is a relatively important target, inflation remains the main policy goal. From an economic point of view, this finding is plausible and in line with the statements that inflation should be the main target variable in monetary policy's objective function. Moreover, Castelnuovo (2004) finds through a calibration exercise in the framework of discretionary monetary policy, a value for the interest rate smoothing weight close to ours whenever forward-looking agents are added to the model. When agents are assumed to be backward-looking only, this weight increases considerably up to a point where interest rate smoothing becomes twice as important as the inflation target. This leads Castelnuovo (2004) to conclude that finding an economically difficult justifiable high value for q_r is probably due to model misspecification by the omission of factors like forward-looking behaviour. Since the model we consider includes forward-looking agents, our values of 0.6309 and 0.624 for q_r are not

[31] Lippi and Neri (2005) describe the output gap as the deviation of output from a linear trend. On the contrary, we assume that the output gap is the deviation of output from the natural output level in the absence of nominal rigidities and the three i.i.d. cost-push shocks.

[32] Söderström et al. (2003) show in their calibration exercise under discretion analogously a low concern for output gap stabilization based on US data. See also Favero and Rovelli (2003) and Salemi (2001), who considers the case of commitment to an optimal Taylor rule, for findings of a relatively low weight on output gap stabilization.

[33] Söderström et al. (2003) show in their calibration exercise under discretion analogously a high importance for interest rate smoothing based on US data.

surprising[34]. An intuitive explanation for this moderating effect of the presence of forward-looking agents on the estimated weight assigned to the interest rate smoothing component in the loss function can be given as follows[35]. Whenever (rational) agents are forward-looking, their expectations will play a key role in the stabilization process of monetary policy and the law of motion of the target variables. Thus current inflation and output are determined by past expectations, and current expectations will determine future inflation and output. If the economy is hit by a shock in the current period, requiring a change in the policy instrument rate in order to stabilize the target variables, expectations will adjust accordingly and since agents are rational they will take into account the fact that interest rate smoothing is a target variable as well. Therefore a slow and persistent move in the interest rates is anticipated. Hence expectations will have a stabilizing effect on current inflation and output gap, which in turn results in a slow and inertial behaviour in the interest rates. If agents were assumed to be backward-looking, like in the case of Dennis (2006) and Ozlale (2003), this inertial behaviour in the interest rates could be only taken into account by the assumption that smoothing receives a high weight in the loss function of the central bank. If agents on the other hand are forward-looking, interest rate inertia is attributed to the stabilizing effect of expectations, which results in lower concern for the interest rate smoothing target. In addition to this explanation, we would also like to point out that the commitment framework assumed in this study enforces this history dependence more than would be the case if monetary policy were assumed to optimize under discretion like in most studies previously mentioned. This suggests that if we would perform a similar exercise under discretionary monetary policy, the estimated values for q_r would be probably higher. This would be an interesting extension and a topic for future research. Our estimates of q_r do not seem to support the argument of Svensson (2002b, 2003), that an interest rate stabilization or smoothing component should not enter the loss function at all, since the values obtained for the smoothing target are significantly higher than zero. However, as we showed previously in this part, decreasing the value of q_r does not lead to a very high loss in terms of marginal likelihood, with a small change in the impulse responses compared to the case where this parameter is freely estimated as is done in $M1$ and $M2$.

When nominal wage inflation is introduced in the loss function of monetary policy, as in the

[34] In order to assess this positive link between the degree of backward-lookingness and the estimates of the preference for interest rate smoothing in our model, we look at the correlation between the series on the inflation indexation parameter γ_p and the interest rate smoothing preference parameter q_r obtained from the markov chain monte carlo draws. Based on these draws, we detect a positive correlation of around 0.3, which is in line with the view of Castelnuouvo (2004).

[35] Castelnuovo (2004) provides a detailed explanation on this issue and quantifies the role played by forward-looking agents in lowering the calibrated values of the weights on the interest rate smoothing component.

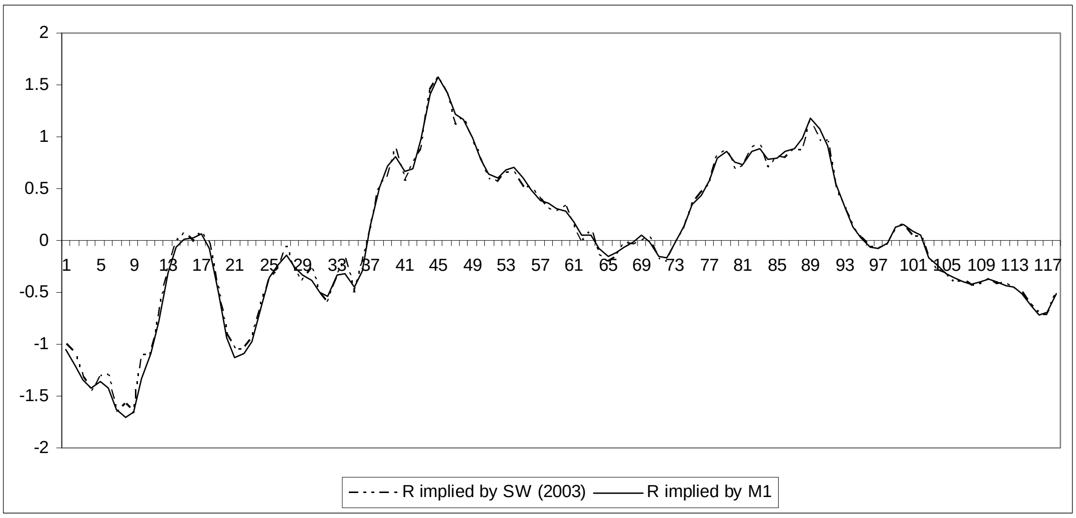
case of $M2$, this additional target receives a weight of 0.269, which suggests a lower importance attached to wage inflation stabilization with respect to the inflation target. However, on the basis of comparison of marginal likelihoods in Table 3, the $M1$ specification of the model where $q_w = 0$ is preferred over $M2$. Hence we can conclude that monetary policy is not concerned about stabilizing nominal wage inflation and that inflation, interest rate smoothing and output gap stabilization are its only targets.

