ON MONETARY POLICY RULES FOR THE EURO AREA

Miguel Casares

2004

BANCO DE ESPAÑA

ON MONETARY POLICY RULES FOR THE EURO AREA

ON MONETARY POLICY RULES FOR THE EURO AREA (*)

Miguel Casares (**)

UNIVERSIDAD PÚBLICA DE NAVARRA

Abstract

In this paper a New Keynesian model is described and partially estimated for the euro area. The model is then used to analyze the stabilizing properties of alternative monetary policy rules for the euro area: instrument (Taylor-type) rules and targeting rules. Our main finding is that if instrument rules are designed optimally they behave similarly to targeting rules both in terms of performance and robustness. This result is obtained for a variety of ECB preferences on stabilizing inflation, the output gap, and the nominal interest rate. Furthermore, the rule quasi-equivalence is also obtained if the ECB objective function is based on welfare maximization.

JEL codes: E0, E4, E5.

Keywords: Instrument rules, targeting rules, euro area.

1 Introduction

Monetary policy rules can be classified into targeting rules and instrument rules as proposed by Lars Svensson (see Svensson (1999, 2002)). Targeting rules are designed by solving a central bank's optimizing program that defines an objective (loss) function and considers a single model describing the economy. Targeting rules are thus model dependent. Typical policy targets in the central bank objective function are variability of inflation, the output gap, or the nominal interest rate. An implicit reaction function, a monetary policy rule, might be written as the optimal response of the policy instrument (usually the nominal interest rate) to the state variables. Two influential seminal papers on targeting rules are Clarida, Galí, and Gertler (1999), and Svensson (1999).

Other authors prefer to propose simple rules that provide good stabilizing properties in a variety of models, the so-called instrument rules by Lars Svensson. The first instrument rule was the famous constant money growth rule recommended by Friedman (1959). Nowadays, John Taylor and Bennett McCallum probably are the most relevant authors on instrument rules (see McCallum (1988), Taylor (1993), Taylor (1999), and McCallum (1999)).[1] A quite popular example of an instrument rule for the nominal interest rate is the well-known Taylor rule proposed in Taylor (1983). According to this interest-rate rule, the central bank would raise (cut) the nominal interest rate as a combined response to inflation deviations above (below) its target, and to positive (negative) observations of the output gap. Advocates for instrument rules argue that targeting rules based on optimal control can be misleading due to its strict dependence on the model.[2] In addition, the reaction function implicitly derived from targeting rules becomes "operational" for policy making only within very simple models involving fully observable variables.

The objective of this paper is to investigate the performance of alternative monetary policy rules for the euro area. It may be considered a continuation to the paper by Taylor (1999) where instrument rules were tested in nine different models estimated or calibrated for the euro area. This paper extends that analysis in two ways: the introduction of the New Keynesian model and the use of targeting rules for the evaluation of instrument rules. Regarding the latter, the (in)efficiency of instrument rules can be captured directly by comparing its performance with the optimal targeting rule. As for the New Keynesian framework, it will allow us to carry out robustness exercises to model changes. So, the policy evaluation will also be conducted in terms of the robustness properties of the rules. In addition, the New Keynesian model provides a social welfare function that can be adopted by the central bank as its objective function. It will give rise to a different view to compare targeting and instrument rules (and even stabilizing targeting rules with welfare-theoretic targeting rules). The welfare-theoretic analysis of monetary policy rules is extensively described in the book by Woodford (2003a).

After describing the model in Section 2, it will be partially calibrated and estimated for the euro area in Section 3. In addition, some aspects of the euro area business cycle will be examined as part of a comparison of the model to the data. Targeting rules will be presented

---

[1] In addition, McCallum and Nelson (2003) provide a point-by-point reply to the criticism on instrument rules shown by Svensson (2003).

[2] Targeting rules directly depend on the model equations, on the technique for calibration/estimation of parameters, and on the definition of the central bank objective function. There are parallel intense debates among researchers on the convenience of using alternative settings for each one of these issues.

in Section 4. Later, the behavior of instrument rules relative to targeting rules will be tested in Section 5 for a variety of ECB policy preferences on stabilizing inflation, the output gap, and the nominal interest rate. In Section 6, the policy analysis will be extended for an ECB objective function based on welfare maximization. Finally, Section 7 concludes the paper with a list of major findings.

2 A New Keynesian model

As mentioned in the introduction, this paper employs a New Keynesian model for monetary policy analysis. The New Keynesian methodology has two major characteristics: first, the equations are derived from optimizing behavior and, second, there are nominal rigidities when setting prices and/or wages.[3] Our particular New Keynesian model represents a closed economy with constant capital, monopolistic competition, and nominal rigidities when setting both prices and wages. Comparatively, the model incorporate the same nominal rigidities as in Erceg, Henderson, and Levin (2000) although it also features internal habit formation. It could also be considered a simplified version of the variable-capital model appearing in Smets and Wouters (2003), with the additional difference of having internal (not external as theirs) habit formation. Finally, the model is quite similar to the one described in Giannoni and Woodford (2003) where a fraction of prices and wages that could not be set optimally are indexed to lagged inflation. As a difference with respect to their model, it will be assumed here that non-optimal prices and wages are always indexed to the long run (steady-state) rate of inflation.

Now let us briefly describe the model. The economy consists of a continuum of households who are consumers and also producers. The representative i^{th} household has the following instantaneous utility function

$$U(\zeta_t, c_t(i) - hc_{t-1}(i), l_t(i)) = \exp(\zeta_t)\frac{[c_t(i) - hc_{t-1}(i)]^{1-\sigma}}{1-\sigma} + \Phi\frac{l_t(i)^{1-\gamma}}{1-\gamma}, \tag{1}$$

where $\sigma, \gamma, \Phi > 0$ and $0 \leq h \leq 1$. Utility in period t depends on three arguments: leisure time $l_t(i)$, a partial change in consumption from the previous period $c_t(i) - hc_{t-1}(i)$, and a economy-wide consumption preference shock ζ_t. The latter follows the AR(1) stochastic process $\zeta_t = \rho_\zeta \zeta_{t-1} + \varepsilon_t^\zeta$ with $\varepsilon_t^\zeta \sim N(0, \sigma_{\varepsilon\zeta}^2)$. Consumption units are given in bundles of differentiated goods as in Dixit and Stiglitz (1977). The presence of lagged consumption features a habit formation effect as advocated by Fuhrer (2000), and now quite extended in the literature.

Households are not identical for two reasons: they produce differentiated consumption goods, and supply differentiated labor services. In both cases, they have market power to respectively decide the selling price and nominal wage that will be placed in a monopolistic competitive market. Thus, the amount produced by the i-th household $y_t(i)$ is linked to her pricing decision $P_t(i)$ through the Dixit-Stiglitz demand equation

$$y_t(i) = \left[\frac{P_t(i)}{P_t}\right]^{-\theta_P} y_t, \tag{2}$$

in which $\theta_P > 0$ is the elasticity of substitution across differentiated goods, and P_t and y_t represent Dixit-Stiglitz aggregate magnitudes of the price level and output. Technology of production is the same across households. Let us assume that the amount produced is given by a Cobb-Douglas function with constant capital (normalized to 1), and a labor-augmenting technology shock. Thus, the production of the ith household would be

$$y_t(i) = (\exp(z_t)n_t^d(i))^{1-\alpha}, \tag{3}$$

---

[3]Some seminal papers on the New Keynesian methodology are Yun (1996), King and Wolman (1996), and Rotemberg and Woodford (1997).

with $0 \le \alpha < 1$ as the capital-share coefficient of the Cobb-Douglas technology. The amount produced by the i-th household is obtained by employing $n_t^d(i)$ units of the household-specific labor demand whose productivity is influenced by the economy-wide technology shock z_t. The technology shock is given by the AR(1) stochastic process $z_t = \rho_z z_{t-1} + \varepsilon_t^z$ with $\varepsilon_t^z \sim N(0, \sigma_{\varepsilon z}^2)$.

In an analogous way to the household-specific output decision, the labor supply of the ith household $n_t^s(i)$ is given by the Dixit-Stiglitz demand equation

$$n_t^s(i) = \left[\frac{W_t(i)}{W_t} \right]^{-\theta_W} n_t, \tag{4}$$

where $W_t(i)$ is the nominal wage set by household i, θ_W is the elasticity of substitution across differentiated labor services, and, W_t and n_t are the Dixit-Stiglitz aggregated figures for the nominal wage and labor.

The rate of inflation in period t is defined as $\pi_t = (P_t/P_{t-1}) - 1$, and the real wage as $w_t = W_t/P_t$. In addition, let r_t denote the real rate of interest that will be reimbursed in period $t + 1$ for a private bond purchased in period t. As a result from the previous lines, the budget constraint for the representative household in period t expressed in units of the Dixit-Stiglitz aggregate output is

$$y_t(P_t(i)/P_t)^{1-\theta_P} = c_t(i) + w_t(n_t^d(i) - n_t(W_t(i)/W_t)^{1-\theta_W}) + (1+r_t)^{-1}b_{t+1}(i) - b_t(i). \tag{5}$$

Households raise income from selling production $y_t(P_t(i)/P_t)^{1-\theta_P}$. Income is spent on bundles of consumption $c_t(i)$, on paying the market real wage to the excess of labor demand $w_t(n_t^d(i) - n_t(W_t(i)/W_t)^{1-\theta_W})$, and on net purchases of private bonds $(1+r_t)^{-1}b_{t+1}(i) - b_t(i)$.

Households also face the following time constraint

$$n_t^s(i) + l_t(i) = 1, \tag{6}$$

which implies that total time (normalized to 1) is devoted to either labor supply $n_t^s(i)$ or leisure time $l_t(i)$.

The optimizing program of the i-th representative household consists of deciding $c_t(i)$, $n_t^d(i)$, $b_{t+1}(i)$, $W_t(i)$, and $P_t(i)$ that maximize

$$E_t \sum_{j=0}^{\infty} \beta^j U(\zeta_{t+j}, c_{t+j}(i) - hc_{t-1+j}(i), l_{t+j}(i))$$

subject to constraints (2)-(6) in period t and analogous expected constraints for all future periods. Note that future utility values are discounted at a constant rate $\beta < 1.0$.

The model incorporates nominal rigidities when setting both the selling price and the nominal wage. In particular, we assume that prices and wages can be decided optimally with fixed probability as in Calvo (1983). If either the price or the nominal wage cannot be adjusted optimally they are automatically indexed to the long-run (steady-state) rate of inflation.[4]

A dynamic stochastic general equilibrium (DSGE) model can be obtained from the household's first order conditions, market-clearing conditions, a monetary policy rule, and definitions of π_t, w_t, P_t, and W_t. There are several examples of the procedure in the literature

---

[4]This assumption is necessary to avoid the undesirable steady-state results of the Calvo model with no price indexation (see Casares (2004) for this result).

(see Erceg *et al.* (2000), Smets and Wouters (2003), and Giannoni and Woodford (2003)). For practical purposes, we will skip most of the technical details on derivation of the whole DSGE model and focus on reducing the model to make it tractable for monetary policy analysis. As a starting point, the dynamic behavior of aggregate output, inflation and the real wage is governed by the following set of equations (after loglinearizing and neglecting constant terms)

$$\widehat{y}_t = a_0\widehat{y}_{t-1} + a_1 E_t\widehat{y}_{t+1} - a_2 E_t\widehat{y}_{t+2} - a_3(R_t - E_t\pi_{t+1}) + a_4\zeta_t, \tag{7}$$

$$\pi_t = \beta E_t\pi_{t+1} + \kappa_\pi\widehat{mc}_t, \tag{8}$$

$$\widehat{mc}_t = \widehat{w}_t + \frac{\alpha}{1-\alpha}\widehat{y}_t - z_t, \tag{9}$$

$$\widehat{w}_t = \frac{1}{1+\beta}(\widehat{w}_{t-1} - \pi_t) + \frac{\beta}{1+\beta}E_t(\widehat{w}_{t+1} + \pi_{t+1}) + \kappa_w(\widehat{mrs}_t - \widehat{w}_t), \tag{10}$$

$$\widehat{mrs}_t = \left(\frac{\gamma n^{ss}}{(1-\alpha)l^{ss}} + c_1\right)\widehat{y}_t - c_2\widehat{y}_{t-1} - \beta c_2 E_t\widehat{y}_{t+1} - \frac{\gamma n^{ss}}{l^{ss}}z_t - c_3\zeta_t \tag{11}$$

where $a_0 = \frac{h}{1+h+\beta h^2}$, $a_1 = \frac{1+\beta h+\beta h^2}{1+h+\beta h^2}$, $a_2 = \frac{\beta h}{1+h+\beta h^2}$, $a_3 = \frac{(1-h)(1-\beta h)}{\sigma(1+h+\beta h^2)}$, $a_4 = \frac{(1-\rho_\zeta)(1-\beta h\rho_\zeta)(1-h)}{\sigma(1+h+\beta h^2)}$, $\kappa_\pi = \frac{(1-\beta\eta_P)(1-\eta_P)(1-\alpha)}{\eta_P(1-\alpha+\alpha\theta_P)}$, $\kappa_w = \frac{(1-\beta\eta_W)(1-\eta_W)}{\eta_W(1+\beta)(1+\theta_W\gamma n^{ss}/l^{ss})}$, $c_1 = \frac{\sigma(1+\beta h^2)}{(1-h)(1-\beta h)}$, $c_2 = \frac{h\sigma}{(1-h)(1-\beta h)}$, and $c_3 = \frac{(1-\beta h\rho_\zeta)}{1-\beta h}$. Variables topped with a "∧" symbol represent fractional deviations of the original variable from its steady state value; for example, $\widehat{y}_t = \log(y_t/y^{ss})$ with y^{ss} as the steady state level of output. Both the nominal interest rate R_t and the rate of inflation π_t denote level deviations from its steady-state value. This notation will be maintained throughout the paper.

Equation (7) is an IS curve describing aggregate output fluctuations in an economy with consumption habit formation and constant capital (see Nelson (2002), and Amato and Laubach (2004) for similar derivations). It is obtained by jointly using the first order conditions of consumption and bonds, and the market-clearing condition of aggregate output. The habit formation structure gives rise to the presence of $\widehat{y}_{t-1}$ and $E_t\widehat{y}_{t+2}$ in the IS curve. The consumption preference shock ζ_t enters the IS curve with a positive effect on output. Actually, our consumption preference shock ζ_t plays the role of any expenditure-type shock. Therefore, we will also refer to this shock as a demand shock.[5]

The inflation dynamic behavior is governed by the New Keynesian Phillips curve (8) which was obtained from the selling price first order condition with staggered prices *á la* Calvo (see Sbordone (2001) for a detailed derivation). As shown in (8), inflation π_t depends positively on expected inflation $E_t\pi_{t+1}$, and the aggregate real marginal cost $\widehat{mc}_t$. Equation (9) is the loglinearized definition of the real marginal cost as obtained from the Cobb-Douglas production function (3).

