

Learning and the Monetary Policy Strategy of the European Central Bank*

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Abstract

This paper examines the welfare implications of alternative inflation targeting proposals for the monetary policy of the European Central Bank. We assume that policy makers have to "learn" the laws of motion of inflation in an economy characterized by "stickiness" in domestic price setting behavior and subjected to recurring shocks to productivity, exports and foreign price. We find that a switch from an "asymmetric" inflation targeting strategy to a "symmetric" makes little difference in welfare payoffs, but it comes at a cost of much higher interest-rate variability. We also find that there are practically no welfare gains from switching from an inflation-targeting strategy based on the Harmonized Index of Consumer Prices (HICP) to a strategy based on the domestic price component of the HICP.

Key Words: Inflation targeting, central bank learning, monetary policy

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1 Introduction

This paper examines alternative proposals for the inflation targeting program and the overall monetary strategy of the European Central Bank (ECB). In particular, we compare the current practice of asymmetric inflation targeting with the recent proposal by Svensson (2003a) for a fully symmetric inflation-targeting program. We also compare the current practice of targeting inflation in the Harmonized Index of Consumer Prices (HICP) with that of targeting inflation in just the domestic price component of the HICP.

While the European Central Bank has indeed modified its asymmetric strategy to an inflation target of "below but close to 2%", Svensson (2003b) contends that while this is a "move in the right direction", it is "not good enough". Agreeing with De Grauwe (2003), he asserts that the ECB has missed an opportunity "to thoroughly modernize its strategy, remove the ambiguity, and explicitly and transparently adopt flexible inflation targeting" [Svensson (2003b): p.2].

As for the appropriate index for inflation targeting, Gali and Monacelli (2002) found, for a small open economy with sticky price setting behavior, that domestic inflation targeting dominates, from a welfare point of view, both aggregate CPI inflation targeting and an exchange-rate peg. They base their argument on the "excess smoothness" induced in the exchange rate by CPI targeting or an exchange rate peg. This smoothness, in combination with the assumed stickiness in nominal prices, prevents relative prices from adjusting "sufficiently fast", thus causing "a significant deviation from the first best allocation" [Gali and Monacelli (2002), p.2].

In contrast to this point, Svensson (2000) has pointed out that "all real-world inflation targeting economies are quite open economies" and "all inflation targeting economies have chosen to target the CPI inflation" [Svensson (2000): p.155]. More recently, Kara and Nelson (2002) found that for the United Kingdom, CPI inflation in the data "behaves much like domestic-goods price inflation" [Kara and Nelson (2002), p.22]. They report that models which characterize all imported goods as intermediate goods "provides the most attractive alternatives" for understanding UK data, and argue that their evidence is "consistent with CPI inflation-targeting followed in the UK and other open economies" [Kara and Nelson (2002), p. 22].

In this paper, these alternative targeting strategies are examined using the model put forward by Smets and Wouters (2002) which is calibrated for the Euro area data. In that model, all imported goods are intermediate goods and it has both domestic and import price stickiness. However, our analysis incorporates a learning mechanism for the central bank.

While there has been a wide discussion of alternative inflation targeting rules for open and closed economies, learning has, for the most part, been introduced in this literature in only one dimension, as private sector learning of the policy rule of the central bank.¹ In contrast, we assume, following Sargent (1999) and Cogley and Sargent (2003), that the learning process is on the side of the central bank. The monetary policy authority does not

¹For example, Bullard and Mitra (2002) incorporate private sector learning of the specific Taylor rules used by the central bank in the Rotemberg-Woodford closed economy framework. They argue for Taylor rules based on *expectations of current* inflation and output deviations from target levels, rather than rules based on lagged values or forecasts further into the future. Orphanides and Williams (2002) also assume private sector learning, but the learning is about the "true" inflation dynamics as they reformulate their expectations.

know the "true laws of motion" of inflation generated by the private sector whose behavior can be described by a stochastic dynamic, nonlinear general equilibrium model, with forward-looking rational expectations. Instead the central bank has to learn about the laws of motion of inflation from past data, through continuously updated least squares regression. This information is then used to obtain an optimal interest rate feedback rule based on linear quadratic optimization, using weights in the objective function for inflation which can vary with current conditions. Such a learning framework accords more closely with real life Central Bank policy setting behavior based on approximating models of the true economy. The monetary authority is thus "boundedly rational", in the sense of Sargent (1999), with "rational" describing the use of least squares, and "bounded" meaning model misspecification. The policy setting framework may also be viewed as an adaptation of the robust optimal control modelling framework of Hansen and Sargent (2002).