Finally, we plot the prior and the posterior distributions of the parameters for model $M1$ in figures A1-A3, which can be found in the Appendix. We apply the Metropolis-Hastings sampling algorithm, as described in e.g. Bauwens et al. (2000), Gamerman (1997) and Schorfheide (2006), based on 100.000 draws in order to derive the posterior distributions. Convergence is assessed graphically by the Brooks and Gelman (1998) mcmc univartiate diagnostics for each individual parameter and the mcmc multivariate diagnostics for all paramteres simultaneously[36].

3.3.3 Optimal Rule in M1 vs. Empirical Taylor rule in SW (2003)

Since we include an i.i.d. measurement error in the nominal interest rates in order to correct for mismeasurement in the observed data series, these errors, ϵ_t^R, take into account the non-systematic part of the interest rate movements that are not implied by optimal monetary policy. These errors can be compared to the monetary policy shocks, η_t^R, included in the emprirical Taylor rule (9) in SW (2003). The systematic part of the optimal policy rate implied by the model $M1$[37] is plotted in figure 5 (upper part) against the systematic part of the estimated Taylor rule in SW (2003), i.e. as implied by equation (9) without the corresponding periodical monetary policy shocks η_t^R. As becomes clear from the figure, the implied series on the systematic optimal rule and the empirical Taylor rule show similar patterns. This similarity is not very surprising since the empirical Taylor rule considered by SW (2003) mainly includes lagged variables. By definition, the optimal commitment rule, which is derived as an explicit reaction function from the monetary policy optimization, responds to lagged endogenous variables. Hence, the backward-looking characteristic that both rules have in common explains to a considerable extent the similarity in figure 5.

[36] These graphs are available upon request.
[37] We focus on the smoothed series.



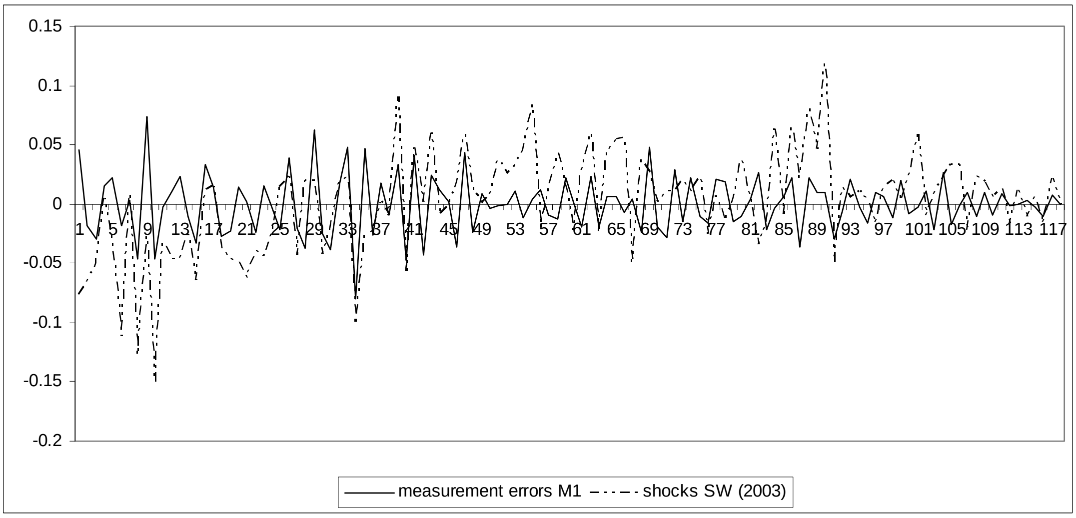


Figure 5. Systematic part of instrument rule in SW (2003) vs. optimal rule in M1 (upper part) and measurement errors M1 vs. monetary policy shocks SW (2003) (lower part)

The lower part of figure 5 plots the series obtained for the measurement errors, ϵ_t^R, over the sample period, i.e. the difference between the actual interest rate movements and the optimal policy rate implied by model $M1$. The figure also shows the monetary policy shocks, η_t^R, implied by SW (2003) that includes an empirical Taylor rule. The monetary policy shocks in the benchmark SW (2003) model generally appear to be of a higher magnitude than the measurement errors in model $M1$.

4 Model Comparison

In this part we compare and rank the models characterized by optimizing monetary policy behaviour, i.e. the models $M1$ and $M2$, and the benchmark SW (2003) model in which monetary policy is described by an empirical Taylor rule, based on their marginal likelihood values[38] reported in Table 3. In a next step, we compare Bayesian impulse responses for selected shocks under optimizing monetary policy authorities ($M1$) to those under SW (2003).