As for the real wage equation (10), the papers by Erceg *et al.* (2000), Sbordone (2002), and Smets and Wouters (2003) describe its derivation and discuss on the implications of introducing staggered wages *á la* Calvo. As displayed in (10), the dynamic evolution of the real wage presents both a backward-looking and forward-looking component. There are also two effects of inflation; the real wage $\widehat{w}_t$ is affected negatively by current inflation π_t and positively by expected next period inflation $E_t\pi_{t+1}$. In addition, the gap between the aggregate leisure-consumption marginal rate of substitution and the real wage $\widehat{mrs}_t - \widehat{w}_t$

---

[5]Other types of demand-side shocks would be a government expenditure shock like in Rotemberg and Woodford (1999), or an investment shock like in Smets and Wouters (2003).

(originated by the nominal wage rigidities) enters equation (10) with a positive sign. Finally, equation (11) defines $\widehat{mrs}_t$ from the utility function (1) and the production function (3).

The system of equations (7)-(11) can be simplified by substituting the aggregate real marginal cost $\widehat{mc}_t$ from (9) into the inflation equation (8), and equation (11) which defines the aggregate marginal rate of substitution $\widehat{mrs}_t$ into the real wage equation (10). They lead to the three-equation system

$$
\begin{aligned}
\widehat{y}_t &= a_0\widehat{y}_{t-1} + a_1 E_t\widehat{y}_{t+1} - a_2 E_t\widehat{y}_{t+2} - a_3(R_t - E_t\pi_{t+1}) + a_4\zeta_t, & (12) \\
\pi_t &= \beta E_t\pi_{t+1} + \kappa_\pi\left(\widehat{w}_t + \frac{\alpha}{1-\alpha}\widehat{y}_t - z_t\right), & (13) \\
\widehat{w}_t &= \frac{1}{1+\beta}(\widehat{w}_{t-1} - \pi_t) + \frac{\beta}{1+\beta}E_t(\widehat{w}_{t+1} + \pi_{t+1}) + & (14) \\
&\quad \kappa_w\left(\left(\frac{\gamma n^{ss}}{(1-\alpha)l^{ss}} + c_1\right)\widehat{y}_t - c_2\widehat{y}_{t-1} - \beta c_2 E_t\widehat{y}_{t+1} - \frac{\gamma n^{ss}}{l^{ss}}z_t - c_3\zeta_t - \widehat{w}_t\right),
\end{aligned}
$$

which includes four endogenous variables variables: $\widehat{y}_t$, π_t, $\widehat{w}_t$ and R_t, and two exogenous variables: ζ_t and z_t. So, we have four endogenous variables and only three equations. Therefore, a monetary policy rule is required to identify a time path for R_t and close to the model. Let us introduce initially the following Taylor-type instrument rule with nominal interest rate smoothing

$$
R_t = \mu_1\pi_t + \mu_2\widetilde{y}_t + \mu_3 R_{t-1} \tag{15}
$$

with $\mu_1, \mu_2, \mu_3 \geq 0$ excluding those combinations that leave the model undetermined.[6] Notice that $\widetilde{y}_t$ is the output gap which we define as the fractional difference between current output $\widehat{y}_t$ and potential output $\widehat{\overline{y}}_t$,

$$
\widetilde{y}_t = \widehat{y}_t - \widehat{\overline{y}}_t. \tag{16}
$$

The presence of the output gap in (15) involves one more variable entering the model: potential output $\widehat{\overline{y}}_t$. Following Woodford (2003a), pages 247-249, potential (natural-rate) output is defined as the amount that would prevail in an economy without rigidities. By assuming fully flexible prices and wages, and solving out the model for output, the dynamic equation for fluctuations of potential output is

$$
\left(\frac{\alpha}{1-\alpha} + \frac{\gamma n^{ss}}{(1-\alpha)l^{ss}} + c_1\right)\widehat{\overline{y}}_t = c_2\widehat{\overline{y}}_{t-1} + \beta c_2 E_t\widehat{\overline{y}}_{t+1} + c_3\zeta_t + \left(1 + \frac{\gamma n^{ss}}{l^{ss}}\right)z_t. \tag{17}
$$

Potential (natural rate) output depends positively upon realizations of the supply-side shock z_t, and the demand-side shock ζ_t. Moreover, the habit formation structure makes past and expected future values of the shocks also affect potential output.

In the end, the DSGE model has been reduced to a set of six equations (12)-(17) which fully determine dynamic paths for the six endogenous variables $\widehat{y}_t$, π_t, $\widehat{w}_t$, R_t, $\widetilde{y}_t$, and $\widehat{\overline{y}}_t$, provided exogenous processes for z_t and ζ_t.

---

[6] For example, the coefficients should meet the constraint $\mu_1 + \mu_3 > 1$ when $\mu_2 = 0$. See Rotemberg and Woodford (1999) for a characterization of bubble solutions that lead to model indeterminacy.

3 Calibration and estimation for the euro area

The parameters of the model will be split into two groups: $\Omega_1 = [\alpha, \beta, \sigma, h, \gamma, \rho_z, \rho_\zeta]$ contains those describing the production technology and household preferences, and $\Omega_2 = [\mu_1, \mu_2, \mu_3, \kappa_\pi, \kappa_w, \sigma_{\varepsilon^z}, \sigma_{\varepsilon\zeta}]$ which includes the coefficients of the Taylor-type rule, the elasticities on inflation and real wage equations, and the standard deviations of the shocks. The first group of parameters Ω_1 will be calibrated whereas the parameters in Ω_2 will be estimated. The partial calibration-estimation strategy was decided because we intentionally wanted to set parameters defining technology and preferences (those collected in Ω_1) in accordance to the standard calibration of business-cycle models similar to the one at hand. In other words, calibration of Ω_1 will consist of setting figures commonly used in the business cycle literature. Thus, an important portion of the economic structure of the model will be consistent with similar models and our findings on monetary policy analysis can be comparable to others. The parameters to be estimated are those more relevant for monetary issues (collected in Ω_2). The estimation procedure is intended to make the model appropriate for the monetary policy analysis in the euro area that will be conducted below.

Let us begin with the calibration of the parameters in Ω_1. The Cobb-Douglas production technology is characterized by the capital share coefficient α. Here we set $\alpha = 0.36$, as standard in real business cycle models because it implies a realistic ratio of capital to output in steady state. Next, the discount rate is $\beta = 0.995$, implying a rate of intertemporal preference of 0.5% per quarter. It leads to a realistic 2% real interest rate per year in steady state. Regarding the parameters of the utility function, the consumption relative risk aversion coefficient is set at $\sigma = 1.5$, and the habit formation coefficient is $h = 0.85$, slightly higher than $h = 0.8$ as estimated for the US by Fuhrer (2000). The figures decided for σ and h are consistent with the estimates calculated for the euro area by Smets and Wouters (2003), and Andrés, López-Salido, and Nelson (2003).[7] With respect to the leisure relative risk aversion coefficient γ, we decided to assign a value that implies a low labor supply (Frisch) elasticity to the real wage $\left(\frac{l^{ss}}{\gamma n^{ss}} \right)$. That was found in a number of empirical papers that analyze micro evidence (see Altonji (1986), Johnson and Pencavel (1986), Pencavel (1986), and Card (1994)).[8] In turn, we set $\gamma = 16$ so as to imply a Frisch elasticity of labor supply equal to 1/8 when leisure takes twice the time of labor hours in steady-state, $l^{ss}/n^{ss} = 2$. The last two calibrated parameters are the coefficients of autocorrelation of the shocks, ρ_z and ρ_ζ. The supply shock will have strong inertia by taking the standard figure from the real business cycle literature $\rho_z = 0.95$, whereas the process originating the demand shock has a moderate serial correlation as we set $\rho_\zeta = 0.6$.

The parameters in Ω_2 were estimated using euro area quarterly data. Our data source for estimation is the area-wide model data base developed by Fagan, Henry, and Mestre (2001).[9] The sample period chosen is 1980.1-2002.4. Detrending techniques were applied to obtain stationary series for output $(\widehat{y})$ and the real wage $(\widehat{w})$. Thus, the business-cycle

---

[7]Smets and Wouters (2003) find quite a lower estimate for h using a utility function with external habit formation. In our utility function specification (1), habit formation depends upon household-specific values of lagged consumption which is referred as an internal habit formation. It may explain why their estimate for the habit formation parameter is a low figure.

[8]Besides, if the labor supply elasticity is high the impact of a demand-type shock on potential output will be unrealistically large and variability of potential output would be explained mostly from a demand shock.

[9]Four quarterly series were utilized in the estimation procedure: Real GDP (YER), GDP deflator (YED), Short-Term Interest Rate (STN), and Compensation to Employees (WIN).

component of output is obtained by taking off a linear time trend from the original series; which would imply a constant rate of growth in steady state. For the same argument, the real wage was linearly detrended. Nevertheless, the rate of inflation (π) and the nominal interest rate (R) are the original series since these variables do not possess any steady-state growth.[10] Figure 1 contains the plots of the euro area series employed in the estimation over the selected sample period.

The estimation procedure is aimed at replicating with the model a number of second-moment statistics that represent the euro area business cycle.[11] In particular, standard deviations, coefficients of autocorrelation, and one-to-one coefficients of correlation of the four observable variables of the model ($\widehat{y}$, π, R, and $\widehat{w}$). The vector of estimated parameters Ω_2 is the one that minimizes the following sum of squared deviations

$$[F_d - F_m(\Omega_1, \Omega_2)]'W[F_d - F_m(\Omega_1, \Omega_2)],$$

where F_d is the vector of sample data statistics, $F_m(\Omega_1, \Omega_2)$ is the vector of model statistics, and W is the weighting matrix. The entries in the diagonal of W are the inverse of the average sample statistics obtained for each one of the three types of statistics.[12] All the elements outside the diagonal are zero. Therefore, deviations are weighted taking into account its relative size across types of statistics.

The estimation results are shown in Table 1 together with the calibrated parameters. The estimated Taylor rule coefficients are $\mu_1 = 0.47$, $\mu_2 = 0.13$, and $\mu_3 = 0.53$ in line with the estimates for individual countries of the euro area reported by Clarida, Galí, and Gertler (1998). However, this estimated rule should not be intended to represent the monetary policy behavior observed in the euro area countries. There was no single monetary policy in the current euro area prior to 1999 which is at the very end of the sample period. Moreover, the policy instrument was in many cases the rate of money growth and not the nominal interest rate (especially during the 80's). Therefore, our estimation must be simply understood as a necessary device to close the model by finding the best estimates for such a proposed linear relationship between R, π, and $\widetilde{y}$.

The estimate of the Phillips curve elasticity is $\kappa_\pi = 0.028$. Compared to estimates from other papers, it is higher than the figure reported in Smets and Wouters (2003) and lower than the one found by Galí, Gertler, and López-Salido (2001). The estimate of the real wage elasticity is $\kappa_w = 0.003$ which is lower than the implicit estimate by Smets and Wouters (2003). These differences might be explained by the fact that in Smets and Wouters (2003) non-optimal prices and wages are indexed to lagged inflation whereas in our model they are indexed to steady-state inflation.[13]

Finally, the estimates of the (percent) standard deviations of the shocks are $\sigma_{\varepsilon^z} = 0.95$ and $\sigma_{\varepsilon^\zeta} = 5.62$. There is more expenditure-originated volatility because it favours the positive correlations between the pairs of variables ($\widehat{y}, \pi$) and ($\widehat{y}, R$), which are observed in

---

[10]It is clear, however, that both π and R feature a downward trend due to the disinflationary episode that characterized the years previous to the launching of the euro. Some authors time detrend these variables. However, we decided to maintain them as the original series so as to be consistent with our model and, therefore, assumed that the observed trend is simply a sample period (non-structural) coincidence.

[11]It follows the spirit of the seminal paper by Christiano and Eichenbaum (1992).

[12]The average statistics obtained were utilized instead of individual statistics in order to avoid giving a extremely large weight to those sample statistics which are very close to zero (particularly the coefficient of correlation between π and $\widehat{w}$).

[13]Besides, their estimation technique is different.

the data and cannot be originated from a supply shock.[14] Despite the size of $\sigma_{\varepsilon\zeta}$ relative to σ_{ε^z}, variability of the model is quite evenly coming from both shocks. This issue was examined by calculating the forecast error variance decomposition at a 100-period time horizon (25 years). We found that demand-side shocks explain most of the movements in the output gap (76%), near two thirds of changes in current output (64%), and around half of fluctuations of the nominal interest rate (53%) and inflation (44%). Meanwhile, shocks on the supply sector explain the remaining variability of these variables, and most changes in potential output (85%).

The model and the data.

Table 2 displays a comparison between the business cycle statistics from the euro area data and those obtained in the calibrated/estimated model. Particularly, the statistics reported are the ones that were used in the estimation procedure: standard deviations (in percent annualized units), coefficients of autocorrelation, and coefficients of correlation.

As Table 2 shows, the standard deviation of output (1.73) is substantially lower than the standard deviation of inflation (2.87) in the euro area data. This difference is captured by the model although the relative volatility of output with respect to inflation is slightly higher than in the data; the standard deviation of output is 2.00 while the standard deviation of inflation is 2.73. The nominal interest rate is the most volatile variable both in the data (3.51) and in the model (3.58). Regarding the real wage, it reports a variability similar to output in the data (1.71) and lower to output in the model (1.30).

The coefficients of autocorrelation obtained from the data are high for inflation (0.88), and even higher for output (0.93), the nominal interest rate (0.96), and the real wage (0.96). The model replicates very closely these figures as the four variables also show long time persistence with coefficients of autocorrelation close to 1.0.

The capacity of the model to match the dynamic relationships between the variables can be evaluated by comparing their coefficients of correlation to output and inflation (see Table 2). Noticeably, all the coefficients of correlation reported in Table 2 are positive both in the model and in the data. Thus, inflation is slightly procyclical with a similar coefficient of correlation to output in the data (0.13) and in the model (0.16). The nominal interest rate is also weakly procyclical in the data (0.28) and in the model (0.19).[15] By contrast, the real wage is more procyclical in the model (0.89) than in the data (0.51). The coefficient of correlation between inflation and the real wage is so close to 0.0 in the data (0.01) that we can say that there is no observed sign in its relationship. The model reports a low positive coefficient (0.16). Finally, there is a strong positive relationship between inflation and the nominal interest rate observed in the data (0.88) which is replicated by the model (0.94). Overall, the model gives a reasonably good matching of the coefficients of correlation. Furthermore, Figure 2 shows that the dynamic correlation functions which incorporate a eight-quarter period of lags and leads. As shown there, the model provides a good approximation to the actual dynamic relationships found in the data with a successful matching of the correlation lags and leads. The only significant difference to be mentioned

---

[14] A supply (technology) shock drives inflation and the nominal interest rate down while output is gradually moving up.

[15] Remarkably, the model replicates a positive coefficient of correlation between output and the nominal interest rate. This is a standard difficulty of optimizing models with nominal rigidities: the negative slope of the structural IS curve makes it complicated to obtain such a positive correlation.

is the stronger procyclical behavior of the real wage reported by the model (see second cell in Figure 2). The other five cells display great similarities between the model (solid lines) and the euro area data (dotted lines).

In summary, our calibrated/estimated New Keynesian model is able to replicate reasonably well many regularities observed in the euro area business cycle. Consequently, we can select it as an appropriate tool for the monetary policy analysis to be conducted in Section 5 and Section 6.

