Simple Price-Level-Targeting versus Inflation-Targeting Monetary Policy Rules under Model Uncertainty

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Abstract

This paper compares the performance and robustness of simple price-level-targeting (PLT) and inflation-targeting (IT) monetary policy rules in three non-nested models of the euro area. Taking advantage of the expectations channel, PLT outperforms IT in two out of the three models. However, the quantitative difference in the stabilization performance of the two types of policy rules is generally small. Optimal model-specific rules of both classes are not robust to model uncertainty but by taking a Bayesian policy approach it is possible to identify rules that perform well across all three models. While the Bayesian PLT and IT rules exhibit similar stabilization outcomes, minor perturbations in the policy parameters can lead to indeterminacy under IT.

Keywords: Monetary policy, Optimal simple rules, Price-level targeting, Model uncertainty

JEL-Codes: E31, E52, E58, E61

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1 Introduction

In stylized modern monetary models with forward-looking agents, a price-level-targeting (PLT) strategy can improve the tradeoff between output and inflation stabilization relative to inflation targeting (IT). This result from economic theory stands in sharp contrast to current monetary policymaking used in practice. No central bank is currently pursuing an explicit price-level-targeting strategy and only the Bank of Canada is considering the possibility of doing so (Bank of Canada, 2006).

Since experimenting with policies in actual economies usually is prohibitively expensive (Lucas, 1980), a key drawback of price-level targeting is the lack of modern practical experience with such a strategy. Operating experience dates back to the 1930s when stabilization of the price level was the official goal of the Swedish monetary policy, see Berg and Jonung (1999).

Instead, policymakers can use quantitative monetary models as laboratories to evaluate the performance of alternative monetary policy strategies. Thinking about these strategies in terms of alternative policy rules, the policymaker chooses the rule that is optimal from the perspective of her objective function. However, policymakers are confronted with a wide range of competing models that may lead to different recommendations for the conduct of monetary policy. A particular policy rule might perform well in one macroeconomic model but lead to poor results in a different model. Hence, a responsible policymaker searches for a monetary policy rule that performs well across a variety of empirically plausible macroeconomic models, that is, a rule that is robust to model uncertainty.[1]

Specifically, today's policymakers are likely to refrain from implementing a PLT strategy unless more evidence is presented on whether the gains from PLT are robust to a range of alternative modeling assumptions and paradigms.[2]

The purpose of this paper is to contribute to this objective. We compare the performance of PLT and IT rules moving beyond the standard New Keynesian model to more elaborated medium-size models. We then evaluate the robustness of PLT rules and IT rules under model uncertainty.

In the standard New Keynesian benchmark model, price-level targeting outperforms inflation targeting under optimal discretionary policy (Vestin, 2006) and under optimized simple rules (Giannoni,

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[1] Previous work by Levin and Williams (2003), among others, has shown that the degree of model uncertainty is quite enormous and would be understated when restricting the analysis to specification errors or parameter uncertainty in the neighborhood of a particular benchmark model.

[2] See Kahn (2009) and Deutsche Bundesbank (2010) for a similar argument.

2010). Price-level targeting makes monetary policy history dependent, which allows the policymaker to steer private sector expectations more effectively. Specifically, an unexpected rise in inflation that leads to a price level above the price-level-path target fosters the policymaker to stabilize inflation below trend in the following periods, so that the price level returns to its target path. To the extent that current inflation depends on expected future inflation, the expected below-trend future inflation dampens the impact on current inflation.[3]

The literature on robust monetary policy under model uncertainty, however, has focused mainly on a class of instrument rules that relate the short-term nominal interest rate to the inflation rate, the output gap and the lagged interest rate, see Levin et al. (1999, 2003), Levin and Williams (2003), Adalid et al. (2005), Taylor and Wieland (2009) and Kuester and Wieland (2010).[4] These studies have established some important insights such as that rules optimized for a single reference model may perform poorly in competing models, but that it is possible to find simple policy rules that exhibit good operating characteristics across a wide range of structural models. In addition, as shown by Levin et al. (1999), more complicated rules often provide only small performance improvements and tend to be less robust to model uncertainty. In line with this result our analysis focuses on simple feedback rules.[5]

We follow the standard approach in the literature in assuming that monetary policy is delegated to a policymaker, whose objective is to minimize the weighted sum of the unconditional variances of the inflation rate, the output gap and the change in the nominal interest rate. Optimal response coefficients of simple PLT and IT interest rate rules are determined in each model and the performance of these rules is evaluated in the rule-generating model, as well as across competing models.