4.1 Marginal Likelihood Comparison

The marginal likelihood of a model can be represented as follows:

$$p(Q_T \mid M_i) = \int_\omega p(Q_T \mid \omega, M_i) p(\omega \mid M_i) d\omega \tag{22}$$

where Q_T contains the observable data series, ω the vector of parameters and M_i the model under consideration, in our case of three models $i = 1, 2$ or $SW(2003)$. The likelihood function $p(Q_T \mid \omega, M_i)$ of the data series is conditional on the parameter vector ω and the model M_i. $p(\omega \mid M_i)$ is the prior density of the parameters conditional on the model. Since we use the same dataset and the same initialization period in the estimation of the three models, the marginal likelihood values shown in Table 3 are comparable[39]. As in Schorfheide (2000), we use the Laplace approximation to approximate the marginal likelihood through the evaluation at the posterior mode. Table 3 also reports the Modified Harmonic Mean for each model, obtained through the markov chain monte carlo simulations, which does not differ much from the Laplace approximation. As pointed out by Del Negro and Schorfheide (2006) and Sims (2003), using the same priors for alternative specifications of a model can bias our choice towards one type of specification. Given this potential pitfall in model comparison within Bayesian frameworks, we correct for the effect of common priors by estimating and evaluating the models over the training sample 1970:2-1980:2 as well, and substract accordingly the corresponding marginal likelihood from the one obtained by estimation over the whole sample period 1970:2-1999:4. The results, however, turn out to be qualitatively comparable to those reported in the first three lines in Table 3.

Although from the table we can conclude that model $M1$ where $q_w = 0$ fits the data better than model $M2$ where nominal wage inflation is included as a target variable in the loss function,

[38] See Geweke (1998) and Schorfheide (2006) for a detailed discussion on the marginal likelihood function in Bayesian estimation.

[39] However, it is important to keep in mind that comparison across models based on the marginal likelihood does not guarantee a waterproof selection of the most suitable model, since the parameter space might be too sparse (Sims, 2003).

both models perform relatively worse compared to the benchmark SW (2003) specification of the model where monetary policy is characterized by an empirical Taylor rule only. This might be due to the fact that, by introducing optimizing monetary policy into the models $M1$ and $M2$, we impose a different and more restrictive structure. This result could also indicate that monetary policy was not optimal (under commitment) during the sample period. However, it is worth to point out that in the SW (2003) description of monetary policy behaviour, the Taylor rule includes five parameters, while there are only two monetary policy preference parameters to be estimated in $M1$. Hence it is not very surprising that the SW (2003) model with more free parameters to be estimated performs better than $M1$. Therefore, we re-estimate the SW (2003) model with a slightly different specification of the empirical Taylor rule (9). We consider the following rule that responds to only the lagged inflation rate and the lagged output gap:

$$\hat{R}_t = \rho \hat{R}_{t-1} + (1-\rho)\left\{\bar{\pi}_t + r_\pi(\hat{\pi}_{t-1} - \bar{\pi}_t) + r_y(\hat{Y}_{t-1} - \hat{Y}^p_{t-1})\right\} \tag{23}$$

so we drop the second part of reaction function (9) by setting $r_{\Delta\pi} = r_{\Delta y} = 0$. The marginal likelihood of the SW (2003) model under this specification of the Taylor rule worsens to -301.08 (Laplace approximation), with $\rho = 0.8894$, $r_\pi = 1.6454$ and $r_y = 0.1291$. Given that it might be more appropriate to compare the optimal monetary policy model $M1$ to the SW (2003) model with a rule like (23), the optimal monetary policy specification is clearly preferred by the data.

4.2 Bayesian Impulse Response Analysis

In this part we visualize the consequences of assuming optimizing monetary policy aurthorities on the impact and the dynamics of the variables in the case of a supply shock (productivity shock), a demand shock (equity premium shock) and a cost push shock (price-markup shock) over a period of 20 quarters. We take the SW (2003) model which includes an estimated policy reaction function as the benchmark case (green lines) and assess to which extent the reactions of the variables differ when monetary policy minimizes an intertemporal loss function with one period loss as specified under model $M1$(dark lines)[40]. We look at the responses of nine variables, i.e. output, consumption, inflation, interest rate, wages, rental rate of capital, employment, investment and the output gap. The solid lines are the mean impulse responses, whereas the dotted lines are the 10% and the 90% posterior intervals.

[40] Since $M1$ performs relatively better than $M2$, we prefer to focus only on the impulse responses obtained under $M1$. However, the impulse respones under $M2$ are, with the exception of responses to the equity premium shock, very similar to those under $M1$.

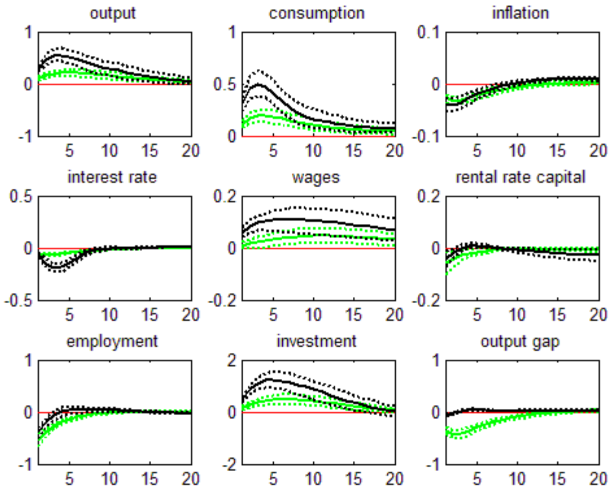


Figure 6. Productivity shock

Figure 6 shows the responses of the variables to a productivity shock. The interest rate, which is the policy instrument and responsable for the main differences between the two alternative model specifications $M1$ and SW (2003), shows a slightly lower impact and gets more negative (accommodative) around the third quarter under $M1$ as opposed to the benchmark SW (2003) case. Hence consumption and investment both increase to a greater extent, resulting into a higher increase in output and lower decrease in employment. The output gap does not become negative, in contrast to the SW (2003) benchmark case, since monetary policy accommodates the productivity shock more strongly. Although the impact on wages are higher, the rental rate of capital shows a similar pattern in the two models. Finally, the initial effect on inflation is slightly more negative.