4 Targeting rules

Now it is time to introduce targeting rules. Let us assume that monetary policy is aimed at targeting three objectives: inflation stability, output gap stability, and nominal interest rate (instrument) stability. The variances of these variables give the measure of their volatility over the business cycle. Since the unconditional expectations of π, $\widetilde{y}$, and R are zero their unconditional variances will be computed taking the squared values.[16] Thus, the central bank objective function is represented by the following (generic) stabilizing loss function in period t

$$L_t = \pi_t^2 + \lambda_{\widetilde{y}}\widetilde{y}_t^2 + \lambda_R R_t^2 \tag{18}$$

where $\lambda_{\widetilde{y}}$ and λ_R are the relative weights on stabilizing the output gap and the nominal interest rate. Note that the weight on stabilizing inflation is normalized to be 1.0. The objective function (18) gives rise to the following optimizing program of the central bank

$$Min \quad E_t \sum_{j=0}^{\infty} \beta^j L_{t+j}$$

subject to the following equations representing the economy

$$\pi_t = \beta E_t \pi_{t+1} + \kappa_\pi \widehat{w}_t + \tfrac{\alpha}{1-\alpha}\kappa_\pi \widetilde{y}_t + \varepsilon_t, \tag{19}$$

$$\widetilde{y}_t = a_0\widetilde{y}_{t-1} + a_1 E_t\widetilde{y}_{t+1} - a_2 E_t\widetilde{y}_{t+2} - a_3(R_t - E_t\pi_{t+1}) + \upsilon_t \tag{20}$$

$$\widehat{w}_t = \tfrac{1}{1+\beta}(\widehat{w}_{t-1} - \pi_t) + \tfrac{\beta}{1+\beta}E_t(\widehat{w}_{t+1} + \pi_{t+1}) + \tag{21}$$

$$\kappa_w\left(\left(\tfrac{\gamma n^{ss}}{(1-\alpha)l^{ss}} + c_1\right)\widetilde{y}_t - c_2\widetilde{y}_{t-1} - \beta c_2 E_t\widetilde{y}_{t+1} - \widehat{w}_t\right) + \chi_t,$$

in all (past and future) periods.[17] Equations (19)-(21) resemble very much the behavioral equations (12)-(14). Actually, they are reached by replacing current output $\widehat{y}_t$ with the sum of the output gap and potential output $\widetilde{y}_t + \widehat{\overline{y}}_t$, as implied by (16). This substitution is also applied to $\widehat{y}_{t-1}$, $\widehat{y}_{t+1}$, and $\widehat{y}_{t+2}$. As a result, the output gap appears now in the behavioral equations (19)-(21) as required for being one targeted variable of the central-bank optimizing program. The three exogenous process ε_t, υ_t, and χ_t, can be expressed as combined functions of the supply and demand shocks.[18] In turn, the first order conditions for the optimizing

---

[16]Let us recall that both π and R denote deviations from their steady-state values whereas the definition of the output gap (16) implies a zero unconditional expectation.

[17]We follow the "timeless perspective" approach introduced in Woodford (1999), page 18.

[18]These exogenous processes are:

$$\varepsilon_t = \kappa_\pi\tfrac{\alpha}{1-\alpha}\widehat{\overline{y}}_t - \kappa_\pi z_t,$$

$$\upsilon_t = a_4\zeta_t - \widehat{\overline{y}}_t + a_0\widehat{\overline{y}}_{t-1} + a_1 E_t\widehat{\overline{y}}_{t+1} - a_2 E_t\widehat{\overline{y}}_{t+2},$$

$$\chi_t = \kappa_w\left(\left(\tfrac{\gamma n^{ss}}{(1-\alpha)l^{ss}} + c_1\right)\widehat{\overline{y}}_t - c_2\widehat{\overline{y}}_{t-1} - \beta c_2 E_t\widehat{\overline{y}}_{t+1} - \tfrac{\gamma n^{ss}}{l^{ss}}z_t - c_3\zeta_t\right),$$

with $\widehat{\overline{y}}_t$ fully exogenous as defined in (17).

program are (19)-(21), and

$$2\pi_t + \varphi_t^{PH} - \varphi_{t-1}^{PH} + \frac{1}{1+\beta}\varphi_t^w - \frac{1}{1+\beta}\varphi_{t-1}^w - a_3\beta^{-1}\varphi_{t-1}^{IS} = 0, \tag{22}$$

$$2\lambda_{\widetilde{y}}\widetilde{y}_t - \kappa_\pi\frac{\alpha}{1-\alpha}\varphi_t^{PH} - \kappa_w\left(\frac{\gamma n^{ss}}{(1-\alpha)l^{ss}} + c_1\right)\varphi_t^w + \beta\kappa_w c_2 E_t\varphi_{t+1}^w + \kappa_w c_2\varphi_{t-1}^w + \tag{23}$$

$$\varphi_t^{IS} - a_0\beta E_t\varphi_{t+1}^{IS} - a_1\beta^{-1}\varphi_{t-1}^{IS} + a_2\beta^{-2}\varphi_{t-2}^{IS} = 0,$$

$$2\lambda_R R_t + a_3\varphi_t^{IS} = 0, \tag{24}$$

$$-\kappa_\pi\varphi_t^{PH} + (1+\kappa_\pi)\varphi_t^w - \frac{\beta}{1+\beta}E_t\varphi_{t+1}^w - \frac{1}{1+\beta}\varphi_{t-1}^w = 0, \tag{25}$$

where φ_t^{PH}, φ_t^{IS}, and φ_t^w are the Lagrange multipliers respectively attached to the Phillips curve (19), the IS curve (20), and the real wage equation (21). The optimal control program comprises seven equations (19)-(25) that can be solved for the seven endogenous variables π_t, $\widetilde{y}_t$, $\widehat{w}_t$, R_t, φ_t^{PH}, φ_t^{IS}, and φ_t^w. The targeting rule would be the solution path for R_t. Can we express it in an operational way? In spite of the rather simple New Keynesian structure at hand, the Lagrange multipliers cannot be algebraically eliminated in order to find a simple reaction function for R_t. Thus, the targeting rule can only be represented by the optimal reaction function of R_t to all the nine state variables (summing up both predetermined and exogenous variables): $\widetilde{y}_{t-1}$, $\widehat{w}_{t-1}$, φ_{t-1}^{PH}, φ_{t-1}^w, φ_{t-1}^{IS}, φ_{t-2}^{IS}, ε_t, υ_t, and χ_t. As a practical consequence, the targeting rule would be difficult to apply due to the large numbers of variables involved. Furthermore, some of the state variables are not observable by the monetary authorities.[19]

According to these two arguments (too many variables and presence of unobservable variables), we will try to approximate the behavior of a targeting rule with much simpler instrument rules. It will serve to exemplify how instrument rules may replicate quite closely the optimal policy behavior of targeting rules without undue practical complexity.

---

[19]Particularly the unobservable variables are the three exogenous terms (shocks), the lagged output gap, and the Lagrange multipliers φ_{t-1}^{PH}, φ_{t-1}^w. Put differently, the only observable variables are the lagged real wage and the IS-related Lagrange multipliers, φ_{t-1}^{IS} and φ_{t-2}^{IS}, that depend only on the nominal interest rate (see (24)) which is known by the central bank.

5 Evaluating alternative monetary policy rules

This section is divided into two parts. In the first part attention will be focused on the performance of instrument rules and targeting rules (efficiency). Particularly, we will measure how much instrument rules deviate from the optimal targeting rule. In the second part of the section, rules will be compared according to their robustness to model changes. In other words, we will examine how poorly they perform if the model that represents the economy is not correct in some aspect.

As a preliminary issue, some discussion on the values assigned to the loss function weights ($\lambda_{\widetilde{y}}$ and λ_R) needs to be addressed. The ECB preferences with respect to the policy targets might play a key role in the design of an euro area monetary policy rule (either targeting or instrument rule). The main objective declared by the ECB is "to maintain price stability",[20] which would imply close-to-zero figures for $\lambda_{\widetilde{y}}$ and λ_R. However, it is not clear how small these figures should be because stabilizing either the output gap or the nominal interest rate might help the main objective. Besides, "output gap stability" or "interest rate stability" may be considered secondary objectives for the ECB. In any case, our analysis will cover a variety of policy preferences. Since the weight on stabilizing inflation is always 1.0, the rules will be tested under different parameterization for $\lambda_{\widetilde{y}}$ and λ_R. The proposed grids of three different values for $\lambda_{\widetilde{y}}$ and λ_R are

$$\lambda_{\widetilde{y}} = [0, 0.01, 0.1] \text{ and } \lambda_R = [0, 0.1, 0.5],$$

which, by making combinations, give rise to a total number of 9 pairs of policy parameters ($\lambda_{\widetilde{y}}, \lambda_R$).

5.1 Efficiency

The targeting rule is completely efficient since it is the rule obtained from the central-bank optimizing program.[21] In turn, the level of efficiency of any instrument rule can be obtained by examining how much it deviates from the targeting rule. As in Levin and Williams (2003), this deviation can be measured by the percent change in the unconditional expectation of the instantaneous loss function (18), denoted $\%\triangle L$. However, this measure does not have any intuitive significance because it represents loss units. One alternative way of showing differences is by comparing the (annualized) standard deviations of inflation σ_π, the output gap $\sigma_{\widetilde{y}}$, and the nominal interest rate σ_R, as components of the objective function (18). Both ways will be used to compare rules performance.

As a preliminary exercise, let us examine the Taylor-type instrument rule (15) with the estimated coefficients $\mu_1 = 0.47$, $\mu_2 = 0.13$, and $\mu_3 = 0.53$. Table 3 shows a poor stabilizing capacity of the estimated rule in comparison to targeting rules for any pair of ECB weights ($\lambda_{\widetilde{y}}, \lambda_R$). The percent change of the loss function ($\%\triangle L$) is always higher than 700%, and extremely high when $\lambda_R = 0.0$. In many cases, the annualized standard deviations obtained with the targeting rule are substantially lower than the ones obtained with the estimated Taylor rule (compare figures of σ_π, $\sigma_{\widetilde{y}}$, and σ_R across columns of Table 3). Hence, the

---

[20] See European Central Bank (2003).

[21] Nevertheless, Jensen and McCallum (2002) argue that the targeting rule obtained under timeless perspective commitment is slightly suboptimal according to the criterion of minimizing the unconditional expectation of the central bank loss function. Woodford (2003b) responds to that criticism.

stabilizing performance of the estimated Taylor rule is far from being satisfactory for the ECB stabilizing preferences considered here. Alternatively, we searched for the policy weights of a targeting rule that best replicated the volatilities observed in the data. There is one added row at the bottom of Table 3 that shows our findings. The best matching is obtained with $\lambda_{\widetilde{y}} = 2.37$ and $\lambda_R = 1.83$. Nevertheless, the approximation is still very poor since the value of the loss function with the estimated Taylor-type rules is 387% higher. Roughly speaking, the standard deviations with the targeting rule are half of the values provided with the estimated rule. As a result, there is no parameterization of a stabilizing targeting rule able to approximate well the variabilities observed in the data.

Does the previous paragraph imply that Taylor-type rules are very inefficient in the euro area? Not necessarily. We still need to analyze the performance of the best Taylor-type rule according to our euro area model and the ECB stabilizing preferences. In other words, the Taylor-type instrument rule (15) can be optimized by setting the values of the coefficients of the rule that best approximate the targeting rule. This exercise was done by finding the triplet of coefficients $(\mu_1^*,\mu_2^*,\mu_3^*)$ that give a minimal value in the loss function (18) for each pair of policy weights $(\lambda_{\widetilde{y}},\lambda_R)$. Results of this policy exercise are shown in Table 4. The overall picture looks very different from Table 3. Let us start by discussing the results on the strict inflation targeting monetary policy $(\lambda_{\widetilde{y}} = \lambda_R = 0.0)$. This policy rule deserves a special attention as representative of the ECB first objective, say, price stability. As Table 4 displays, the strict inflation targeting can be fully achieved by setting a Taylor-type instrument rule with $\mu_1^* = \infty$, and $\mu_2^* = \mu_3^* = 0.0.$[22] If so, there would be constant inflation $(\sigma_\pi = 0.0)$, and a extremely high interest rate volatility $(\sigma_R = 244.5)$. This policy is fully efficient in the sense of keeping inflation "on target" but it requires a huge instrument volatility. Indeed, variability of the nominal interest rate is so high that this policy cannot be considered desirable from a realistic policy perspective.

Under other ECB policy weights, the targeting rule always performs slightly better than the optimized instrument rule. Particularly, the loss function values obtained with the instrument rule are between 4% and 35% higher than the ones obtained with the targeting rule. Regarding the standard deviations, values of σ_π, $\sigma_{\widetilde{y}}$, and σ_R obtained under the Taylor-type instrument rule are always very close to the ones obtained with the targeting rule. In fact, there are a number of cases in which the standard deviation of one targeted variable (especially $\sigma_{\widetilde{y}}$) is lower with the optimized instrument rule. Therefore, we find that an optimized instrument rule á la Taylor is nearly as efficient as the targeting rule. Confirming this result, Figure 3 plots impulse response functions for the particular ECB preference setting $\lambda_{\widetilde{y}} = 0.1$ and $\lambda_R = 0.5$. It can be observed that responses to either supply or demand shocks are indeed very similar with the targeting rule (solid line) and the optimized Taylor-type rule (dotted line) for the three targeted variables π, $\widetilde{y}$, and R. Actually, it is quite difficult to distinguish them because they almost overlap (especially in the responses of π). By contrast, responses are always much larger with the estimated Taylor-type rule (dash-dotted line). Therefore, the variability induced by the estimated Taylor-type rule is much bigger than the one observed when optimizing that instrument rule.

The design of optimized Taylor-type rules leads to three interesting conclusions on the optimal coefficients $(\mu_1^*,\mu_2^*,\mu_3^*)$ which also appear in Table 4. First, the optimal inflation coefficient μ_1^* is very sensitive to the ECB-preference parameters $\lambda_{\widetilde{y}}$ and λ_R. Thus, if the

---

[22]The optimized Taylor-type rule contains an infinite coefficient $(\mu_1^* = \infty)$ which is represented in practice by $\mu_1^* = 10^8$.