Of course, this definition of learning is rather specific. Svensson (2003c) characterizes this set-up, with the central bank operating with a quadratic loss function and a view of the transmission mechanism based on linear relations, as "mean forecast targeting". Information is thus "filtered through the forecasts", which provides a "safe-guard against overactivism and too much response to incoming information" [Svensson (2003c), p.4].

In contrast to Smets and Wouters, we also do not simplify the analysis by linearizing the model around steady state values. Rather, we use a nonlinear solution method, and we incorporate shocks from productivity, exports and foreign price. To anticipate results, we find only small welfare differences between an "asymmetric" or "symmetric" targeting strategy, and between

overall CPI inflation or domestic inflation targeting. From a welfare point of view, these results suggest that there is little urgency, if at all, for the ECB to "modernize its strategy, remove the ambiguity, and explicitly and transparently adopt flexible inflation targeting". Moreover, the results show that a switch from asymmetric to symmetric targeting comes at a cost of higher interest rate variability.

The paper is organized as follows. The Smets and Wouter model is briefly described in Section 2, together with our model of central bank learning. Section 3 reports on the calibration and solution algorithm. The simulation results are presented in Section 4 and concluding remarks are in Section 5.

2 Model Specification

The framework of analysis contains two modules - a module which describes the behavior of the private sector and a module which describes the behavior of the central bank.

2.1 Private Sector Behavior

The private sector is assumed to follow the standard optimizing behavior characterized in dynamic stochastic general equilibrium models. We adopt the model presented in Smets and Wouter (2002) for the private sector in the Euro Area. The aggregate form of the model is presented next.

2.1.1 Consumption and Labour Supply

A householder is assumed to have a utility function of the form:

$$U_t(.) = \frac{(C_t)^{1-\sigma}}{1-\sigma} - \frac{(\kappa L_t)^{1+\varpi}}{1+\varpi} \quad (1)$$

where C is consumption aggregated over the consumption of domestic goods C_t^D and the consumption of foreign goods C_t^F in the form:

$$C_t = \left[(1 - \alpha_c) (C_t^D)^{(\eta-1)/\eta} + \alpha_c (C_t^F)^{(\eta-1)/\eta} \right]^{\eta/(\eta-1)} \quad (2)$$

where η is the elasticity of substitution between domestic and foreign goods and α_c is the share of imported goods in total consumption. In equation (1) σ is the coefficient of relative risk aversion; L is labour services and ϖ is the elasticity of marginal disutility with respect to labour supply. The parameter κ is the coefficient of the disutility of labor.

The intertemporal budget constraint is of the form:

$$\frac{S_t F_t}{(1 + R_t^*)} = S_t F_{t-1} + W_t L_t - P_t C_t \quad (3)$$

where F is foreign debt, S is the nominal exchange rate, W is the wage rate, P is the overall price index and R^* is the foreign interest rate.²

The aggregate first-order conditions are:

$$\frac{(1 + R_t)}{(1 + R_t^*)} = \frac{S_{t+1}}{S_t} \quad (4)$$

$$\left(\frac{C_{t+1}}{C_t} \right)^\sigma = \beta \frac{(1 + R_t)}{(P_{t+1}/P_t)} \quad (5)$$

$$(L_t)^\varpi = \frac{1}{\kappa} (C_t)^{-\sigma} \frac{W_t}{P_t} \quad (6)$$

where R is the domestic policy interest rate and β is the discount factor.

2.1.2 Production

Production follows a Leontief technology:

$$Y_t^D = \min \left\{ \frac{v_t L_t}{1 - \alpha_y}, \frac{K_t}{\alpha_y} \right\} \quad (7)$$

²As in Smets and Woulter, we assume that government debt is always equal to zero, meaning that government expenditures equal net transfers.

where Y_t^D is the production of domestic goods, v is an aggregate productivity shock, and K represents the imported intermediate goods which is a fixed proportion α_y of output.