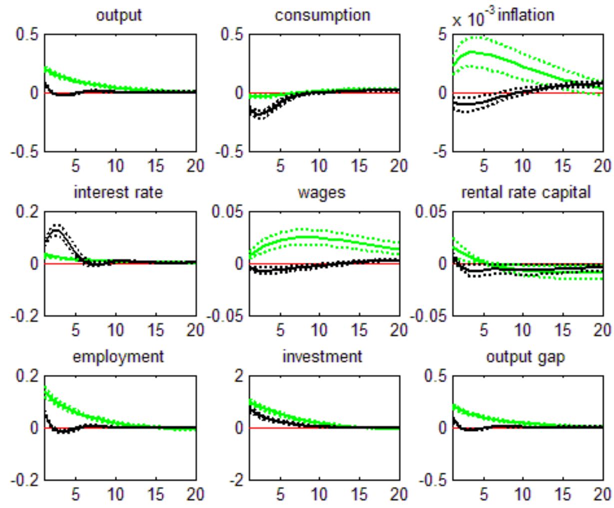


Figure 7. Equity premium shock

Figure 7 shows the impulse responses of the equity premium shock. The interest rate responds more strongly to the equity premium shock and gets more positive (more activist policy) around the third quarter, in contrast to the baseline model, which explains the stronger initial decline in consumption, the weaker response of investment and hence employment, output and analogically the output gap. The impact on both wages and rental rate of capital is much weaker and even turns slightly negative. Therefore, inflation responds negatively, however, the effect is very small.

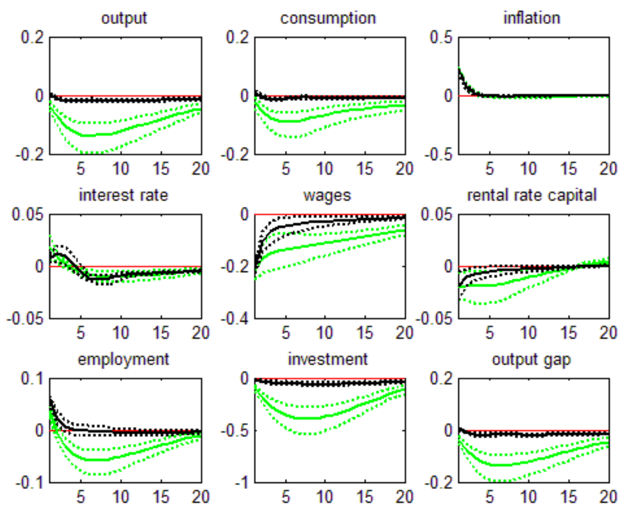


Figure 8. Price mark-up shock

Comparing the impulse responses to a price mark-up shock in figure 8 to the benchmark case yields the following conclusions. The impact and dynamics of the interest rate are similar to the benchmark case. The initial decrease in investment is lower than the benchmark model, followed by weak dynamics that are close to zero. In contrast to what we observe for SW (2003), the impact of the shock on consumption is slightly positive, followed by smaller dynamics also in this case. Hence, it is not surprising that output and employment are affected very weakly in the initial period. The former reaches its lowest value around the tenth quarter, which is still higher than in SW (2003). Note that, like in the case of the equity premium shock, the output gap mimics here the behaviour of output too. This is logical since potential output is not affected by these cost-push shocks and therefore the output gap follows the same dynamics as output. Perhaps a bit surprising, inflation shows very similar patterns in both models.

5 Implied Variances and Taylor Rules

In this part we adopt an alternative framework for comparing optimizing monetary policy behaviour to the empirical Taylor rule in the benchmark SW (2003)[41]. We derive both the unrestricted optimal rule and the optimal coefficients of the Taylor rule (9) for the SW (2003) model under a standard ad hoc loss function of the type (11) where the weight parameters q_y and q_r are assigned the values obtained from the estimation of model $M1$, i.e. 0.0401 and 0.6309, respectively. Accordingly, we compare these two rules, belonging to the optimal class of rules, to the estimated Taylor rule in the benchmark SW (2003) model whose coefficients are reported in Table 2. We analyze the differences in the unconditional variances of the targets and the efficiency frontiers between the two alternative approaches towards monetary policy. The variances of the three target variables, which are reported in Table 4, under the optimal Taylor rule are similar to those implied by the unrestricted optimal commitment rule[42]. The values of the unconditional losses (where $q_y = 0.0401$ and $q_r = 0.6309$) are therefore similar as well (0.095 in the case of the unrestricted optimal commitment rule vs. 0.1035 in case of the optimal Taylor rule). The finding that the optimal Taylor rule approaches the unrestricted optimal commitment rule quite well is not surprising, since both rules are history dependent. Therefore, we will focus on differences

[41] Since parameter estimates of $M1$ and the benchmark SW (2003) reported in tables 1 and 2 differ, we prefer to consider the analysis in this part only in the framework of SW (2003). This way we are able to correct for the differences in the coefficients of the structural equations between the two models. In addition, we check the dynamics under the estimated model $M1$ and the benchmark SW (2003) model to which we attach the same loss function and weights estimated for $M1$. The differences appear to be small, which provides an additional justification for our focus on optimal monetary policy rules in SW (2003).

[42] Moreover, from the impulse response analysis, it appears that the dynamics under the optimal Taylor rule are similar to those under the unrestricted optimal commitment rule.