ECB pursues strict inflation targeting ($\lambda_{\widetilde{y}} = \lambda_R = 0.0$) the optimal inflation coefficient μ_1^* rises asymptotically to ∞. The value of μ_1^* remains high when $\lambda_{\widetilde{y}}$ and λ_R are low. As either the weight of output gap volatility $\lambda_{\widetilde{y}}$ or, especially, the weight of interest rate volatility λ_R goes up the optimal inflation coefficient μ_1^* goes substantially down (check this result in Table 4). The second result states that the optimal output gap coefficient μ_2^* is generally low.[23] Actually, μ_2^* is only substantially higher than zero with a positive $\lambda_{\widetilde{y}}$ and $\lambda_R = 0.0$. Our third conclusion is that the interest rate smoothing coefficient μ_3^* is slightly higher than one for all the proposed combinations of ($\lambda_{\widetilde{y}}$,λ_R), except in the limiting case of strict inflation targeting ($\lambda_{\widetilde{y}} = \lambda_R = 0.0$) when it becomes zero. Moreover, the value of μ_3^* moves in a very narrow range always above the unit coefficient in all the former cases. This high policy inertia (*superinertia*) on Taylor-type rules was also recommended in Rotemberg and Woodford (1999).[24]

It is frequently argued that an instrument rule should be fully operational in the sense that the variables involved are perfectly observable by the central bank (e.g., see McCallum (1999)). The Taylor-type instrument rule (15) includes the output gap $\widetilde{y}_t$ defined in (16) as the fractional difference between fluctuations in current output ($\widehat{y}_t$, observable) and fluctuations in potential output ($\overline{\widehat{y}}_t$, unobservable). Thus, if $\overline{\widehat{y}}_t$ cannot be identified, the inclusion of $\widetilde{y}_t$ in (15) would no longer maintain the rule operational. We tested two alternative solutions for the identification problem:

i) Substitute the unobservable output gap $\widetilde{y}_t$ for the observable current output $\widehat{y}_t$. Results are shown in Table 5. Overall, the optimized instrument rule with $\widehat{y}_t$ maintains most of the good performance of the original optimized Taylor-type rule for all the cases analyzed (compare Table 5 with Table 4). There is an increase in the loss function in seven cases, whereas the losses remain the same in the two cases that had no output gap response in the instrument rule. Anyway, differences are quantitatively very small and the triplets of standard deviations are almost identical to the ones provided in Table 4. Also, it is worth noticing that the optimal values of μ_2^* are now very low (always below 0.10) or even equal to 0.0 in a number of cases. Accordingly, an operational instrument rule could also be designed assuming that there is no output-related response as argued in our second proposal.

ii) Set the output gap coefficient at $\mu_2^* = 0.0$. The absence of an output gap term does not lead to any significant worsening in the stabilizing properties of optimized instrument rules (see Table 6). The increments of losses relative to the targeting rule are still quite small and only slightly higher than the ones obtained with a positive output gap response (compare Table 6 with Table 4). In addition, the standard deviations obtained with $\mu_2^* = 0.0$ are also very similar to the ones obtained with a positive μ_2^*. Consequently, the optimized instrument rule (15) constrained to $\mu_2^* = 0.0$ is nearly as efficient as the unconstrained optimized rule.

After examining the performance of the rules, we can conclude by saying that instrument rules *á la* Taylor can be designed to yield stabilizing properties that closely replicate those obtained with targeting rules. Moreover, two proposals for operational instrument rules which involve only observable variables were also evaluated and still maintained good performance relative to targeting rules.

---

[23]A low value for μ_2^* in Taylor-type rules was already suggested by Rotemberg and Woodford (1999) to approximate targeting rules that maximize social welfare from a sticky price optimizing model.

[24]See Woodford (2003b) for further dicussions on monetary policy inertia.

5.2 Robustness

Exercises on robustness are conducted by testing how the monetary policy rules obtained under one model specification perform in different model settings (see Levin and Williams (2003) as one reference paper). Implicitly, we are supposing that the monetary authorities take a modeled representation of the economy which is "wrong" in some particular aspect. Thus, the policy rule is designed according to one model which is not the "right" model. Here we will consider three changes in the baseline model to evaluate robustness: i) eliminate price rigidities (assume flexible prices), ii) eliminate wage rigidities (assume flexible wages), and iii) set household's preferences without habit formation.

i) Robustness to price flexibility.

If prices are fully flexible, the first order condition of the goods price implies that the real marginal cost is always constant, i.e. $\widehat{mc}_t = 0$. Using this condition in the real marginal cost definition (9) yields

$$\widehat{y}_t = -\left(\tfrac{1-\alpha}{\alpha}\right)\widehat{w}_t + \left(\tfrac{1-\alpha}{\alpha}\right)z_t, \tag{13'}$$

which would replace the New Keynesian Phillips curve (13) in the six-equation system described in Section 2. The robustness analysis is carried out by solving the model with flexible prices (including (13')) where the monetary policy rule is obtained supposing that the economy featured price rigidities (i.e., using a "wrong" model by including (13) instead of (13')). Table 7 informs about the results by showing the standard deviations obtained with the wrongly-defined targeting and instrument rules to be compared with the ones obtained with the correct targeting rule. It also reports their increments in the loss function ($\%\triangle L$) relative to the loss value obtained with the correct targeting rule.

Three major conclusions arise after observing Table 7. First, both targeting rules and optimized Taylor-type rules are fully robust to price stability if the ECB pursues strict inflation targeting ($\lambda_{\widetilde{y}} = \lambda_R = 0.0$). In that case both rules deliver the optimal monetary policy even though they were designed assuming price stickiness. Second, both rules are moderately robust to price flexibility in all cases except when the ECB stabilizing preferences include a positive output gap targeting ($\lambda_{\widetilde{y}} \geq 0.0$) and no interest rate targeting ($\lambda_R = 0.0$). In these two cases, the loss function value and the standard deviations of the targeted variables are clearly higher than the ones obtained under the "right" targeting rule. In the six cases with $\lambda_R > 0.0$, deviations from the optimal rule are small in terms of loss function changes and standard deviations (see Table 7). So, rules are especially robust to price flexibility when there is nominal interest rate targeting. Third, the rules report a similar level of robustness for any pair of policy weights. We cannot conclude that the optimized Taylor-type rule is more robust to price flexibility than the targeting rule (or *vice versa*). Comparing the $\%\triangle L$ columns of Table 7, the instrument rule is more robust (lower $\%\triangle L$) in 4 cases, the targeting rule in other 4 cases, and they both are fully robust in the limiting case of strict inflation targeting.

ii) Robustness to wage flexibility.

If there were no rigidities on setting wages, the nominal wage first order condition would give rise to a constant ratio of the consumption-leisure marginal rate of substitution over the

real wage. It implies (in loglinearized terms) $\widehat{mrs}_t = \widehat{w}_t$. By using the definition of $\widehat{mrs}_t$ given in (11) we obtain the following real wage equation

$$\widehat{w}_t = \left(\tfrac{\gamma n^{ss}}{(1-\alpha)l^{ss}} + c_1 \right) \widehat{y}_t - c_2 \widehat{y}_{t-1} - \beta c_2 E_t \widehat{y}_{t+1} - \tfrac{\gamma n^{ss}}{l^{ss}} z_t - c_3 \zeta_t, \qquad (14')$$

which would replace equation (14) in the six-equation system of Section 2.

How do monetary policy rules behave in a flexible-wage economy when they were designed assuming wage rigidities? Are they robust to wage flexibility? Table 8 displays a comparison relative to the optimal targeting rule with the right model. Results are in line with the robustness to price flexibility. Both instrument rules and targeting rules are perfectly robust to wage flexibility if the ECB pursues strict inflation targeting ($\lambda_{\widetilde{y}} = \lambda_R = 0.0$) because they completely stabilize inflation. If there is output gap targeting ($\lambda_{\widetilde{y}} > 0.0$) and no interest rate targeting ($\lambda_R = 0.0$), both the inflation and output gap stabilization targets can be simultaneously attained with a targeting rule (see Erceg *et al.* (2000) for more details on this result). Remarkably, the incorrect targeting rule still delivers full stabilization of inflation and the output gap. In these two cases of Table 8 (second and third row), the "wrong" instrument rule reports an infinite increment in its loss function while the application of the "wrong" targeting rule leads to no increment in the loss function.[25] This extreme result is not observed in terms of standard deviations because the figures of σ_π and $\sigma_{\widetilde{y}}$ obtained are only slightly higher with the instrument rule relative to the targeting rule. These similitudes are even more clear when there is nominal interest rate targeting ($\lambda_R > 0$). The Taylor-type rule is then more robust to flexible wages than the targeting rule although figures of increments in the loss function and standard deviations are quite alike. In any case, deviations from the performance of the "right" targeting rule are always moderate and the effects of model mis-specification are smaller for higher values of $\lambda_{\widetilde{y}}$ and and λ_R. The wrong policy making tend to increase volatility of inflation and reduce volatility of the nominal interest rate. The volatility of the output gap is generally low in all cases since one source of nominal frictions has been eliminated.

Summarizing the previous paragraph, "wrong" Taylor-type instrument rules are fully robust to wage flexibility in one case ($\lambda_{\widetilde{y}} = \lambda_R = 0.0$), moderately robust in 6 cases ($\lambda_R > 0.0$), and no robust at all in 2 cases ($\lambda_{\widetilde{y}} > 0$, $\lambda_R = 0.0$). As for the "wrong" targeting rules, they are fully robust in 3 cases ($\lambda_R = 0.0$) and moderately robust in the other 6 cases ($\lambda_R > 0.0$). When comparing across types of rules, Taylor-type rules are more robust to wage flexibility than targeting rules except in 2 cases (when $\lambda_{\widetilde{y}} > 0$ and $\lambda_R = 0.0$) that the opposite result is found.

iii) Robustness to preferences without habit formation.

Finally, we will study the robustness of policy rules to some change in households' preferences. In particular, the utility function will no longer feature habit formation as in Erceg *et al.* (2000). This is readily included in the model by setting the habit formation coefficient at zero ($h = 0.0$). In turn, the equations of the model (12)-(17) can be maintained with the following parameterization $a_0 = 0.0$, $a_1 = 1.0$, $a_2 = 0.0$, $a_3 = \frac{1}{\sigma}$, $a_4 = \frac{(1-\rho_\zeta)}{\sigma}$, $c_1 = \sigma$,

---

[25]The percent change ($\%\triangle L$) under the "wrong" instrument rule becomes infinity because it delivers some positive value in the loss function while the targeting rule achieves a zero loss. In percent change that implies an infinite change.

$c_2 = 0.0$ and $c_3 = 1.0$, that affect the IS curve, the real wage equation, and the potential output equation as follows

$$\widehat{y}_t = E_t\widehat{y}_{t+1} - \tfrac{1}{\sigma}(R_t - E_t\pi_{t+1}) + \tfrac{(1-\rho_\zeta)}{\sigma}\zeta_t, \tag{12}$$

$$\widehat{w}_t = \tfrac{1}{1+\beta}(\widehat{w}_{t-1} - \pi_t) + \tfrac{\beta}{1+\beta}E_t(\widehat{w}_{t+1} + \pi_{t+1}) + \tag{14}$$

$$\kappa_w\left(\left(\tfrac{\gamma n^{ss}}{(1-\alpha)l^{ss}} + \sigma\right)\widehat{y}_t - \tfrac{\gamma n^{ss}}{l^{ss}}z_t - \zeta_t - \widehat{w}_t\right),$$

$$\left(\tfrac{\alpha}{1-\alpha} + \tfrac{\gamma n^{ss}}{(1-\alpha)l^{ss}} + \sigma\right)\widehat{\overline{y}}_t = \zeta_t + \left(1 + \tfrac{\gamma n^{ss}}{l^{ss}}\right)z_t. \tag{17}$$

Now the robustness exercise consists of evaluating the stabilizing properties of rules wrongly obtained by assuming habit formation ($h = 0.85$) in this economy without habit formation ($h = 0.0$). The results on the robustness analysis are shown in Table 9. Once again both optimized Taylor-type rules and targeting rules are fully robust to a change in household preferences if the ECB only targets inflation volatility ($\lambda_{\widetilde{y}} = \lambda_R = 0.0$). In the other 8 combinations of the ECB policy weights ($\lambda_{\widetilde{y}}, \lambda_R$), results are mixed being each rule more robust in half of the cases. Targeting rules are clearly more robust when $\lambda_{\widetilde{y}} > 0.0$ and $\lambda_R = 0.0$ because instrument rules fail to reduce output gap volatility ($\sigma_{\widetilde{y}}$ with the "wrong" instrument rule is more than twice the value obtained under the "wrong" targeting rule). On the contrary, if the ECB targets the nominal interest rate volatility ($\lambda_R > 0.0$), Taylor-type optimized rules are more robust to preference changes. In these cases, the implementation of the "wrong" targeting rules generate significant increments of $\sigma_{\widetilde{y}}$ and reductions of σ_R. Nevertheless, differences in standard deviation are never very high. Thus, we could affirm that both types of rules are moderately robust to preferences without habit formation.

A general conclusion can be assessed after discussing the three exercises of robustness. Both targeting rules and optimized instrument rules are moderately robust to changes in price/wage rigidities and households' preferences. Furthermore they generally show a similar level of robustness because they deviate in analogous magnitudes from the stabilizing properties of the correct optimal rule.[26] Thus, targeting and optimized Taylor-type instrument rules not only reach a similar level of performance, they also show analogous levels of robustness to model changes.

---

[26] The opposite result is found by Levin, Wieland, and Williams (1999), and Levin and Williams (2003) in robustness exercises with respectively four and three different models calibrated with US data.

6 Extensions: The welfare-theoretic loss function

Following Woodford (2003a), chapter 8, and Giannoni and Woodford (2003), the welfare-theoretic loss function according to our structural model can be approximated by the second-order function

$$\mathfrak{L}_t = \lambda_\pi \pi_t^2 + \lambda_{\pi W}(\pi_t^W)^2 + \lambda_{\widetilde{y}-\delta\widetilde{y}_{-1}}(\widetilde{y}_t - \delta\widetilde{y}_{t-1})^2 \tag{18'}$$

in which π_t^W is nominal wage inflation, $\pi_t^W = \widehat{w}_t - \widehat{w}_{t-1} + \pi_t$, and $0 \leq \delta \leq h$. The weights of the policy targets are fully defined from the structural parameters as follows:
$\lambda_\pi = \frac{\theta_P \kappa_\pi^{-1}}{\theta_P \kappa_\pi^{-1} + \theta_W(1-\alpha)^{-1}(1+\beta)\kappa_w^{-1}}$, $\lambda_{\pi W} = 1 - \lambda_\pi$, and $\lambda_{\widetilde{y}-\delta\widetilde{y}_{-1}} = \lambda_\pi \frac{\kappa_\pi h}{\theta_P \varphi^{-1}\delta}$.[27] The value of $\lambda_{\widetilde{y}-\delta\widetilde{y}_{-1}}$ depends on two new parameters: φ^{-1} is the elasticity of intertemporal substitution with a habit formation structure ($\varphi^{-1} = \frac{(1-\beta h)(1-h)}{\sigma}$), and δ is the smaller root of the quadratic equation

$$h\varphi(1 + \beta\delta^2) - \left[\frac{\alpha}{1-\alpha} + \frac{\gamma n^{ss}}{(1-\alpha)l^{ss}} + \varphi(1 + \beta h^2)\right]\delta = 0. \tag{26}$$

The figure assigned to the the elasticity of intertemporal substitution φ^{-1} depends on the calibrated parameters β, h, and σ. Inserting the numbers assigned in the calibration of Section 3 ($\beta = 0.995$, $h = 0.85$, and $\sigma = 1.5$) leads to $\varphi^{-1} = \frac{(1-\beta h)(1-h)}{\sigma} = 0.015$. With respect to δ, the roots of equation (26) also depends on the values of parameters calibrated in Section 3. Using their numbers, the smaller root was found to be $\delta = 0.60$.