2.1.3 Pricing Equations

Prices are determined according to the Calvo system of staggered pricing for both intermediate and final goods. For intermediate goods, the price equations are:

$$\begin{aligned}
P_t^{F1} &= P_{t-1}^F \\
P_t^{F2} &= \frac{Y_t^F (P_t^{F*} S_t) + \sum_{j=1}^{\infty} \left(\frac{1}{\prod_{k=0}^{j-1} (1+R_{t+k})} \right) \xi_F^j Y_{t+j}^F (P_{t+j}^{F*} S_{t+j})}{Y_t^F + \sum_{j=1}^{\infty} \left(\frac{1}{\prod_{k=0}^{j-1} (1+R_{t+k})} \right) \xi_F^j Y_{t+j}^F} \\
P_t^F &= \xi_F (P_t^{F1}) + (1 - \xi_F) (P_t^{F2})
\end{aligned} \tag{8}$$

where P_t^{F1} describes the price of the sticky-price setters, P_t^{F2} describes the price of the optimisers and equation (8) is the aggregate domestic price of the intermediate goods P_t^F expressed as a weighted average of the non-optimising price P_t^{F1} and optimising price P_t^{F2} .

Similarly, the corresponding equations to determine the aggregate domestic price P_t^D are:

$$\begin{aligned}
P_t^{D1} &= P_{t-1}^D \\
P_t^{D2} &= \frac{Y_t^D MC_t + \sum_{j=1}^{\infty} \left(\frac{1}{\prod_{k=0}^{j-1} (1+R_{t+k})} \right) \xi_D^j Y_{t+j}^D MC_{t+j}}{Y_{t+j}^D + \sum_{j=1}^{\infty} \left(\frac{1}{\prod_{k=0}^{j-1} (1+R_{t+k})} \right) \xi_D^j Y_{t+j}^D}
\end{aligned}$$

$$\text{where } MC_t = (1 - \alpha_y) \frac{W_t}{v_t} + \alpha_y P_t^F$$

$$P_t^D = \xi_D (P_t^{D1}) + (1 - \xi_D) (P_t^{D2}) \quad (9)$$

The aggregate price is given by:

$$P_t = \left[(1 - \alpha_c) (P_t^D)^{1-\eta} + \alpha_c (P_t^F)^{1-\eta} \right]^{1/(1-\eta)} \quad (10)$$

2.1.4 Macroeconomic identities

The consumption of domestic goods and intermediate goods are as follows:

$$C_t^D = (1 - \alpha_c) \left(\frac{P_t^D}{P_t} \right)^{-\eta} C_t \quad (11)$$

$$C_t^F = \alpha_c \left(\frac{P_t^F}{P_t} \right)^{-\eta} C_t \quad (12)$$

In aggregate, the market clearing equations for domestic goods and for imports are respectively:

$$Y_t^D = C_t^D + X_t \quad (13)$$

$$Y_t^F = C_t^F + K_t \quad (14)$$

The exports, X is determined as:

$$X_t = \left(\frac{P_t^{D*}}{P_t^{F*}} \right)^{-\eta} C_t^* \quad (15)$$

where P_t^{D*} is normalised at unity and C_t^* is aggregate world consumption.

The change in foreign debt evolves as follows:

$$(P_t^D X_t - P_t^F K_t) = -S_t [F_{t+1} - F_t(1 + R_t^*)] \quad (16)$$

2.1.5 Euler Equations

The model has six forward-looking variables and they are in the expressions for consumption, the spot rate and the terms in the numerators and denom-

inators of the two Calvo pricing equations:

$$C_t = \mathbf{E} \left[C_{t+1} \left(\frac{P_{t+1}/P_t}{\beta(1+R_t)} \right)^{1/\sigma} \right] \quad (17)$$

$$S_t = \left[\frac{1+R_t^*}{1+R_t} \right] \mathbf{E} S_{t+1} \quad (18)$$

$$V_{t+1}^F = \mathbf{E} \left[\sum_{j=1}^{\infty} \left(\frac{1}{\prod_{k=0}^{j-1} (1+R_{t+k})} \right) \xi_F^j Y_{t+j}^F (P_{t+j}^{F*} S_{t+j}) \right] \quad (19)$$

$$Z_{t+1}^F = \mathbf{E} \left[\sum_{j=1}^{\infty} \left(\frac{1}{\prod_{k=0}^{j-1} (1+R_{t+k})} \right) \xi_F^j Y_{t+j}^F \right] \quad (20)$$