Table 4: Variances of Target Variables and Unconditional Losses Optimal Rules and Estimated Taylor Rule

	Unrestricted Optimal Rule	Optimal Taylor Rule	Estimated Taylor Rule
variance π_t	0.0582	0.0639	0.1227
variance $(Y_t - Y_t^p)$	0.5511	0.5465	7.6577
variance $(R_t - R_{t-1})$	0.0228	0.028	0.0185
Unconditional loss $[q_y = 0.0401, q_r = 0.6309]$	0.095	0.1035	0.441

between the optimized coefficients of (9) and their estimated counterparts.

As reported in Table 2, estimation of the SW (2003) specification of the model yields the following coefficients for the interest rate equation:

$$\begin{aligned} \hat{R}_t &= 0.976\hat{R}_{t-1} + (1-0.976)\left\{1.7\hat{\pi}_{t-1} + 0.1265(\hat{Y}_{t-1} - \hat{Y}^p_{t-1})\right\} \\ &\quad +0.0977(\hat{\pi}_t - \hat{\pi}_{t-1}) + 0.1392((\hat{Y}_t - \hat{Y}^p_t) - (\hat{Y}_{t-1} - \hat{Y}^p_{t-1})) \\ &= 0.976\hat{R}_{t-1} + 0.0408\hat{\pi}_{t-1} + 0.003(\hat{Y}_{t-1} - \hat{Y}^p_{t-1}) \\ &\quad +0.0977(\hat{\pi}_t - \hat{\pi}_{t-1}) + 0.1392((\hat{Y}_t - \hat{Y}^p_t) - (\hat{Y}_{t-1} - \hat{Y}^p_{t-1})) \end{aligned} \tag{24}$$

The optimized coefficients of the Taylor rule for the preference parameters in the loss function $q_y = 0.0401$ and $q_r = 0.6309$ for the output gap and the interest rate difference, respectively, are as follows[43]:

$$\begin{aligned} \hat{R}_t &= 0.9939\hat{R}_{t-1} + (1-0.9939)\left\{25.66\hat{\pi}_{t-1} + 36.7669(\hat{Y}_{t-1} - \hat{Y}^p_{t-1})\right\} \\ &\quad +0.0576(\hat{\pi}_t - \hat{\pi}_{t-1}) + 0.1791((\hat{Y}_t - \hat{Y}^p_t) - (\hat{Y}_{t-1} - \hat{Y}^p_{t-1})) \\ &= 0.9939\hat{R}_{t-1} + 0.1565\hat{\pi}_{t-1} + 0.2243(\hat{Y}_{t-1} - \hat{Y}^p_{t-1}) \\ &\quad +0.0576(\hat{\pi}_t - \hat{\pi}_{t-1}) + 0.1791((\hat{Y}_t - \hat{Y}^p_t) - (\hat{Y}_{t-1} - \hat{Y}^p_{t-1})) \end{aligned} \tag{25}$$

Comparison of these optimized coefficients in (25) to the estimated values in (24), shows that there is a higher degree of interest rate persistence present when monetary policy follows the optimal Taylor rule. Hence the optimal rule approaches more closely a difference rule. In addition, the optimal coefficients on lagged inflation, lagged output gap and one-period difference

[43] These results are robust to changes in initial values. Therefore, we are quite confident about the fact that these values are globally optimal.

in the output gap are higher than the estimated coefficients, which implies a more active interest rate policy under the optimal approach towards monetary policy.

Finally, figure 9 shows the efficiency frontiers, i.e. the tradeoff between inflation and output gap variability, in the case of an unrestricted optimal commitment rule and an optimal Taylor rule of the type (9). The variance of inflation is plotted on the horizontal axis against the variance of the output gap on the vertical axis[44]. The frontiers are obtained by combining the corresponding variances of output gap and inflation for altering weights on the output gap q_y in the loss function. The combinations of inflation and output gap variability for the estimated pair of weights ($q_y = 0.0401$,$q_r = 0.6309$) are highlighted in the figure for each rule. As noted earlier, the figure confirms that the efficiency frontier under the optimal Taylor rule approaches the efficiency frontier under the unrestricted optimal rule closely. The combination of the variance of inflation and the output gap under the estimated Taylor rule (24), on the other hand, lies far away from the efficiency frontiers. This is mainly due to the fact that the variances of these two target variables are considerably higher than the ones found for the optimal rules, with a corresponding value of the loss function equal to 0.441, as reported in Table 4.

[44] Although the analysis would be more complete if we would include all target variables and therefore consider the variance of the interest rate as well, which would require a plot in three-dimensional space, we prefer to focus on only two of the three target variables in order to keep the analysis simple and in line with common practice in the literature.