Notice that the Dixit-Stiglitz elasticities θ_P and θ_W appear in the determination of the policy weights λ_π, $\lambda_{\pi W}$, and $\lambda_{\widetilde{y}-\delta\widetilde{y}_{-1}}$. Their values will be calibrated using the elasticity parameters κ_π and κ_w, defined in Section 2 and estimated for the euro area in Section 3. Their definition and estimation resulted in $\kappa_\pi = \frac{(1-\beta\eta_P)(1-\eta_P)(1-\alpha)}{\eta_P(1-\alpha+\alpha\theta_P)} = 0.028$, and $\kappa_w = \frac{(1-\beta\eta_W)(1-\eta_W)}{\eta_W(1+\beta)(1+\theta_W\gamma n^{ss}/l^{ss})} = 0.003$. The Calvo probabilities η_P and η_W must be calibrated in order to respectively determine the values of θ_P and θ_W. Here we set $\eta_P = \eta_W = 2/3$ which imply that on average both prices and wages are decided optimally once every three quarters (i.e., nine months).[28] So, recalling the calibrated parameters $\beta = 0.995$ and $\alpha = 0.36$, and setting the Calvo sticky-price parameter at $\eta_P = 2/3$, the estimated value $\kappa_\pi = 0.028$ in the Phillips curve is obtained with an elasticity of substitution across differentiated goods equal to $\theta_P = 9.3$. Thus, we set $\theta_P = 9.3$. It implies that in steady-state the mark-up of prices over marginal costs is nearly 11%.

Analogously, assuming a Calvo sticky-wage probability $\eta_W = 2/3$, using the calibrated parameters $\beta = 0.995$ and $\gamma n^{ss}/l^{ss} = 8$, the estimate of the slope of the real wage curve $\kappa_w = 0.003$ is obtained for an implied elasticity of substitution across differentiated labor services equal to $\theta_W = 3.4$.

Summarizing, the calibrated-estimated figures of our euro area model parameterization ($\theta_P = 9.3$, $\kappa_\pi = 0.028$, $\theta_W = 3.4$, $\beta = 0.995$, $\alpha = 0.36$, $\kappa_w = 0.003$, $h = 0.85$, $\varphi^{-1} = 0.015$, $\delta = 0.60$) result in the following welfare-theoretic policy weights: $\lambda_\pi = 0.47$, $\lambda_{\pi W} = 0.53$,

---

[27]See Woodford (2003a), chapters 6-8, for a characterization of the parameter-based policy weights in alternative welfare-theoretic loss functions.

[28]Sbordone (2002) finds that $\eta_P = 2/3$ leads to a degree of price inertia which is appropriate to fit the US data with a Calvo-type sticky-price model. She also mentions the empirical findings by Blinder *et al.* (1998) that give support to this calibration of η_P. As for the sticky-wage parameter η_W, we set $\eta_W = 2/3$ in order to have a level of wage stickiness identical to price stickiness.

and $\lambda_{\widetilde{y}-\delta\widetilde{y}_{-1}} = 0.13$. These numbers are quite different from the estimates of Giannoni and Woodford (2003) for the US economy. Their inflation targeting weight λ_π is very close to 1.0 and therefore the wage inflation weight $\lambda_{\pi W}$ is very low. Likewise, the weight on the volatility of the adjusted first difference of the output gap $\lambda_{\widetilde{y}-\delta\widetilde{y}_{-1}}$ is very close to 0.0. Two reasons can be pointed out to explain the differences: first, their implicit estimated value of θ_P for the US is very high as it takes a value almost 90 times larger than the one assigned to θ_W.[29] It leads to place much more weight on price inflation stabilization relative to wage inflation targeting. The second difference has to do with the elasticity of intertemporal substitution φ^{-1}. Giannoni and Woodford (2003) find an implicit estimate of this elasticity for the US equal to $\varphi^{-1} = 1.33$ which is much higher than our calibrated value for the euro area ($\varphi^{-1} = 0.015$). Since the elasticity of intertemporal substitution φ^{-1} affects negatively to $\lambda_{\widetilde{y}-\delta\widetilde{y}_{-1}}$ (as defined above), a very high φ^{-1} brings about a much lower figure for $\lambda_{\widetilde{y}-\delta\widetilde{y}_{-1}}$. Thus, it can explain why they set such a low weight on $\lambda_{\widetilde{y}-\delta\widetilde{y}_{-1}}$.

Similarly to stabilizing targeting rules, the welfare-based targeting rule is the one obtained by minimizing $E_t \sum_{j=0}^{\infty} \beta^j \mathfrak{L}_{t+j}$ subject to the behavioral equations (19)-(21) plus one extra equation defining nominal wage inflation as $\pi_t^W = \widehat{w}_t - \widehat{w}_{t-1} + \pi_t$. Now we will discuss the implications of taking this welfare-theoretic loss function for the ECB monetary policy. In terms of its stabilizing properties, the welfare-theoretic targeting rule gives rise to the following (annualized) percent standard deviations of the policy targets: $\sigma_\pi = 0.42$, $\sigma_{\pi W} = 0.20$, and $\sigma_{\widetilde{y}-\delta\widetilde{y}_{-1}} = 0.016$. Figures are reported in part i) of Table 10. Thus, variability of price inflation is low (0.42) and variability of wage inflation even lower (0.20). The variability of the output gap adjusted first difference is close to zero (0.016). Interestingly, variability of the output gap is also near zero ($\sigma_{\widetilde{y}} = 0.038$). Thus, the welfare-based policy is aimed at reducing very much deviations of output from its (friction-free) potential level. Put differently, the targeting rule that maximizes households' welfare eliminates most of the price-wage dispersion due to nominal rigidities in order to restore the flexible price-wage economy. As explained in Erceg *et al.* (2000), targeting price inflation volatility reduces the gap between the real wage and marginal costs. Similarly, when targeting variability of wage inflation, the gap between the consumption-leisure marginal rate of substitution and the real wage also gets smaller. Both gaps together cause the output gap. Therefore, hitting price and wage inflation indirectly drives the output gap volatility down.[30]

Extending the analysis to (alternative) instrument rules, let us first compare the performance of the estimated Taylor-type rule ($\mu_1 = 0.47$, $\mu_2 = 0.13$, and $\mu_3 = 0.53$) relative to the one of the welfare-theoretic targeting rule. The estimated instrument rule leads to a level of losses in the welfare-based loss function (18') much higher than the one obtained with the targeting rule (see results collected in part ii of Table 10). Losses are nearly 80 times higher ($\%\triangle\mathfrak{L} = 7931$). Likewise, the standard deviations of the three policy targets are several times higher than the ones provided by the targeting rule. Figure 4 contains

---

[29] Concretely, their implicit estimates of θ_P and θ_W for the US are $\theta_P = 251$ and $\theta_W = 2.85$. The estimated figure for θ_P implies $\frac{\theta_P}{\theta_P-1} = 1.004$ which results in an extremely low steady-state markup of prices over marginal costs. Consequently, producers have very little monopolistic power and the goods market is very close to perfect competition.

[30] One could believe that the low output gap volatility is also related to the moderately high figure (0.13) assigned to $\lambda_{\widetilde{y}-\delta\widetilde{y}_{-1}}$. However, this is not true because if the rule were designed with $\lambda_{\widetilde{y}-\delta\widetilde{y}_{-1}} = 0.0$, keeping λ_π and $\lambda_{\pi W}$ constant, the standard deviations would barely change ($\sigma_\pi = 0.41$, $\sigma_{\pi W} = 0.21$, and $\sigma_{\widetilde{y}-\delta\widetilde{y}_{-1}} = 0.018$). The policy weight $\lambda_{\widetilde{y}-\delta\widetilde{y}_{-1}}$ seems to have little quantitative significance in the welfare-theoretic targeting rule.

plots of the responses to either demand or supply shocks. It is clearly observed that all responses under the targeting rule (solid lines) are much less volatile than responses under the estimated instrument rule (dashed lines). Consequently, the estimated Taylor-type rule is also far from being optimal when the welfare criterion is considered.

Can the welfare-maximizing properties of our Taylor-type instrument rule (15) be substantially improved by searching the best-performing coefficients? Analogously to the procedure followed in the previous section for the stabilizing loss function, we will find the instrument-rule coefficients for (15) that minimize the welfare-theoretic loss function (18') subject to the model equations (19)-(21) plus the additional equation defining π_t^W. The policy exercise will be implemented with the figures of λ_π, λ_{π^W}, and $\lambda_{\widetilde{y}-\delta\widetilde{y}_{-1}}$ implied from the euro area parameterization of the model.

Noteworthily, the optimized Taylor-type rule has no reaction to inflation deviations ($\mu_1^* = 0.0$) combined with a very aggressive response to the output gap ($\mu_2^* = 147$). The level of interest rate smoothing is also quite high ($\mu_3^* = 2.55$). This policy design is very different from the ones obtained in the previous section which never had a large output gap coefficient. An intuitive explanation to this result would come from the very little output gap volatility that the targeting welfare-based rule permits (as discussed above). The optimized Taylor-type rule now tries to imitate the welfare-based targeting rule and finds the best way to approximate by means of responding very aggressively to the output gap. Numbers provided in part iii of Table 10 show that this aggressive output gap response provides a level of policy achievement close to efficiency. The optimized instrument rule performs very closely to the welfare-theoretic targeting rule. For example, the loss function value increases only by 7% compared to the targeting rule. As for the standard deviations, there is slightly more volatility of price inflation, σ_π, and less of wage inflation, σ_{π^W}, with the optimized instrument rule. The standard deviation of the term involving the output gap, $\sigma_{\widetilde{y}-\delta\widetilde{y}_{-1}}$, is also close to 0 with the optimized Taylor-type rule. In any case, differences are quantitative small (compare part i and part iii of Table 10). These similarities are also found in the impulse response functions of the three targeted variables which are plotted in Figure 4. As observed there for both demand and supply shocks, differences between responses under the welfare-theoretic targeting rule (solid lines) and the optimized Taylor-type rule (dotted lines) are hardly distinguishable.

Recalling the discussion on operational instrument rules from the end of subsection 5.1, the unobservable output gap term $\widetilde{y}_t$ from the Taylor-type instrument rule (15) should be replaced by some observable variable to make the rule fully operational. One strong candidate to enter the instrument rule is wage inflation π_t^W both as observable and as a policy target appearing in the welfare-theoretic loss function (18').[31] Results for an operational instrument rule with π_t^W instead of $\widetilde{y}_t$ are shown in part iv of Table 10. The optimized coefficients found are very high figures for both price inflation ($\mu_1^* = 52$) and wage inflation ($\mu_2^* = 108$), and a moderate interest rate smoothing ($\mu_3^* = 1.15$). The optimized instrument rule with wage inflation performs nearly as efficient as the targeting rule. Actually, it performs even better than the optimized Taylor-type rule (15). As documented in part iv of Table 10, the percent change in the loss function is very low (2.2%) and the standard deviations of the three policy targets very much resemble the ones obtained with the targeting rule. They are identical for wage inflation σ_{π^W}, almost identical for price inflation σ_π, and slightly higher

---

[31] It is also one of the policy recommendations suggested by Erceg *et al.* (2000).

plots of the responses to either demand or supply shocks. It is clearly observed that all responses under the targeting rule (solid lines) are much less volatile than responses under the estimated instrument rule (dashed lines). Consequently, the estimated Taylor-type rule is also far from being optimal when the welfare criterion is considered.

Can the welfare-maximizing properties of our Taylor-type instrument rule (15) be substantially improved by searching the best-performing coefficients? Analogously to the procedure followed in the previous section for the stabilizing loss function, we will find the instrument-rule coefficients for (15) that minimize the welfare-theoretic loss function (18') subject to the model equations (19)-(21) plus the additional equation defining π_t^W. The policy exercise will be implemented with the figures of λ_π, $\lambda_{\pi W}$, and $\lambda_{\widetilde{y}-\delta\widetilde{y}_{-1}}$ implied from the euro area parameterization of the model.

Noteworthily, the optimized Taylor-type rule has no reaction to inflation deviations ($\mu_1^* = 0.0$) combined with a very aggressive response to the output gap ($\mu_2^* = 147$). The level of interest rate smoothing is also quite high ($\mu_3^* = 2.55$). This policy design is very different from the ones obtained in the previous section which never had a large output gap coefficient. An intuitive explanation to this result would come from the very little output gap volatility that the targeting welfare-based rule permits (as discussed above). The optimized Taylor-type rule now tries to imitate the welfare-based targeting rule and finds the best way to approximate by means of responding very aggressively to the output gap. Numbers provided in part iii of Table 10 show that this aggressive output gap response provides a level of policy achievement close to efficiency. The optimized instrument rule performs very closely to the welfare-theoretic targeting rule. For example, the loss function value increases only by 7% compared to the targeting rule. As for the standard deviations, there is slightly more volatility of price inflation, σ_π, and less of wage inflation, $\sigma_{\pi W}$, with the optimized instrument rule. The standard deviation of the term involving the output gap, $\sigma_{\widetilde{y}-\delta\widetilde{y}_{-1}}$, is also close to 0 with the optimized Taylor-type rule. In any case, differences are quantitative small (compare part i and part iii of Table 10). These similarities are also found in the impulse response functions of the three targeted variables which are plotted in Figure 4. As observed there for both demand and supply shocks, differences between responses under the welfare-theoretic targeting rule (solid lines) and the optimized Taylor-type rule (dotted lines) are hardly distinguishable.

Recalling the discussion on operational instrument rules from the end of subsection 5.1, the unobservable output gap term $\widetilde{y}_t$ from the Taylor-type instrument rule (15) should be replaced by some observable variable to make the rule fully operational. One strong candidate to enter the instrument rule is wage inflation π_t^W both as observable and as a policy target appearing in the welfare-theoretic loss function (18').[31] Results for an operational instrument rule with π_t^W instead of $\widetilde{y}_t$ are shown in part iv of Table 10. The optimized coefficients found are very high figures for both price inflation ($\mu_1^* = 52$) and wage inflation ($\mu_2^* = 108$), and a moderate interest rate smoothing ($\mu_3^* = 1.15$). The optimized instrument rule with wage inflation performs nearly as efficient as the targeting rule. Actually, it performs even better than the optimized Taylor-type rule (15). As documented in part iv of Table 10, the percent change in the loss function is very low (2.2%) and the standard deviations of the three policy targets very much resemble the ones obtained with the targeting rule. They are identical for wage inflation $\sigma_{\pi W}$, almost identical for price inflation σ_π, and slightly higher

---

[31] It is also one of the policy recommendations suggested by Erceg *et al.* (2000).

for $\sigma_{\widetilde{y}-\delta\widetilde{y}_{-1}}$. In conclusion, the welfare-theoretic targeting rule can be well represented by a (simple) instrument rule on the nominal interest rate. The rule would consist of reacting very aggressively to deviations of price inflation and, even more strongly, to deviations of wage inflation. In addition, the rule should have a long time inertia.

Since large optimized coefficients were found, the instrument rules were re-optimized constrained to be designed for not-so-high figures. Otherwise, very high coefficients found could generate much instability in case of model mis-specification or other mistakes in policy design. Thus, let us bind the optimized coefficients to be lower than 5.0, as a moderate reference value. Results appear for the optimized Taylor-type rule (15) in part v of Table 10. Now the coefficient on inflation is $\mu_1^* = 2.3$, the output gap coefficient is at its upper bound ($\mu_2^* = 5.0$), and there is a unit lagged nominal interest rate coefficient ($\mu_3^* = 1.0$). The welfare-maximizing properties of the constrained optimized rule are not as good as the unconstrained rule (compare part v with part iii of Table 10). Nevertheless, the unconstrained rule still performs quite well. The increase in the welfare-theoretic loss function is 16.9% (it was 7% with the unconstrained rule). The figures of σ_π and $\sigma_{\pi W}$ are similar to the ones obtained with the unconstrained rule whereas $\sigma_{\widetilde{y}-\delta\widetilde{y}_{-1}}$ is a bit higher.