More specifically, we employ three alternative macroeconomic models of the euro area: the area-wide (AW) model of Fagan et al. (2005), the euro area model of Coenen and Wieland (2005) (CW), and the dynamic stochastic general equilibrium model of Smets and Wouters (2003) (SW).[6] These

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[3] In the standard New Keynesian model history dependence is also a characteristic of optimal monetary policy under commitment, see Clarida et al. (1999) and Woodford (2003).

[4] Exceptions are Jaeaeskelae (2005) and Cateau (2008), who compare the performance and robustness of PLT and IT instrument rules. In contrast to this paper, the analysis of Jaeaeskelae (2005) focuses on the standard hybrid New Keynesian model and uncertainty is restricted to the degree of inflation persistence. Cateau (2008) uses the Terms-of-Trade Economic Model of the Bank of Canada and evaluates the performance of PLT if the correct model is a robust control version of ToTEM.

[5] See Taylor and Williams (2010) for a recent review of simple rules for monetary policy.

[6] All three models are listed as “Macroeconomic models of the euro area” on the ECB’s webpage, see www.ecb.int/home/html/researcher.en.html.

models differ along a number of dimensions including their size and the type of employed frictions. In particular, they vary in the weight assigned to forward-looking behavioral elements. Such forward-looking elements play only a minor role in the AW model but become crucial in the SW model. The CW model represents an in-between setting, exhibiting forward- and backward-looking behavioral elements.

We find that in the SW and CW models PLT outperforms IT, whereas IT provides superior stabilization policy in the AW model. The quantitative difference in the stabilization performance of the two types of policy rules is generally small. After introducing model uncertainty, it is shown that model-specific optimized IT and PLT rules can perform poorly in competing models.

Taking a Bayesian policy approach, we identify rules that perform well across models. While the policymaker prefers the Bayesian PLT rule over the Bayesian IT rule for the considered set of models, both types of rules exhibit rather similar stabilization outcomes. However, if we allow for small perturbations in the policy parameters, the Bayesian IT rule can lead to indeterminacy, whereas the PLT rule continues to perform well.

The remainder of the paper proceeds as follows. Section 2 describes the main characteristics of the three euro area models and documents differences in the monetary transmission mechanism. Section 3 determines optimized simple IT and PLT rules and compares their stabilization performance. In section 4, model uncertainty is introduced and the model-specific optimized rules are evaluated in competing models. Section 5 takes a Bayesian approach to identify robust IT and PLT rules and evaluates their performance and fault tolerance. Finally, section 6 summarizes the results.

2 Three Competing Models of the Euro Area

Each of the three considered models features nominal rigidities and claims to represent the dynamic behavior of the euro area economy. Nevertheless, these models differ in terms of the role of forward-looking behavioral elements, the richness of dynamics and adjustment costs, and other structural characteristics, possibly exhibiting different implications for monetary policy.[7]

The SW model is a medium-scale New Keynesian dynamic stochastic general equilibrium model with

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[7] Code for all three models is available in a macroeconomic model data base created by Wieland et al. (2009).

various frictions. On the household side, a representative agent maximizes lifetime utility consisting of two arguments, consumption and leisure, where external habit formation in consumption is added. Firms produce differentiated intermediate goods using a Cobb-Douglas production technology and sell them to a competitive final-goods sector. Price stickiness à la Calvo is augmented by partial indexation of prices to past inflation rates for those firms that are not allowed to reoptimize their price in a given period. Labor is differentiated over households, implying some monopoly power of the households over wages. Nominal wages are assumed to be sticky à la Calvo augmented also by partial indexation. Model dynamics are driven by ten orthogonal structural shocks, three preference shocks, two technology shocks, three cost-push shocks and two monetary policy shocks. It has been estimated by Smets and Wouters (2003) using Bayesian techniques on a quarterly euro area data set consisting of seven key macroeconomic variables over the period 1970:1 to 1999:4.