$$V_{t+1}^D = \mathbf{E} \left[\sum_{j=1}^{\infty} \left(\frac{1}{\prod_{k=0}^{j-1} (1+R_{t+k})} \right) \xi_D^j Y_{t+j}^D M C_{t+j} \right] \quad (21)$$

$$Z_{t+1}^D = \mathbf{E} \left[\sum_{j=1}^{\infty} \left(\frac{1}{\prod_{k=0}^{j-1} (1+R_{t+k})} \right) \xi_D^j Y_{t+j}^D \right] \quad (22)$$

Given these 6 variables, the model can be solved for P_t^D , P_t^F , P_t , S , C , C^D , C^F , L , W , K , Y^D , Y^F , F , and utility U (hence welfare).

The solution is also predicated on a given policy interest rate R_t . This variable is determined in the central bank behavioral model discussed next.

2.2 Central Bank Learning and Policy

The central bank adopts practices consistent with optimal control models, specifically, the linear quadratic regulator problem:

$$\Lambda = \lambda_t (\pi_t - \pi^*)^2 \quad (23)$$

$$\pi_t = \sum_{j=1}^k \Gamma_{1t}^j \pi_{t-j} + \Gamma_{2t} \Delta R_t + e_t \quad (24)$$

$$R_{t+1} = R_t + \sum_{j=1}^k h(\widehat{\Gamma}_{1t}^j, \widehat{\Gamma}_{2t}, \lambda_t) \pi_{t-j} \quad (25)$$

where π_t is an annualized rate of inflation. π^* is the target for inflation, and k is the number of lags for forecasting the evolution of the state variable.

The weight on the loss function, λ_t are chosen to reflect the Central Bank's concerns about inflation and is shown in Table I.

In this asymmetric anti-inflation scenario or "monetary policy strategy", if inflation is less than the target level π^* , the central bank does not optimize; in other words, the interest rate remains at its level: $R_{t+1} = R_t$. This is the "no intervention" case. However, if inflation is above the target rate ($\pi > \pi^*$), the monetary authority implements its optimal interest policy according to equation (25). In the symmetric anti-inflation strategy, we replace the level of inflation with its absolute value, that is we consider ($|\pi| > \pi^*$). In the case of domestic price inflation targeting, π represents the annualized rate of change in the domestic price index P^D ; otherwise it represents the annualized rate of change in the aggregate price index, P .

Thus, corresponding to each scenario, the central bank optimizes a loss function Λ and actively formulates its optimal interest rate feedback rule. It also acts at time t as if its estimated model for the evolution of inflation is true "forever", and that the weight for inflation in the loss function is permanently fixed. However, as Sargent (1999) points out in a similar model, the monetary authority's own procedure for re-estimation "falsifies" this pretense as it updates the coefficients $\{\Gamma_{1t}^j, \Gamma_{2t}\}$, and solves the linear quadratic regulator problem for a new optimal response "rule" of the interest rate to the evolution of the state variables at every point of time t .

3 Calibration and Solution Algorithm

3.1 Parameters and Initial Conditions

The model is calibrated using the values suggested by Smets and Wouters (2002):

$\sigma = 1.5$	$\beta = 0.99$	$\eta = 1.5$
$\varpi = 0.25$	$\alpha_y = 0.15$	$\xi_D = 0.85$
$\kappa = 0.5$	$\alpha_C = 0.075$	$\xi_F = 0.85$

The exception, is that instead of assuming that $\alpha_C = 0$ (that is that all imported goods are intermediate goods, so that there are no imported consumption goods) we have set $\alpha_C = 0.075$ to recognize the empirical fact that the share of imported consumer goods to total imports is about 30 percent.

The initial values of the variables are based on the steady state solutions to the model and again are based on the assumptions in Smets and Woulter.