Regarding the operational instrument rule with π_t^W (instead of $\widetilde{y}_t$) with optimized coefficients equal or lower than 5.0, the optimal coefficients are $\mu_1^* = 5.0$ (upper bound), $\mu_2^* = 5.0$, (upper bound), and $\mu_3^* = 0.96$. Again, the rule without large coefficients does not reach the very good stabilizing properties of the unconstrained rule although differences are not very large (compare part iv and vi of Table 10). The loss function is 31.8% higher than the value obtained under the targeting rule (it was 2.2% higher with the unconstrained rule). As for the standard deviations, they are higher for $\sigma_{\pi W}$ and $\sigma_{\widetilde{y}-\delta\widetilde{y}_{-1}}$, and, by contrast, slightly lower for σ_π. In conclusion, the optimized instrument rule constrained to be designed with coefficients lower than 5.0 does not perform noticeably worse than the unconstrained rule and still represents a reasonably good approximation to the welfare-theoretic targeting rule.

Finally, we will investigate the stabilizing properties of the welfare-theoretic targeting rule. This exercise can be readily done by finding the weights of the stabilizing loss function (18) which would best approximate the volatilities implied by the welfare-theoretic loss function (18'). As previously mentioned in this section, the welfare-theoretic targeting rule seems to situate the economy near its natural-rate level of output defined as the amount that would prevail in a economy free of nominal rigidities. Translating this welfare criterion in terms of stabilizing criteria, the weight of the output gap target ought to be high enough so that variability of the output gap became low. Confirming this guess, it was found that the stabilizing targeting rule that best resemble the welfare-theoretic rule is that with a very high output gap weight ($\lambda_{\widetilde{y}} = 1.88$) and no interest rate weight ($\lambda_R = 0.0$). Under these stabilizing parameters, the monetary policy is conducted in a really similar way to the welfare-theoretic targeting rule. Table 11 shows this good matching. The standard deviations of the three targeted variables (σ_π, $\sigma_{\pi W}$, and $\sigma_{\widetilde{y}-\delta\widetilde{y}_{-1}}$) are all strikingly alike. The welfare-theoretic loss function value obtained with a stabilizing targeting rule with $\lambda_{\widetilde{y}} = 1.88$ and $\lambda_R = 0.0$ is just 2.6% higher than the one obtained with the welfare-theoretic targeting rule. Therefore, social welfare could be nearly maximized by implementing a stabilizing targeting rule with a very strong output gap targeting and no interest rate targeting.The welfare-maximizing

policy would then result in an economy with low inflation volatility, near zero output gap volatility, and a very high volatility in the nominal interest rate (see the standard deviations reported in Table 11).[32]

---

7 Conclusions

This paper has examined the behavior of instrument (Taylor-type) rules relative to targeting rules in a euro area New Keynesian model. The results can be summarized into two major findings:

i) Rules quasi-equivalence for stabilizing purposes. Instrument rules á la Taylor can be designed with optimized coefficients in order to perform closely to the efficient targeting rules. The quasi-equivalence in performance holds for a variety of ECB preferences on stabilizing inflation, the output gap, and the nominal interest rate. The evaluation of instrument rules has also served to characterize the optimal coefficients of Taylor-type rules for the euro area. Thus, the coefficient of the responses to inflation deviations goes significantly up as ECB targets inflation variability more strongly, the coefficient of the responses to the output gap is generally low, and the coefficient on the lagged nominal interest rate is slightly above one (except under strict inflation targeting). This last feature implies a great extent of monetary policy inertia. The rules quasi-equivalence still maintains when considering instrument rules that only involve fully observable variables (e.g., excluding the output gap). In addition to their similar performance, both types of rules are also closely equivalent in their robustness to model changes. There were a few exceptions to the latter reported in the text.

ii) Rules quasi-equivalence for maximizing welfare. Optimized instrument rules can also be designed to perform very closely to a targeting rule based on maximizing households' welfare. The resulting welfare-theoretic rule situates the economy near its free-rigidity (natural rate) equilibrium as it yields a low variability of the output gap. By contrast, the welfare-theoretic rule leads to a very high nominal interest rate variability. This policy behavior can also be attained by applying a stabilizing targeting rule with a unit weight on inflation volatility, a large weight on the output gap volatility, and no weight on the nominal interest rate volatility.

These results lead to a double message for monetary policy making in the euro area. First, instrument rules á la Taylor can represent quite closely the optimal policy behavior of either stabilizing or welfare-theoretic targeting rules. Therefore, instrument rules can be designed as simple rules that imply policy reactions very close to those provided by the optimal targeting rules. Second, the design of a monetary policy rule for the euro area depends very much on the ECB policy preferences. Thus, the definition of the ECB policy targets and their relative weights play a crucial role in the optimal design of monetary policy rules for the euro area.

The whole monetary policy analysis conducted here is unavoidably linked to the closed-economy New Keynesian model described in the text. This particular model was selected for the analysis due to both its theoretical appeal as based on optimizing behavior, and to its capacity to replicate many regularities observed in the euro area business cycle. However, it would be interesting to repeat the exercises of policy evaluation using other models that were also able to explain reasonably well the euro area business cycle. Actually, that would be necessary to validate the robustness of our results. Unfortunately, it lies beyond the scope of this paper, remaining open for future research.

REFERENCES

Altonji, J. A., 1986, Intertemporal substitution in labor supply: evidence from micro data", Journal of Political Economy 94, 176-215.

Amato, J. D., and T. Laubach, 2004, Implications of habit formation for optimal monetary policy, Journal of Monetary Economics, 51, 305-325.

Andrés, J., J.D. López-Salido, and E. Nelson, 2003, Money and the natural rate of interest (structural estimates for the UK, the US, and the Euro Area, manuscript.

Blinder, A.S., E.R.D. Canetti, D. Lebow, and J.B. Rudd, 1998, Asking about prices: a new approach to understand price stickiness, Russell Sage Foundation, New York.

Calvo, G. A., 1983, Staggered pricing in a utility-maximizing framework, Journal of Monetary Economics 12, 383-396.

Card, D., 1994, Intertemporal labor supply: an assessment, in Advances in Econometrics, C. Sims ed., Cambridge University Press, New York.

Casares, M., 2004, Price setting and the steady-state effects of inflation, Spanish Economic Review, forthcoming.

Christiano, L.J, and M. Eichenbaum, 1992, Current real business cycle theories and aggregate labor market fluctuations", American Economic Review 82, 430-450.

Clarida, R., J. Galí, and M. Gertler, 1998, Monetary policy rule in practice: Some international evidence", European Economic Review 42, 1033-1067.

——, ——, and ——, 1999, The science of monetary policy: a new Keynesian perspective, Journal of Economic Literature 37, 1661-1707.

Dixit, A. K., and J. E. Stiglitz, 1977, Monopolistic competition and optimum product diversity, American Economic Review 67, 297-308.

Erceg, C.J., D.W. Henderson, and A.T. Levin, 2000, Optimal monetary policy with staggered wage and price contracts, Journal of Monetary Economics 46, 281-313.

European Central Bank, 2003, The mission of the European Central Bank, www.ecb.int.

Fagan, G., J. Henry, and R. Mestre, 2001, An area-wide model for the euro area, Econometric Modelling Division, European Central Bank, ECB Working Paper Series No. 42.

Friedman, M., 1959, A program for monetary stability, Fordham University Press, New York.

Galí, J., and M. Gertler, 1999, Inflation dynamics: a structural econometric analysis, Journal of Monetary Economics 44, 195-222.

——,——, and J.D. López-Salido, 2001, European inflation dynamics, European Economic Review 45, 1237-1270.

Fuhrer, J.C., 2000, Habit formation in consumption and its implications for monetary-policy models, American Economic Review 90, 367-390.

Giannoni, M.P., and M. Woodford, 2003, Optimal inflation targeting rules, NBER working paper series, 9939.

Jensen, C., and B.T. McCallum, 2002, The non-optimality of proposed monetary policy rules under timeless perspective commitment, Economics Letters 77, 163-168.

Johnson, T.R., and J.H. Pencavel, 1984, Dynamic hours of work functions for husbands, wifes, and single females, Econometrica 52 (2), 363-389.

King, R.G., and A.L. Wolman, 1996, Inflation targeting in a St. Louis model of the 21st century, Federal Reserve Bank of St. Louis Review 78, 83-107.

Levin, A.T., Wieland, W., and J.C. Williams, 1999, Robustness of simple monetary policy rules under model uncertainty, in J.B. Taylor, ed., Monetary Policy Rules, University of Chicago Press, 263-299.

——, and J.C. Williams, 2003, Robust monetary policy with competing reference models, Journal of Monetary Economics 50, 945-975.

McCallum, B.T., 1988, Robustness properties of a rule for monetary policy, Carnegie-Rochester Conference Series on Public Policy 29, 173-203.

——, 1999, Issues in the design of monetary policy rules, in Handbook of Macroeocnomics, John B. Taylor and Michael Woodford, eds., North-Holland, Amsterdam.

——, and E. Nelson 2003, Targeting vs. instrument rules for monetary policy, manuscript.

Nelson, E., 2002, Direct effects of base money on aggregate demand: theory and evidence, Journal of Monetary Economics 49, 687-708.

Pencavel, J.H., 1986, Labor supply of men: a survey, in Handbook of Labor Economics, O. Ashenfelter and R. Layard eds., North Holland, Amsterdam.

Rotemberg, J. J., and M. Woodford, 1997, An optimizing-based econometric framework for the evaluation of monetary policy, NBER Macroeconomics Annual 1997, B.M. Bernanke and J.J. Rotemberg, eds. MIT Press, (Cambridge, MA).

——, and ——, 1999, Interest rate rules in an estimated sticky price model, in J.B. Taylor, ed., Monetary Policy Rules, University of Chicago Press, 57-119.

Sbordone, A. M., 2001, An optimizing model of US wage and price dynamics, manuscript, Rutgers University.

——, 2002, Prices and unit labor costs: a new test of price stickiness, Journal of Monetary Economics 49, 265-292.

Smets, F., and R. Wouters, 2003, An estimated Dynamic Stochastic General Equilibrium model of the euro area, Journal of the European Economic Association, 1 (5), 1123-1175.

Svensson, L.E.O., 1999, Inflation targeting as a monetary policy rule, Journal of Monetary Economics 43, Special Issue on Monetary Policy Rules, 607-654.

——, 2002, Inflation targeting: Should it be modeled as an instrument rule or a targeting rule?, European Economic Review 46, 771-780.

——, 2003, What is wrong with Taylor rules? Using judgment in monetary policy through targeting rules, Journal of Economic Literature 41, 426-477.

Taylor, J. B., 1993, Discretion versus policy rules in practice, Carnegie-Rochester Conference Series on Public Policy 39, 195-214.

——, 1999, The robustness and efficiency of monetary policy rules as guidelines for interest rate setting by the European Central Bank, Journal of Monetary Economics 43, Special Issue on Monetary Policy Rules, 655-680.

Woodford, M., 1999, Commentary: How should monetary policy be conducted in an era of price stability?, in New Challenges for Monetary Policy: A Symposium Sponsored by the Federal Reserve Bank of Kansas City, Federal Reserve Bank of Kansas City, 277-316.

——, 2003a, Interest and prices: Foundations of a theory of monetary policy, Princeton University Press.

——, 2003b, Optimal interest-rate smoothing, Review of Economic Studies 70, 861-886.

Yun, T., 1996, Nominal price rigidity, money supply endogeneity, and business cycles, Journal of Monetary Economics 37, 345-370.

Table 1. Calibration/Estimation of parameters			
Calibrated parameters		Estimated parameters	
$\alpha = 0.36$	$\beta = 0.995$	$\mu_1 = 0.47$	$\mu_2 = 0.13$
$\sigma = 1.5$	$h = 0.85$	$\mu_3 = 0.53$	
$\gamma = 16$		$\kappa_\pi = 0.028$	$\kappa_w = 0.003$
$\rho_z = 0.95$	$\rho_\zeta = 0.6$	$\sigma_{\varepsilon^z} = 0.95$	$\sigma_{\varepsilon\zeta} = 5.62$

Table 2. Business cycle statistics. Model-to-data comparison.								
	Model				Euro area data			
	$\widehat{y}$	π	$\widehat{w}$	R	$\widehat{y}$	π	$\widehat{w}$	R
Annualized Std. deviations (%)	2.00	2.73	1.30	3.58	1.73	2.87	1.71	3.51
Coef. of autocorrelation	0.96	0.90	0.98	0.97	0.93	0.88	0.96	0.96
Coef. of correlation to $\widehat{y}$	1.0	0.16	0.89	0.19	1.0	0.13	0.51	0.28
Coef. of correlation to π	0.16	1.0	0.15	0.94	0.13	1.0	0.01	0.88

Table 3. Efficiency I. Comparing stabilizing targeting rules with the estimated Taylor-type instrument rule.								
Targeting rule				Estimated Taylor-type rule				
$(\lambda_{\widetilde{y}},\lambda_R)$	σ_π	$\sigma_{\widetilde{y}}$	σ_R	(μ_1,μ_2,μ_3)	σ_π	$\sigma_{\widetilde{y}}$	σ_R	$\%\triangle L$
(0.0,0.0)	0.0	1.01	244.5	(0.47,0.13,0.53)	2.73	1.10	3.58	∞
(0.01,0.0)	0.15	0.39	17.20	(0.47,0.13,0.53)	2.73	1.10	3.58	16580
(0.1,0.0)	0.29	0.15	13.00	(0.47,0.13,0.53)	2.73	1.10	3.58	7798
(0.0,0.1)	0.59	0.70	1.48	(0.47,0.13,0.53)	2.73	1.10	3.58	1432
(0.01,0.1)	0.57	0.67	1.56	(0.47,0.13,0.53)	2.73	1.10	3.58	1284
(0.1,0.1)	0.51	0.51	2.14	(0.47,0.13,0.53)	2.73	1.10	3.58	845
(0.0,0.5)	0.85	0.86	0.69	(0.47,0.13,0.53)	2.73	1.10	3.58	1350
(0.01,0.5)	0.83	0.84	0.73	(0.47,0.13,0.53)	2.73	1.10	3.58	1211
(0.1,0.5)	0.79	0.72	1.00	(0.47,0.13,0.53)	2.73	1.10	3.58	716
(2.37,1.82)	1.25	0.49	1.61	(0.47,0.13,0.53)	2.73	1.10	3.58	387