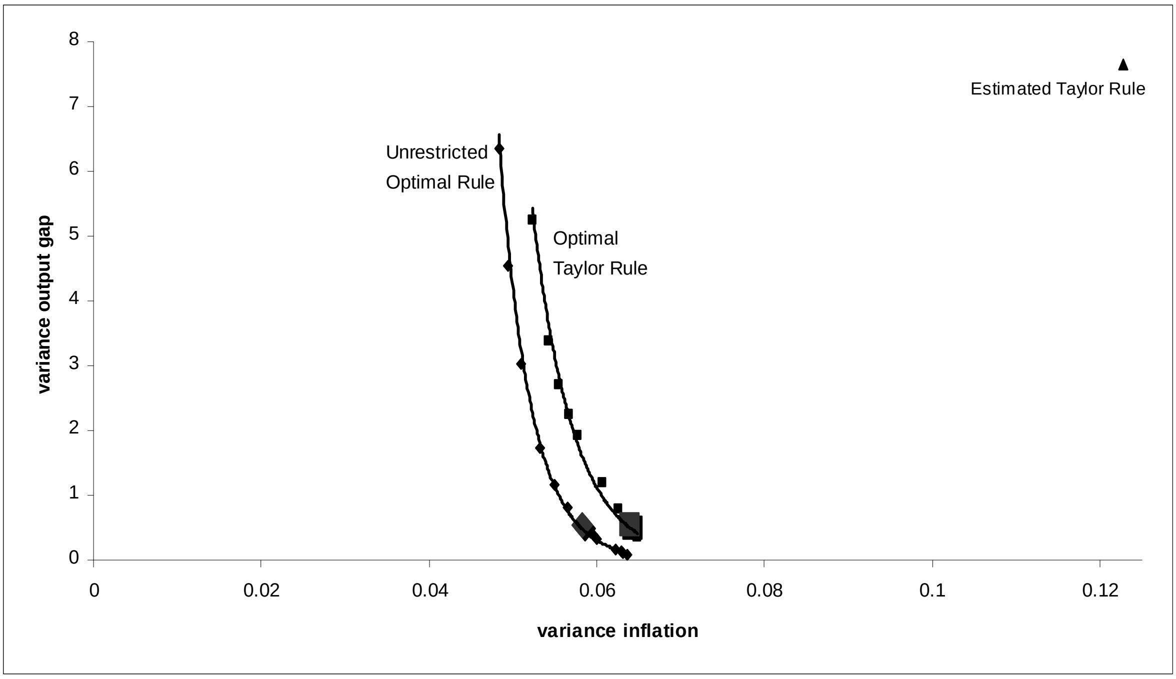


Figure 9. Efficiency frontiers optimal rules

6 A Note on the Lagrange Multipliers and the Timeless Perspective

Due to our assumption that optimal monetary policy is conducted under commitment, we are dealing with a policy that is not time consistent, i.e. past commitments are ignored in the initial period, which is reflected by the fact that the values of the lagrange multipliers of the forward-looking variables are set to zero at that point. Setting these initial lagrange multipliers to zero implies that policy does not value the commitments she has made in the past. The initial state of the economy is exploited, hence the time inconsistent nature of the policy. These lagrange multipliers of forward-looking variables are considered to be the variables reflecting the values that are assigned to past commitments[45]. However, the concept of optimal policy under timeless perspective introduced by Woodford (1999) addresses this potential time-inconsistency problem by rewriting the optimization problem in such a way that the lagrange multipliers in the initial period are not ignored[46]. In our estimation exercise performed above, we assume

[45] See Dennis (2001) for a detailed analysis on this interpretation. Other examples can be found in Jensen and McCallum (2002), Blake and Kirsanova (2003) and McCallum and Nelson (2000).

[46] See also Svensson and Woodford (1999).

that the economy is at steady state in the initial period, i.e. the beginning of the sample period, and the lagrange multipliers are set equal to zero. Hence we treat the first 40 quarters (1970:2-1980:2) of our sample period as the initialization period preceding the estimations. This period should be long enough to ensure us that the effects of the initial values at the beginning of the estimation period become negligable. Accordingly, this should allow us to suggest that we do incorporate the notion of optimal timeless policy in our estimation procedure[47]. In order to check for this, we experiment with different initial values at the start of the initialization period (i.e. at time 1970:2) for the lagrange multipliers of the forward-looking variables only[48]. For our suggestion that we successfully take into account the concept of optimal policy from a timeless perspective to make sense, these changes in initial values should not lead to a (big) difference in the estimation results since the effects of these initial values should have faded away by the end of the initialization and the start of the estimation period[49]. The results obtained from this exercise are almost identical to the original results reported in Tables 1 and 2 in section 3.3 and therefore the impulse responses are similar. This suggests that the results from our estimation procedure are almost unaffected by changes in initial values thanks to a relatively long initialization period. Additionally, we also check for sensitivity of the estimation results to the length of the initialization period. For this purpose we decrease the size of the presample gradually below 40 and re-estimate the model $M1$ twice, i.e. once by setting all initial values equal to zero and once by setting the lagrange multipliers of forward-looking variables equal to nonzero, for a given presample size. It turns out that, while decreasing the sample size, the estimation results start to show higher differences once the presample reaches the size of around 20 quarters and below. This suggests that, in order for the zero initial values of lagrange multipliers to lose their effect, approximately 20 quarters are needed. Therefore, given our presample choice of 40 quarters, our estimation results appear to be robust to the initial values of the lagrange multipliers of forward-looking variables and the presample length. This justifies the assumption that our results hold in the context of optimal policy approached from a timeless perspective[50].

Figure 10 plots the series of the lagrange multipliers (against time) of equations on forward-

[47] The reasoning that the optimal time inconsistent policy approaches closely the timeless perspective policy after a sufficiently long period following the initial period of the optimization, is analogous to the one followed by Juillard and Pelgrin (2005).

[48] Unfortunately, we do not know the exact initial values of the lagrange multipliers of the forward-looking variables because these are not observable. Therefore we experiment with, admittedly arbitrary, values.

[49] We perform this experiment for model $M1$ only.

[50] To our knowledge, there is one empirical application to the timeless perspective solution. Juillard and Pelgrin (2005) show a two-step method to estimate policy from a timeless perspective in a Bayesian framework and apply it to a small open economy.

looking variables obtained after estimation of model $M1$. The implied values of the lagrange multipliers of the real wages, inflation and consumption appear to be higher in absolute value as compared to the values of the lagrange multipliers of the other equations on forward-looking variables that are very close to zero. Hence the values attached to past commitments by monetary policy authorities are higher with respect to wages, inflation and consumption than to the other forward-looking variables. Put differently, the private sector expectations of wages, inflation and consumption are considered to be valued as relatively most important by monetary policy under commitment[51]. Alternatively, the figure suggests that the marginal contributions of the individual constraints on wage and inflation equations are relatively high. Therefore, the nominal rigidities, i.e. wage and price rigidities, seem to impose an important constraint on the model.