$\bar{C} = 1.486$	$\bar{W} = 0.816$	$\bar{P}^D = 0.816$
$\bar{C}^D = 1.375$	$\bar{Y}^D = 1.748$	$\bar{P}^F = 0.816$
$\bar{C}^F = 0.111$	$\bar{Y}^F = 0.373$	$\bar{P} = 0.816$
$\bar{L} = 1.486$	$\bar{S} = 1.000$	$\bar{X} = 0.374$
$\bar{K} = 0.262$	$\bar{F} = 0.002$	$\bar{R} = 0.04$

The foreign interest rate R^* is fixed at the annual rate of 0.04. In the simulations, the effect of initialization is mitigated by discarding the first 25% of the sample size. We note too that this model is specified and calibrated for the case where the steady-state inflation rate is assumed to be zero.

3.2 Stochastic Shocks

Following Kollmann (2002), we assume that productivity, v , foreign demand C^* and foreign price P^{F*} follow the autoregressive processes:

$$v_t = (1 - \rho^v)\bar{v} + \rho^v v_{t-1} + \epsilon_t^v \quad (26)$$

$$C_t^* = (1 - \rho^C)\bar{C}^* + \rho^C C_{t-1}^* + \epsilon_t^{C^*} \quad (27)$$

$$P_t^{F*} = (1 - \rho^F)\bar{P}^{F*} + \rho^F P_{t-1}^{F*} + \epsilon_t^{F*} \quad (28)$$

with autoregressive coefficients set as:

$\rho^v = 0.9 \quad \rho^C = 0.8 \quad \rho^F = 0.8$
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The steady state values of $\{\bar{v}, \bar{C}^*, \bar{P}^{F*}\}$ are respectively $\{1.000, 0.507, 0.816\}$. The shocks $\{\epsilon_t^v, \epsilon_t^{C^*}, \epsilon_t^{F*}\}$ are independently and identically distributed with standard deviations $\{\sigma^v, \sigma^{C^*}, \sigma^{F*}\}$ set at 5% of their respective steady-state values to give an overall coefficient of variation of about 10% for all three shocks.

We note that productivity shocks are transmitted via the production equation (7); that foreign demand shocks affect the economy directly as shocks to exports, see equation (15) and that foreign price shocks act through both the exports equation ((15) and the pricing equation (8).

3.3 Solution Algorithm and Constraints

Following Marcet (1988, 1993), Den Haan and Marcet (1990, 1994), and Duffy and McNelis (2001), the approach of this study is to parameterize the forward-looking expectations in this model, with non-linear functional forms

$\psi^S, \psi^C, \psi^{V^F}, \psi^{Z^F}, \psi^{V^D}$, and ψ^{V^D} :

$$C_{t+1} = \psi^C(\mathbf{x}_{t-1}; \Omega_C) \quad (29)$$

$$S_{t+1} = \psi^S(\mathbf{x}_{t-1}; \Omega_S) \quad (30)$$

$$V_{t+1}^F = \psi^{V^F}(\mathbf{x}_{t-1}; \Omega_{V^F}) \quad (31)$$

$$Z_{t+1}^F = \psi^{Z^F}(\mathbf{x}_{t-1}; \Omega_{Z^F}) \quad (32)$$

$$V_{t+1}^D = \psi^{V^D}(\mathbf{x}_{t-1}; \Omega_{V^D}) \quad (33)$$

$$Z_{t+1}^D = \psi^{V^D}(\mathbf{x}_{t-1}; \Omega_{Z^D}) \quad (34)$$

The symbol \mathbf{x}_{t-1} represents a vector of observable instrumental variables known at time $t-1$. These variables are: consumption C , the exchange rate, S , and the shocks v , C^* , P^{F*} ; all expressed in deviations from their initial steady state:

$$\mathbf{x}_{t-1} = \{C - \bar{C}, S - \bar{S}, v - \bar{v}, C^* - \bar{C}^*, P^{F*} - \bar{P}^{F*}\}$$

The symbols $\Omega_C, \Omega_S, \Omega_{V^F}, \Omega_{Z^F}, \Omega_{V^D}$, and Ω_{Z^D} represent the parameters for the expectation function, while $\psi^C, \psi^S, \psi^{V^F}, \psi^{Z^F}, \psi^{V^D}$ and ψ^{V^D} are the expectation approximation functions.

Judd (1996) classifies this approach as a "projection" or a "weighted residual" method for solving functional equations, and notes that the approach was originally developed by Williams and Wright (1982, 1984, 1991). The functional forms for $\psi^C, \psi^S, \psi^{V^F}, \psi^{Z^F}, \psi^{V^D}$ and ψ^{V^D} are usually second-order polynomial expansions [see, for example, Den Haan and Marcet (1994)]. However, Duffy and McNelis (2001) have shown that neural networks can produce results with greater accuracy for the same number of parameters,

or equal accuracy with fewer parameters, than the second-order polynomial approximation.