Table 4. Efficiency II. Comparing stabilizing targeting rules with optimized Taylor-type instrument rules.								
Targeting rule				Optimized Taylor-type rule				
$(\lambda_{\widetilde{y}},\lambda_R)$	σ_π	$\sigma_{\widetilde{y}}$	σ_R	$(\mu_1^*,\mu_2^*,\mu_3^*)$	σ_π	$\sigma_{\widetilde{y}}$	σ_R	$\%\triangle L$
(0.0,0.0)	0.0	1.01	244.5	$(\infty,0.0,0.0)$	0.0	1.01	244.5	0.0
(0.01,0.0)	0.15	0.39	17.20	(34.3,0.40,1.01)	0.14	0.42	11.89	5.4
(0.1,0.0)	0.29	0.15	13.00	(8.56,2.74,1.06)	0.31	0.20	7.93	35.2
(0.0,0.1)	0.59	0.70	1.48	(0.39,0.02,1.08)	0.67	0.65	1.54	20.4
(0.01,0.1)	0.57	0.67	1.56	(0.39,0.03,1.07)	0.65	0.63	1.62	16.7
(0.1,0.1)	0.51	0.51	2.14	(0.40,0.12,1.05)	0.58	0.51	2.16	7.1
(0.0,0.5)	0.85	0.86	0.69	(0.13,0.0,1.11)	0.93	0.85	0.64	11.4
(0.01,0.5)	0.83	0.84	0.73	(0.10,0.01,1.07)	0.91	0.82	0.68	9.7
(0.1,0.5)	0.79	0.72	1.00	(0.13,0.03,1.07)	0.85	0.71	0.97	4.1

Table 5. Efficiency III. Comparing stabilizing targeting rules with optimized Taylor-type instrument rules with $\widehat{y}_t$ (instead of $\widetilde{y}_t$).								
Targeting rule				Optimized instrument rule with $\widehat{y}_t$				
$(\lambda_{\widetilde{y}},\lambda_R)$	σ_π	$\sigma_{\widetilde{y}}$	σ_R	$(\mu_1^*,\mu_2^*,\mu_3^*)$	σ_π	$\sigma_{\widetilde{y}}$	σ_R	$\%\triangle L$
(0.0,0.0)	0.0	1.01	244.5	$(\infty,0.0,0.0)$	0.0	1.01	244.5	0.0
(0.01,0.0)	0.15	0.39	17.20	(33.8,0.03,0.97)	0.14	0.42	11.89	5.6
(0.1,0.0)	0.29	0.15	13.00	(11.6,0.06,0.82)	0.27	0.26	8.36	58.3
(0.0,0.1)	0.59	0.70	1.48	(0.46,0.0,1.10)	0.67	0.67	1.53	20.9
(0.01,0.1)	0.57	0.67	1.56	(0.52,0.0,1.11)	0.66	0.64	1.62	17.4
(0.1,0.1)	0.51	0.51	2.14	(0.83,0.02,1.15)	0.57	0.53	2.17	9.8
(0.0,0.5)	0.85	0.86	0.69	(0.13,0.0,1.11)	0.93	0.85	0.64	11.4
(0.01,0.5)	0.83	0.84	0.73	(0.15,0.0,1.12)	0.91	0.83	0.70	9.9
(0.1,0.5)	0.79	0.72	1.00	(0.25,0.01,1.18)	0.86	0.70	1.03	6.0

Table 6. Efficiency IV. Comparing stabilizing targeting rules with optimized Taylor-type instrument rules without output-related response ($\mu_2 = 0.0$).								
Targeting rule				Optimized instrument rule with $\mu_2 = 0.0$				
$(\lambda_{\widetilde{y}},\lambda_R)$	σ_π	$\sigma_{\widetilde{y}}$	σ_R	(μ_1^*,μ_3^*)	σ_π	$\sigma_{\widetilde{y}}$	σ_R	$\%\triangle L$
(0.0,0.0)	0.0	1.01	244.5	$(\infty,0.0)$	0.0	1.01	244.5	0.0
(0.01,0.0)	0.15	0.39	17.20	(34.5,0.96)	0.14	0.42	11.99	5.6
(0.1,0.0)	0.29	0.15	13.00	(13.0,0.78)	0.27	0.27	8.72	59.8
(0.0,0.1)	0.59	0.70	1.48	(0.46,1.10)	0.67	0.67	1.53	20.9
(0.01,0.1)	0.57	0.67	1.56	(0.52,1.11)	0.66	0.64	1.62	17.4
(0.1,0.1)	0.51	0.51	2.14	(0.94,1.14)	0.56	0.55	2.16	11.8
(0.0,0.5)	0.85	0.86	0.69	(0.13,1.11)	0.93	0.85	0.64	11.4
(0.01,0.5)	0.83	0.84	0.73	(0.15,1.12)	0.91	0.83	0.70	9.9
(0.1,0.5)	0.79	0.72	1.00	(0.28,1.18)	0.85	0.74	0.97	6.2

Table 7. Robustness I. Robustness to price flexibility.											
Targeting rule with flexible prices (right)				Targeting rule with sticky prices (wrong)				Optimized Taylor-type rule with sticky prices (wrong)			
$(\lambda_{\widetilde{y}},\lambda_R)$	σ_π	$\sigma_{\widetilde{y}}$	σ_R	σ_π	$\sigma_{\widetilde{y}}$	σ_R	$\%\triangle L$	σ_π	$\sigma_{\widetilde{y}}$	σ_R	$\%\triangle L$
(0.0,0.0)	0.0	1.01	244.5	0.0	1.01	244.5	0.0	0.0	1.01	244.5	0.0
(0.01,0.0)	0.05	0.99	243.7	0.88	0.80	173.5	456	1.92	0.67	60.81	2283
(0.1,0.0)	0.45	0.85	236.5	2.61	0.33	52.71	413	2.72	0.37	25.74	460
(0.0,0.1)	3.55	0.47	4.31	3.93	0.48	2.12	10.1	3.84	0.41	3.15	8.9
(0.01,0.1)	3.55	0.46	4.31	3.92	0.46	2.15	9.8	3.84	0.40	3.19	9.0
(0.1,0.1)	3.55	0.41	4.30	3.89	0.39	2.39	8.3	3.80	0.35	3.48	7.5
(0.0,0.5)	3.96	0.52	1.69	4.20	0.59	0.94	5.6	4.14	0.55	1.27	4.6
(0.01,0.5)	3.96	0.51	1.69	4.19	0.58	0.96	5.5	4.19	0.56	1.13	6.5
(0.1,0.5)	3.95	0.48	1.74	4.15	0.53	1.10	4.4	4.10	0.51	1.47	4.6

Table 8. Robustness II. Robustness to wage flexibility.											
Targeting rule with flexible wages (right)				Targeting rule with sticky wages (wrong)				Optimized Taylor-type rule with sticky wages (wrong)			
$(\lambda_{\widetilde{y}},\lambda_R)$	σ_π	$\sigma_{\widetilde{y}}$	σ_R	σ_π	$\sigma_{\widetilde{y}}$	σ_R	$\%\triangle L$	σ_π	$\sigma_{\widetilde{y}}$	σ_R	$\%\triangle L$
(0.0,0.0)	0.0	0.0	12.59	0.0	0.0	12.59	0.0	0.0	0.0	12.59	0.0
(0.01,0.0)	0.0	0.0	12.59	0.0	0.0	12.59	0.0	0.16	0.02	9.53	∞
(0.1,0.0)	0.0	0.0	12.59	0.0	0.0	12.59	0.0	0.35	0.05	7.78	∞
(0.0,0.1)	1.14	0.16	4.25	2.37	0.35	2.12	95.5	2.09	0.29	2.87	66.9
(0.01,0.1)	1.14	0.16	4.26	2.34	0.34	2.15	92.4	2.08	0.29	2.92	67.1
(0.1,0.1)	1.12	0.16	4.29	2.15	0.32	2.39	70.4	1.96	0.27	3.10	56.0
(0.0,0.5)	2.07	0.28	2.19	3.11	0.44	1.01	52.2	2.87	0.39	1.32	35.8
(0.01,0.5)	2.07	0.28	2.20	3.10	0.44	1.02	51.0	3.06	0.42	1.21	50.8
(0.1,0.5)	2.06	0.27	2.22	2.95	0.42	1.13	41.7	2.81	0.39	1.49	35.7

Table 9. Robustness III. Robustness to preferences without habit formation.											
Targeting rule with $h = 0.0$ (right)				Targeting rule with $h = 0.85$ (wrong)				Optimized Taylor-type rule with $h = 0.85$ (wrong)			
$(\lambda_{\widetilde{y}},\lambda_R)$	σ_π	$\sigma_{\widetilde{y}}$	σ_R	σ_π	$\sigma_{\widetilde{y}}$	σ_R	$\%\triangle L$	σ_π	$\sigma_{\widetilde{y}}$	σ_R	$\%\triangle L$
(0.0,0.0)	0.0	1.10	11.54	0.0	1.10	11.54	0.0	0.0	1.10	11.54	0.0
(0.01,0.0)	0.14	0.35	10.09	0.13	0.37	10.10	0.8	0.10	1.11	6.72	439
(0.1,0.0)	0.26	0.14	10.10	0.25	0.15	10.10	0.2	0.32	0.53	7.81	458
(0.0,0.1)	0.47	3.14	1.07	0.57	3.41	0.73	13.4	0.55	2.84	1.19	32.7
(0.01,0.1)	0.40	2.34	2.15	0.53	3.26	0.85	37.6	0.56	2.70	1.36	11.9
(0.1,0.1)	0.49	1.10	5.17	0.44	2.65	1.66	143	0.66	2.01	2.52	55.5
(0.0,0.5)	0.64	3.42	0.49	0.71	3.58	0.36	6.5	0.71	3.47	0.38	9.8
(0.01,0.5)	0.64	2.97	0.82	0.68	3.51	0.40	16.9	0.79	3.03	0.57	4.9
(0.1,0.5)	1.06	1.88	2.37	0.63	3.12	0.70	69.0	0.93	2.59	1.03	27.0

Table 10. Extensions I. Comparing the welfare-theoretic targeting rule with instrument rules.						
i) Welfare-theoretic targeting rule						
$(\lambda_\pi, \lambda_{\pi^W}, \lambda_{\widetilde{y}-\delta\widetilde{y}_{-1}})$	σ_π	σ_{π^W}	$\sigma_{\widetilde{y}-\delta\widetilde{y}_{-1}}$	$\sigma_{\widetilde{y}}$	σ_R	$\%\triangle\mathfrak{L}$
(0.47,0.53,0.13)	0.42	0.20	0.016	0.038	12.32	-
ii) Estimated Taylor-type rule						
(μ_1, μ_2, μ_3)	σ_π	σ_{π^W}	$\sigma_{\widetilde{y}-\delta\widetilde{y}_{-1}}$	$\sigma_{\widetilde{y}}$	σ_R	$\%\triangle\mathfrak{L}$
(0.47,0.13,0.53)	2.73	2.94	0.487	1.10	3.58	7931
iii) Optimized Taylor-type rule						
$(\mu_1^*, \mu_2^*, \mu_3^*)$	σ_π	σ_{π^W}	$\sigma_{\widetilde{y}-\delta\widetilde{y}_{-1}}$	$\sigma_{\widetilde{y}}$	σ_R	$\%\triangle\mathfrak{L}$
(0.0,147,2.55)	0.52	0.09	0.043	0.071	7.74	7.0
iv) Optimized Taylor-type rule with π_t^W (instead of $\widetilde{y}_t$)						
$(\mu_1^*, \mu_2^*, \mu_3^*)$	σ_π	σ_{π^W}	$\sigma_{\widetilde{y}-\delta\widetilde{y}_{-1}}$	$\sigma_{\widetilde{y}}$	σ_R	$\%\triangle\mathfrak{L}$
(52,108,1.15)	0.43	0.20	0.023	0.046	9.87	2.2
v) Optimized Taylor-type rule with coefficients ≤ 5.0						
$(\mu_1^*, \mu_2^*, \mu_3^*)$	σ_π	σ_{π^W}	$\sigma_{\widetilde{y}-\delta\widetilde{y}_{-1}}$	$\sigma_{\widetilde{y}}$	σ_R	$\%\triangle\mathfrak{L}$
(2.30,5.0,1.0)	0.44	0.22	0.053	0.088	6.95	16.9
vi) Optimized Taylor-type rule with π_t^W (instead of $\widetilde{y}_t$) and coefficients ≤ 5.0						
$(\mu_1^*, \mu_2^*, \mu_3^*)$	σ_π	σ_{π^W}	$\sigma_{\widetilde{y}-\delta\widetilde{y}_{-1}}$	$\sigma_{\widetilde{y}}$	σ_R	$\%\triangle\mathfrak{L}$
(5.0,5.0,0.96)	0.42	0.28	0.077	0.140	6.29	31.8

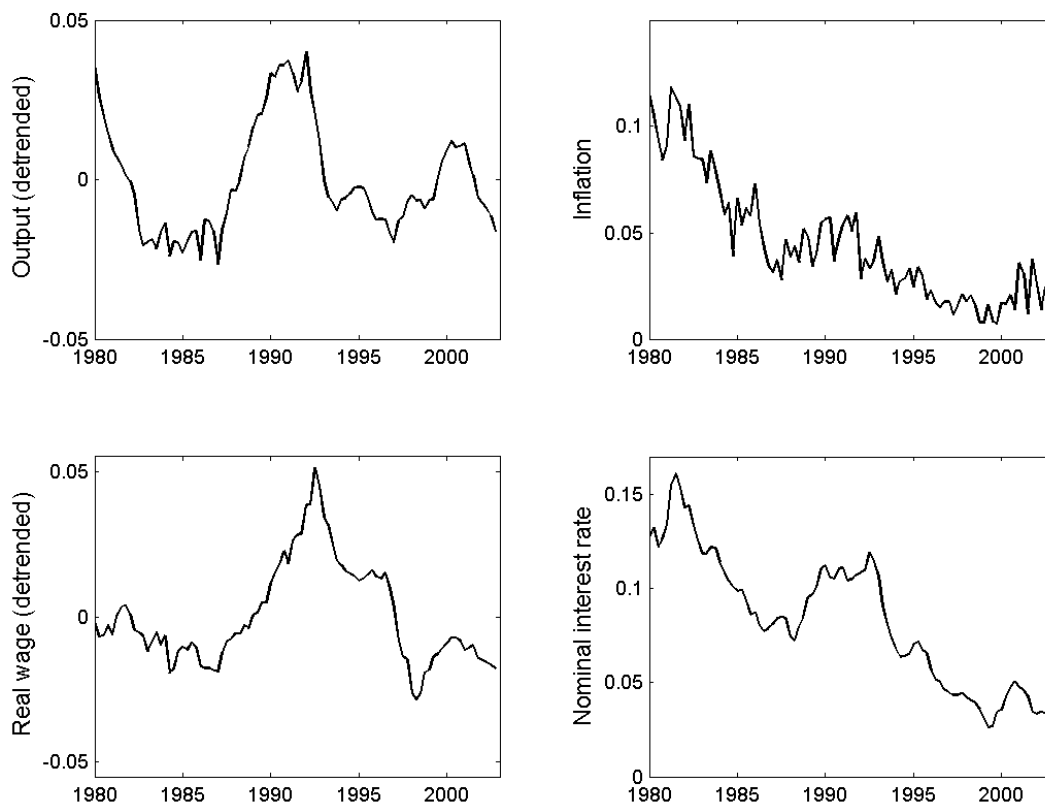| Table 11. Extensions II. Approximating the welfare-theoretic targeting rule with a stabilizing targeting rule.						
i) Welfare-theoretic targeting rule (18')						
$(\lambda_\pi, \lambda_{\pi^W}, \lambda_{\widetilde{y}-\delta\widetilde{y}_{-1}})$	σ_π	σ_{π^W}	$\sigma_{\widetilde{y}-\delta\widetilde{y}_{-1}}$	$\sigma_{\widetilde{y}}$	σ_R	$\%\triangle\mathfrak{L}$
(0.47,0.53,0.13)	0.42	0.20	0.016	0.038	12.32	-
ii) Stabilizing targeting rule (18)						
$(\lambda_{\widetilde{y}}, \lambda_R)$	σ_π	σ_{π^W}	$\sigma_{\widetilde{y}-\delta\widetilde{y}_{-1}}$	$\sigma_{\widetilde{y}}$	σ_R	$\%\triangle\mathfrak{L}$
(1.88,0.0)	0.43	0.19	0.010	0.025	12.80	2.6