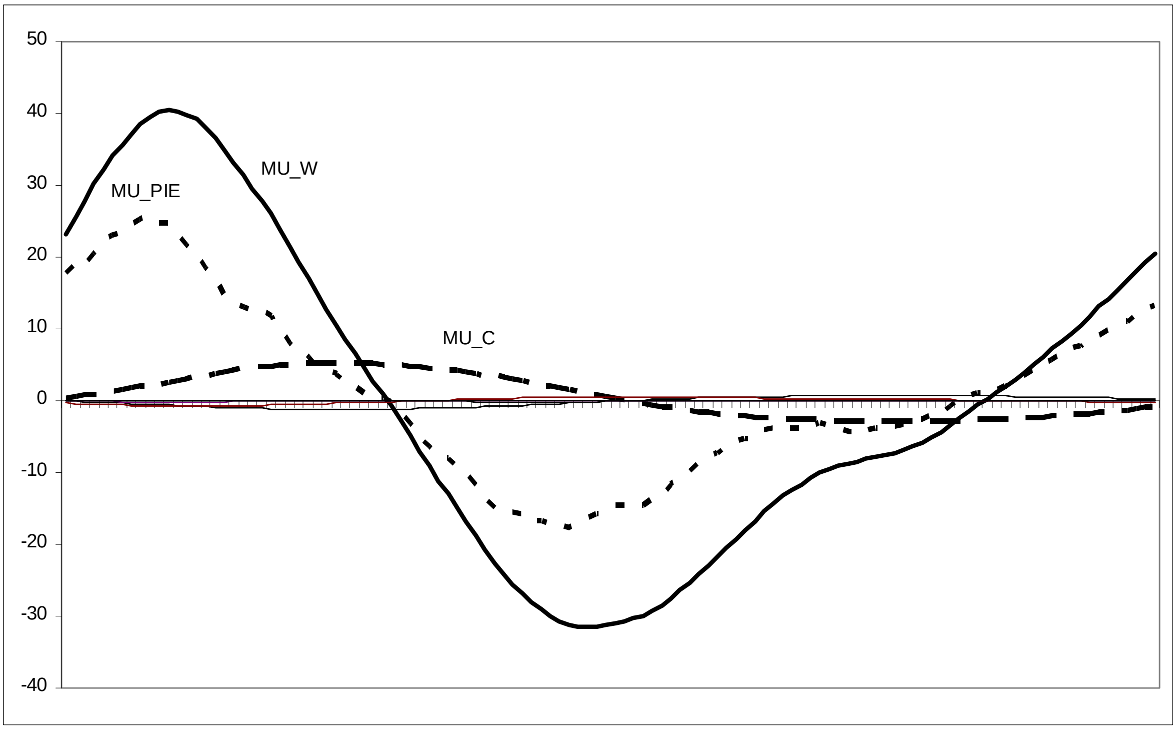


Figure 10. Multipliers of the forward-looking variables obtained after estimation

[51] The importance of these values, however, are described by the coefficients in the explicit monetary policy reaction function.

7 Conclusion

In this paper we estimate the preferences of optimizing monetary policy authorities in a DSGE framework. Taking the Smets and Wouters (2003) model for the euro area as the benchmark case, we look at the effects of the assumption that monetary policy is conducted optimally under commitment. Accordingly, we estimate the preferences in the monetary policy objective function, which is assumed to take a standard quadratic form, using Bayesian estimation techniques. In doing this, we model the optimizing monetary authorities in two alternative ways. The first model adopts a one period loss function that includes inflation, the model-consistent output gap and the one-period difference in the policy instrument. The second model includes an additional wage inflation component. The estimation results for the structural parameters under these two model specifications are compared to the results of the benchmark Smets and Wouters (2003) model.

The estimate of the wage inflation preference parameter in the monetary policy's loss function in our second alternative model does not turn out to be significant. This model performs relatively worse by yielding a lower marginal likelihood than our first alternative model with three target variables defining the loss function. The results for the first model suggest a significant value assigned to both the output gap and interest rate smoothing, in addition to the main inflation objective, in the monetary policy's loss function.

A comparison of the estimated reaction function (generalized Taylor rule) of Smets and Wouters (2003) to an optimized version of the same rule shows that the optimized coefficient on the lagged interest rate is higher than the estimated value, suggesting a more persistent rule in the optimal approach towards monetary policy. The optimal coefficients on lagged inflation, lagged output gap and the one-period difference in the output gap are also higher than the estimated coefficients, which indicates a more active optimal policy.

For the purpose of addressing the time-inconsistency problem that comes along with optimal monetary policy conducted under commitment, where the issue arises because the initial values of the lagrange multipliers on the equations on forward-looking variables are set equal to zero, we precede our estimation procedure by an initialization sample that is long enough to ensure that the effect of the initial values on the estimates wears out. Hence we are able to approach the framework of optimal policy under timeless perspective of Woodford (1999) very closely.