The model was simulated for repeated parameter values for $\{\Omega_C, \Omega_S, \Omega_{VF}, \Omega_{ZF}, \Omega_{VD}, \Omega_{ZD}\}$ and convergence obtained when the expectational errors were minimized.

4 Simulation Analysis

4.1 Base-Line Results

The aim of the simulations is to compare the outcomes for inflation, growth and welfare for the various inflation targeting scenarios - asymmetric inflation targeting, symmetric inflation targeting, CPI inflation targeting, domestic price inflation targeting. To ensure that the results are robust, we conducted 1000 simulations (each containing a time-series of 225 realizations of the shocks).

To ascertain which policy regime yields the higher welfare value, we examined the distribution of the welfare outcomes of the different policy regimes for 1000 different realizations of the various shocks. Before presenting these results, we evaluate the accuracy of the simulation results as well as the "rationality" of the learning mechanism.

4.2 Den Haan-Marcet Accuracy Test

The accuracy of the simulations is checked by the Den Haan-Marcet statistic, originally developed for the parameterized expectations solution algorithm but applicable to other procedures as well. This test makes use of the Euler equation for consumption, under the assumption that with accurate expecta-

tions, the path of consumption would be optimal, so that the expectational term in the Euler equation may be replaced by the actual term and a random error term, ϵ_t^c :

$$C_t - C_{t+1} \left(\frac{(P_{t+1}/P_t)}{\beta(1 + R_t)} \right)^{1/\sigma} = \epsilon_t^c$$

To test whether ϵ_t^c is significantly different from zero, Den Haan and Marcet propose a transformation of ϵ_t^c which has a chi-squared distribution under the hypothesis of accuracy. If the value of this statistic falls in the lower and upper critical regions of the chi-squared distribution, Den Haan and Marcet suggest that this is evidence "against the accuracy of the solution". [Den Haan and Marcet (1994): p. 6]. They also point out that it is a "challenging" test.

Table II presents the percentage of realizations (out of 1000) in which the Den Haan-Marcet statistics fell in the upper or lower critical regions of the chi-squared distribution for the four different policy regimes - symmetric inflation or asymmetric inflation targeting, and the use of the aggregate or domestic price index for the measurement of inflation. These results show that the PEA simulations may be deemed to be reasonably accurate.

4.3 Learning and Quasi-Rationality

In our model, the central bank learns the underlying process for inflation by updating recursively the least-squares estimates of a vector autoregressive model. Marcet and Nicolini (1997) raise the issue of reasonable rationality requirements in their discussion of recurrent hyperinflations and learning behavior. In our model, a similar issue arises. Given that the only shocks in the model are recurring productivity, foreign demand and foreign price shocks,

with no abrupt, unexpected structural changes taking place, the learning behavior of the central bank should not depart, for too long, from the rational expectations paths. The central bank, after a certain period of time, should develop forecasts which converge to the true inflation paths of the economy, unless we wish to make some special assumption about monetary authority behavior.

Marcet and Nicolini discuss the concepts of "asymptotic rationality", "epsilon-delta rationality" and "internal consistency", as criteria for "boundedly rational" solutions. They draw attention to the work of Bray and Savin (1996). These authors examine whether the learning model rejects serially uncorrelated prediction errors between the learning model and the rational expectations solution, with the use of the Durbin-Watson statistic. Marcet and Nicolini point out that the Bray-Savin method carries the flavor of "epsilon-delta" rationality in the sense that it requires that the learning schemes be consistent "even along the transition" [Marcet and Nicolini (2003): p.16, footnote 22].

Following Bray and Savin, we use the Durbin-Watson statistic to examine whether the learning behavior is "boundedly rational". Table III gives the Durbin-Watson statistics for the inflation forecast errors of the central bank, for the simulations with different policy regimes and shock combinations. In all cases we see that the learning behavior does not violate the requirements of bounded rationality for inflation.

4.4 Comparative Welfare Results

This section summarizes the results for 1000 alternate realizations of the shocks (each realization contains 225 observations). Since these shocks are autoregressive processes, the simulated variables would just be deviations from their steady state values and hence the sample means for consumption, inflation and growth would be their steady state values.