Figure 1: Euro area data, 1980.1-2002.4. Output and the real wage are linearly detrended, whereas inflation and the nominal interest rate are the original series.
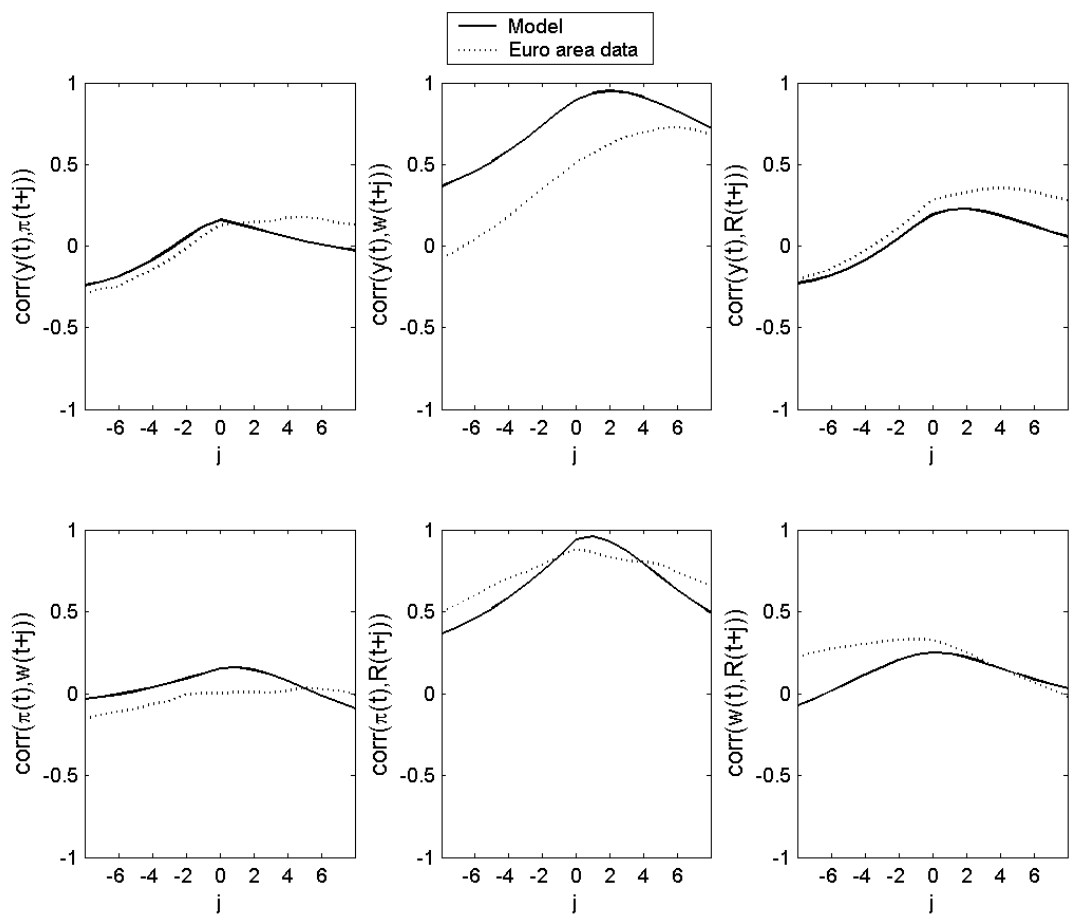
Figure 2: Model-to-data comparison. Correlation functions among output (y), inflation (π), the real wage (w), and the nominal interest rate (R). Eight-quarter (j) lag and lead.
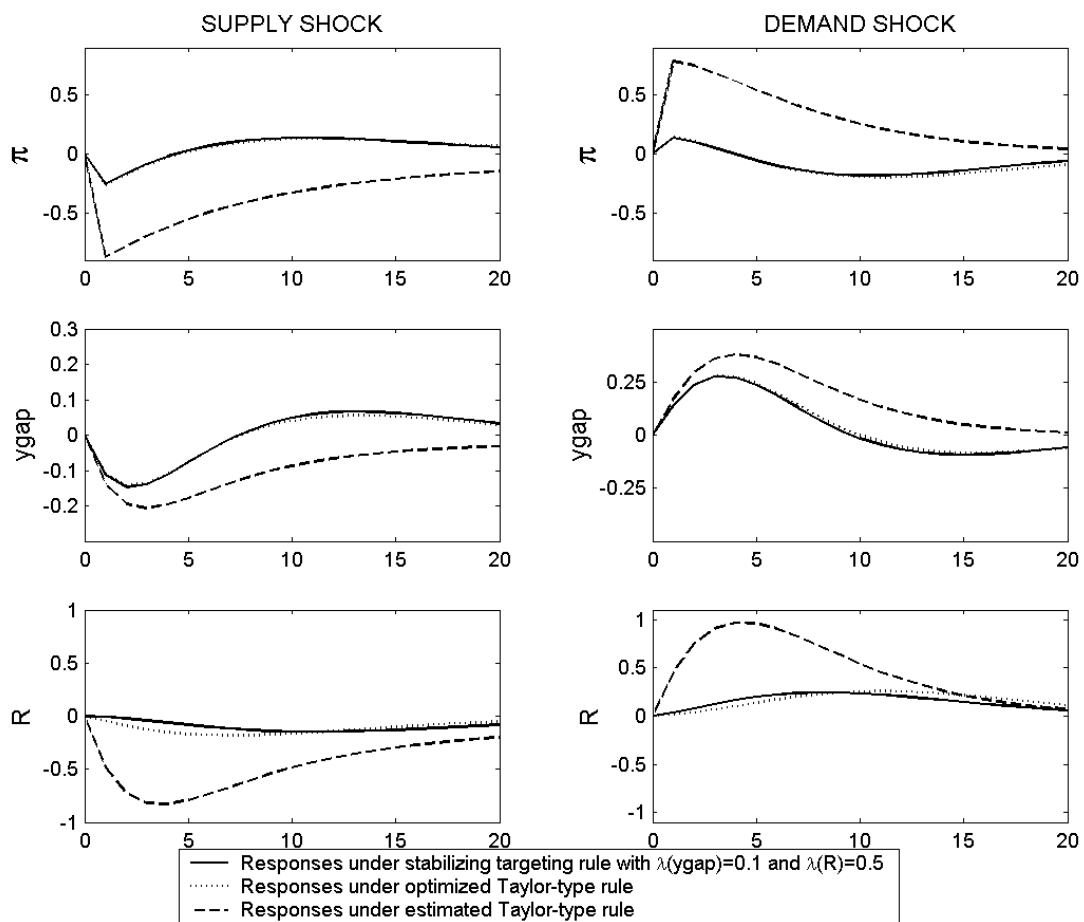
SUPPLY SHOCK   DEMAND SHOCK

Responses under stabilizing targeting rule with $\lambda(ygap)=0.1$ and $\lambda(R)=0.5$
Responses under optimized Taylor-type rule
Responses under estimated Taylor-type rule

Figure 3: Impulse response functions. Comparing a stabilizing targeting rule with Taylor-type instrument rules.

Figure 4: Impulse response functions. Comparing the welfare-theoretic targeting rule with Taylor-type instrument rules.

PUBLICACIONES DEL BANCO DE ESPAÑA

WORKING PAPERS[1]

0216 ALICIA GARCÍA HERRERO, JAVIER SANTILLÁN, SONSOLES GALLEGO, LUCÍA CUADRO AND CARLOS EGEA: Latin American Financial Development in Perspective.

0217 SONSOLES GALLEGO, ALICIA GARCÍA HERRERO AND JESÚS SAURINA: The Asian and European Banking Systems: The case of Spain in the Quest for Development and Stability.

0218 JOSÉ RAMÓN MARTÍNEZ RESANO Y LILIANA TOLEDO FALCÓN: Futuros sobre acciones: Demanda e implicaciones sobre los mercados de renta variable.

0219 JOSÉ MANUEL CAMPA AND JOSÉ M. GONZÁLEZ MÍNGUEZ: Differences in exchange Rate Pass-Through in the Euro Area.

0220 LUIS JULIÁN ÁLVAREZ GONZÁLEZ Y JAVIER JAREÑO MORAGO: ISIS, Un indicador sintético integral de los servicios de mercado.

0221 MARCO HOEBERICHTS: The Credibility of Central Bank Announcements.

0222 KLAUS DESMET: Asymmetric Shocks, Risk Sharing, and the Latter Mundell.

0223 JOSÉ MANUEL CAMPA AND IGNACIO HERNANDO: Value creation in European M&As.

0224 JUAN AYUSO HUERTAS, DANIEL PÉREZ CID AND JESÚS SAURINA SALAS: Are capital buffers pro-cyclical? Evidence from Spanish panel data.

0225 ANDREW BENITO: Does job insecurity affect household consumption?

0226 ANDREW BENITO: Financial pressure, monetary policy effects and inventory adjustment by UK and Spanish firms.

0227 ANDREW BENITO AND IGNACIO HERNANDO: Extricate: Financial Pressure and Firm Behaviour in Spain.

0228 ANA DEL RÍO, El endeudamiento de los hogares españoles.

0229 GABRIEL PÉREZ QUIRÓS AND JORGE SICILIA: Is the European Central Bank (and the United States Federal Reserve) predictable?

0301 JAVIER ANDRÉS, EVA ORTEGA AND JAVIER VALLÉS: Market structure and inflation differentials in the European Monetary Union.

0302 JORDI GALÍ, MARK GERTLER AND J. DAVID LÓPEZ-SALIDO: The euro area inefficiency gap.

0303 ANDREW BENITO, The incidence and persistence of dividend omissions by Spanish firms.

0304 JUAN AYUSO AND FERNANDO RESTOY: House prices and rents: an equilibrium asset pricing approach.

0305 EVA ORTEGA, Persistent inflation differentials in Europe.

0306 PEDRO PABLO ÁLVAREZ LOIS: Capacity utilization and monetary policy.

0307 JORGE MARTÍNEZ PAGÉS AND LUIS ÁNGEL MAZA: Analysis of house prices in Spain. (The Spanish original of this publication has the same number).

0308 CLAUDIO MICHELACCI AND DAVID LÓPEZ-SALIDO: Technology shocks and job flows.

0309 ENRIQUE ALBEROLA: Misalignment, liabilities dollarization and exchange rate adjustment in Latin America.

0310 ANDREW BENITO: The capital structure decisions of firms: is there a pecking order?

0311 FRANCISCO DE CASTRO: The macroeconomic effects of fiscal policy in Spain.

0312 ANDREW BENITO AND IGNACIO HERNANDO: Labour demand, flexible contracts and financial factors: new evidence from Spain.

0313 GABRIEL PÉREZ QUIRÓS AND HUGO RODRÍGUEZ MENDIZÁBAL: The daily market for funds in Europe: what has changed with the EMU?

0314 JAVIER ANDRÉS AND RAFAEL DOMÉNECH: Automatic stabilizers, fiscal rules and macroeconomic stability

0315 ALICIA GARCÍA HERRERO AND PEDRO DEL RÍO: Financial stability and the design of monetary policy.

0316 JUAN CARLOS BERGANZA, ROBERTO CHANG AND ALICIA GARCÍA HERRERO: Balance sheet effects and the country risk premium: an empirical investigation.

0317 ANTONIO DÍEZ DE LOS RÍOS AND ALICIA GARCÍA HERRERO: Contagion and portfolio shift in emerging countries' sovereign bonds.

0318 RAFAEL GÓMEZ AND PABLO HERNÁNDEZ DE COS: Demographic maturity and economic performance: the effect of demographic transitions on per capita GDP growth.

0319 IGNACIO HERNANDO AND CARMEN MARTÍNEZ-CARRASCAL: The impact of financial variables on firms' real decisions: evidence from Spanish firm-level data.

---

1. Previously published Working Papers are listed in the Banco de España publications calalogue.

0320 JORDI GALÍ, J. DAVID LÓPEZ-SALIDO AND JAVIER VALLÉS: Rule-of-thumb consumers and the design of interest rate rules.

0321 JORDI GALÍ, J. DAVID LÓPEZ-SALIDO AND JAVIER VALLÉS: Understanding the effects of government spending on consumption.

0322 ANA BUISÁN Y JUAN CARLOS CABALLERO: Análisis comparado de la demanda de exportación de manufacturas en los países de la UEM.

0401 ROBERTO BLANCO, SIMON BRENNAN AND IAN W. MARSH: An empirical analysis of the dynamic relationship between investment grade bonds and credit default swaps.

0402 ENRIQUE ALBEROLA AND LUIS MOLINA: What does really discipline fiscal policy in emerging markets? The role and dynamics of exchange rate regimes.

0403 PABLO BURRIEL-LLOMBART: An economic analysis of education externalities in the matching process of UK regions (1992-1999).

0404 FABIO CANOVA, MATTEO CICCARELLI AND EVA ORTEGA: Similarities and convergence in G-7 cycles.

0405 ENRIQUE ALBEROLA, HUMBERTO LÓPEZ AND LUIS SERVÉN: Tango with the gringo: the hard peg and real misalignment in Argentina.

0406 ANA BUISÁN, JUAN CARLOS CABALLERO Y NOE LIA JIMÉNEZ: Determinación de las exportaciones de manufacturas en los países de la UEM a partir de un modelo de oferta-demanda.

0407 VÍTOR GASPAR, GABRIEL PÉREZ QUIRÓS AND HUGO RODRÍGUEZ MENDIZÁBAL: Interest rate determination in the interbank market.

0408 MÁXIMO CAMACHO, GABRIEL PÉREZ-QUIRÓS AND LORENA SAIZ: Are European business cycles close enough to be just one?

0409 JAVIER ANDRÉS, J. DAVID LÓPEZ-SALIDO AND EDWARD NELSON: Tobin's imperfect assets substitution in optimizing general equilibrium.

0410 A. BUISÁN, J. C. CABALLERO, J. M. CAMPA Y N. JIMÉNEZ: La importancia de la histéresis en las exportaciones de manufacturas de los países de la UEM.

0411 ANDREW BENITO, FRANCISCO JAVIER DELGADO AND JORGE MARTÍNEZ PAGÉS: A synthetic indicator of financial pressure for Spanish firms.

0412 JAVIER DELGADO, IGNACIO HERNANDO AND MARÍA J. NIETO: Do European primarily Internet banks show scale and experience efficiencies?

0413 ÁNGEL ESTRADA, JOSÉ LUIS FERNÁNDEZ, ESTHER MORAL AND ANA V. REGIL: A quarterly macroeconometric model of the Spanish economy.

0414 GABRIEL JIMÉNEZ AND JESÚS SAURINA: Collateral, type of lender and relationship banking as determinants of credit risk.

0415 MIGUEL CASARES: On monetary policy rules for the euro area.