There are a few points on which we would like to improve and extend this work in the future. First of all, the results presented in this paper are conditional on the assumption that monetary policy performs optimally under commitment. Therefore, these results may change and lead to different conclusions if we would consider the alternative case of discretion. A simplifying and perhaps naive assumption throughout our estimations is that of a constant loss function over the sample period, implying stable preferences over the target variables along the period. The idea of altering policy regimes over the period of our consideration (1980:2 - 1999:4) is not unrealistic, which would require a split of the sample period in order to take changes in monetary policy strategies in the euro area into account. Moreover, it would be interesting to update our sample period and look at changes in monetary policy preferences brought about by the introduction of the Euro. However, this would be a little troublesome for the moment since our sample of the period after the launch of the Euro would be very short, which is the main reason why we would like to leave this exercise for future work. We have restricted our analysis to a case where the inflation target is assumed to be a known constant. An interesting extension would be to estimate the inflation target together with the other parameters in the model and allow for time-variation in this target. It could also be desirable to perform a similar exercise for the US economy, which would allow us to assess differences in monetary policy preferences in the euro area and the US. Finally, we did not consider the possibility of the presence of any kind of uncertainty and/or possible deviations from the assumption that private expectations are formed rationally. Therefore, it would be interesting to test the robustness of our results to a certain degree of uncertainty concerning the structural parameters and/or the underlying structural model, additionally taking into account the assumption that private agents show learning behaviour.

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Appendix: Prior and Posterior Distributions of Parameters in Model $M1$

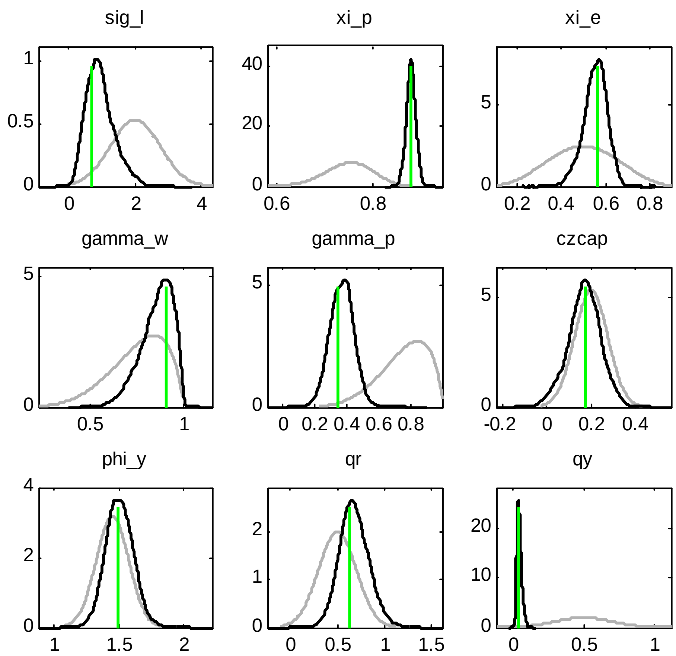

Figure A1 posterior distributions of the parameters of $M1$

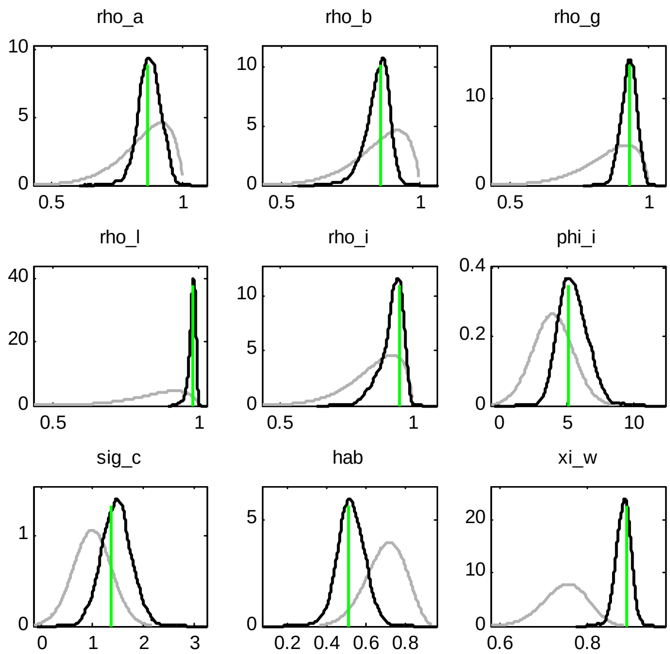

Figure A2 posterior distributions of the parameters of $M1$

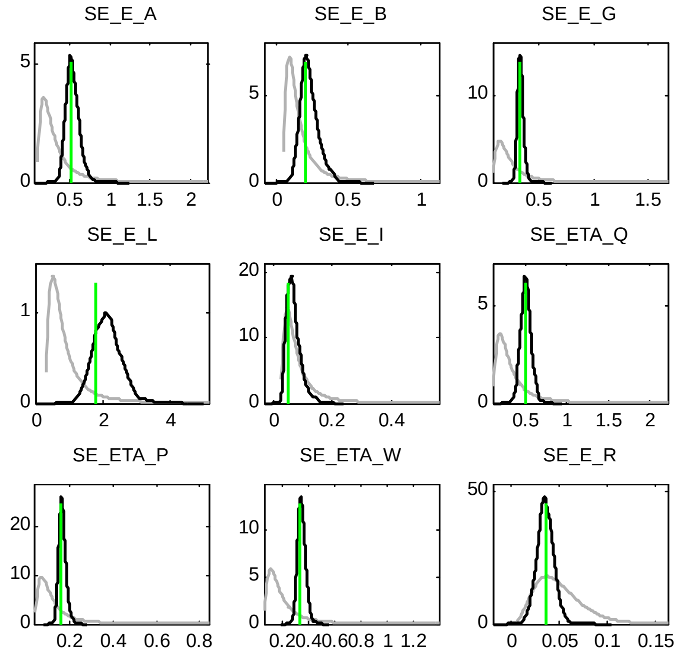

Figure A3 posterior distributions of the parameters of $M1$

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