The results for the intertemporal welfare index (based on the discounted utility function) for the three shocks - productivity, export and foreign price - are presented in a distributional form, see Figure 1. Results are shown for both symmetric and asymmetric inflation targeting and for both aggregate inflation ($\pi_t = \log(P_t/P_{t-4})$) and domestic inflation ($\pi_t = \log(P_t^D/P_{t-4}^D)$) targeting.

For the case of productivity shocks, the results show the welfare distributions for the four scenarios to be almost identical. In this case, given that there is a limited degree of price flexibility (or a limited degree of price stickiness), the best case scenario for monetary policy would be to let prices adjust to the "supply" or real productivity shock. Hence, the similarity in welfare outcomes for the four scenarios.

For the case of export shocks, the results show that the spread of the effect on welfare is small reflecting the small share of exports in domestic production. Although the welfare distribution for the scenario of symmetric targeting using aggregate inflation show a significantly higher welfare, the welfare gain, overall, is very small.

For the case of foreign price shocks, the results show the scenario of sym-

metric domestic inflation targeting to be marginally better but nevertheless it is not significantly different from the distributions for the other scenarios.

Table IV presents some descriptive statistics for the changes in the policy interest rate. The main result to note is that the means and standard deviations are larger under symmetric compared to asymmetric targeting. Overall, these results suggest that the small welfare gains associated with symmetric targeting comes at the cost of higher interest rate variability.

5 Concluding Remarks

This paper has analyzed the welfare implications of one aspect of the current monetary policy strategy of the European Central Bank, namely, the use of asymmetric instead of symmetric response to inflation in a model with learning on the part of the monetary authorities as well as with Calvo-type sticky-price setting behavior for both domestic and foreign goods. We also compare the current practice of targeting inflation in using an aggregate price index with that of targeting inflation in just the domestic price component of the price index. Overall, the results suggest that switching from the practice of asymmetric to symmetric targeting can result in small welfare gains but it comes at a cost of greater variability in interest rate changes.

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Table I: Inflation Targeting	
Policy Weights	
$\pi \leq \pi^*$	$\lambda = 0.0$
$\pi > \pi^*$	$\lambda = 1.0$

Table II: Distribution of Den-Haan Marcet Statistic Percentage in Upper/Lower Critical Region			
Aggregate Inflation Targeting: $\pi_t = \log(P_t/P_{t-4})$			
	v shocks	C^* shocks	P^{F^*} shocks
Symmetric	3.8/1.8	0.5/6.1	3.4/4.6
Asymmetric	8.3/7.4	1.6/0.7	5.6/9.6
Domestic Price Inflation Targeting: $\pi_t = \log(P_t^D/P_{t-4}^D)$			
	v shocks	C^* shocks	P^{F^*} shocks
Symmetric	8.6/8.5	4.7/6.2	0.0/0.0
Asymmetric	6.8/3.6	0.3/5.8	4.7/3.3

Table III: Durbin Watson Statistics for Forecast Error Percentage in Lower/Upper Critical Region			
Aggregate Inflation Targeting: $\pi_t = \log(P_t/P_{t-4})$			
	v shocks	C^* shocks	P^{F^*} shocks
Symmetric	0.0/0.0	0.0/0.0	0.0/0.0
Asymmetric	0.0/0.0	0.0/0.0	0.0/0.0
Domestic Price Targeting: $\pi_t = \log(P_t^D/P_{t-4}^D)$			
	v shocks	C^* shocks	P^{F^*} shocks
Symmetric	0.0/0.0	0.0/8.5	0.0/0.0
Asymmetric	0.0/0.0	0.0/0.0	0.0/0.0

Table IV: Changes in Interest Rates (percentage points) sample means (std.deviation)			
Aggregate Inflation Targeting: $\pi_t = \log(P_t/P_{t-4})$			
	v shocks	C^* shocks	P^{F^*} shocks
Symmetric	0.021 (0.091)	0.267 (0.227)	0.023 (0.101)
Asymmetric	0.001 (0.046)	0.006 (0.017)	0.002 (0.031)
Domestic Price Inflation Targeting: $\pi_t = \log(P_t^D/P_{t-4}^D)$			
	v shocks	C^* shocks	P^{F^*} shocks
Symmetric	0.077 (0.141)	0.156 (0.118)	0.023 (0.102)
Asymmetric	0.002 (0.050)	0.042 (0.090)	-0.006 (0.016)

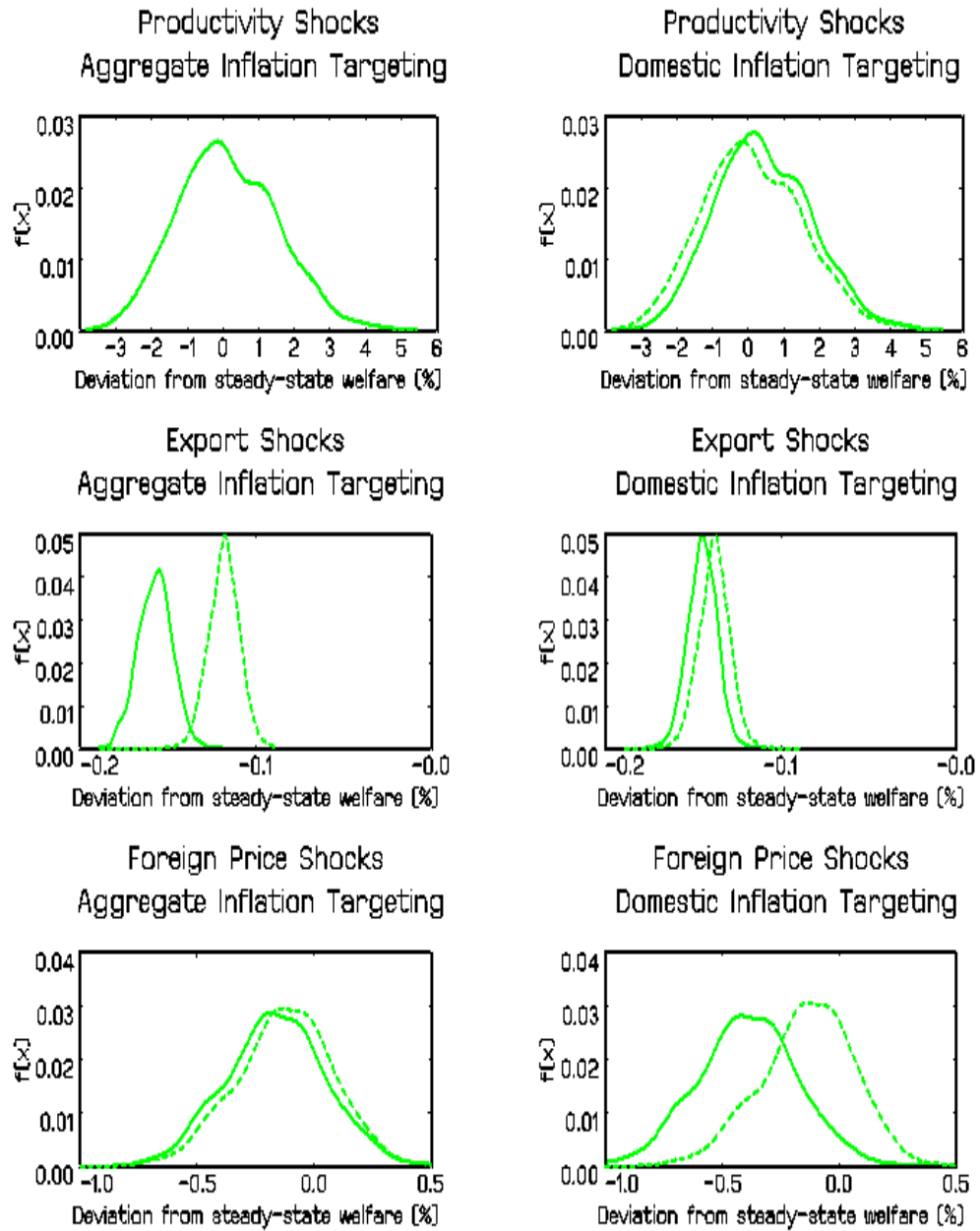


Figure 1: Figure 1: Distribution of Mean Welfare Index; solid line (symmetric targeting), dotted line (asymmetric targeting)