The CW model introduces staggered pricing by employing the nominal contract specification of Taylor (1980). The aggregate demand equation is backward looking, consisting of two lags in aggregate demand and one lag in the long-term real interest rate. The latter is related to the long term nominal interest rate via the Fisher equation. Due to price and wage staggering à la Taylor, inflation follows a hybrid process, depending on its own leads and lags and on the output gap. The dynamics of the model are driven by a demand shock, a contract wage shock and a monetary policy shock. It has been estimated by Coenen and Wieland (2005) on data from the ECB area wide model data set for 1974:1 to 1998:4, using GMM as well as limited information indirect inference techniques.

The AW model has been one of the first models that treated the euro area as a single economy. The linearized version used in this paper originates from Dieppe et al. (2005). It is an open economy model with largely backward-looking expectation formation mechanisms. In the short run, activity is demand-determined, whereas the supply side drives the long run dynamics. Overall demand is disaggregated into private consumption, government consumption, investment, variation of inventories and net exports. The change in the investment/output ratio represents the main channel through which monetary policy affects aggregate demand. Model dynamics are driven by eleven different shocks.

Next, we address the question whether the observed differences in the three models have implications for the transmission of monetary policy. For this purpose it is assumed that monetary policy follows the interest rate rule of Gerdesmeier and Roffia (2004) estimated for the euro area:

$$i_t = 0.66 i_{t-1} + 0.68 \tilde{\pi}_t + 0.10 x_t, \tag{1}$$

where i_t is the annualized short-term nominal interest rate set by the central bank, $\tilde{\pi}_t$ is the year-on-year inflation rate which can be expressed in terms of the annualized quarter-to-quarter inflation rate, π_t, as $\tilde{\pi}_t = \frac{1}{4} \sum_{s=0}^{3} \pi_{t-s}$, and x_t denotes the output gap. The rule has been estimated with monthly data and is transformed to quarterly frequency. Figure 1 plots impulse responses for annual inflation, the output gap and the short-term nominal interest rate to a unit monetary policy shock in the three euro area models. In all three models the interest rate increases by nearly 100 basis points and then gradually decreases to zero over the next five quarters. Comparing the impulse responses of inflation and the output gap across the three models, one observes severe differences in size and persistence. For annual inflation, the peak effect can be observed after around five quarters in the SW and the CW model, whereas it takes much longer and is notedly larger in the AW model. The response of the output gap is longer-lasting in the AW model than in the SW model, whereas the size of the response in the CW model is much lower than in the other two models. Apparently, the three analyzed models do not allow for a unitary view of the euro area monetary transmission mechanism and in that sense should indeed be interpreted as competing models.[8]

3 Optimized Simple Monetary Policy Rules

Similar to the estimated policy rule of Gerdesmeier and Roffia (2004), the literature on optimized simple rules in medium- and large-scale models has mostly focused on specifications in which the short-term nominal interest rate responds to inflation, the output gap and prevalently the lagged interest rate:

$$i_t = \rho_\pi i_{t-1} + \alpha_\pi \tilde{\pi}_t + \beta_\pi x_t. \tag{2}$$

All variables are expressed in percentage deviations from steady state. The parameters α_π and β_π represent the central bank's short-term response coefficients to inflation and the output gap, respectively,

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[8] Adalid et al. (2005) come to a similar result when using the Taylor (1993) rule.

and ρ_π determines the degree of interest-rate smoothing. While it has become standard in the literature on robust monetary policy rules to employ the year-on-year inflation rate, as a sensitivity check we also evaluate the performance of optimized rules that employ the annualized quarter-to-quarter inflation rate instead.[9]

The IT policy rule (2) can be compared to a PLT policy rule:

$$i_t = \rho_p i_{t-1} + \alpha_p p_t + \beta_p x_t, \tag{3}$$

where p_t denotes the deviation of the actual price level from its target. The inclusion of the price level into the policy rule adds an element of history dependence. A failure to hit the price level target in period $t-1$ will not become irrelevant for policy in period t. Rather, the central bank sets the interest rate in period t such that it can expect to redeem the deviation of the previous period. Thus, a PLT policy rule gives the central bank additional power to manage expectations of rational, forward-looking agents.[10]

In order to evaluate the stabilization performance of the two classes of policy rules introduced above, we assume that the policymaker minimizes the weighted sum of the unconditional variances of annualized quarterly inflation, the output gap, and changes in the annualized short-term nominal interest rate:

$$L = Var\left(\pi_t\right) + \lambda Var\left(x_t\right) + \mu Var\left(\Delta i_t\right), \tag{4}$$

subject to either the IT rule or the PLT rule, and the other model equations, through the choice of the policy rule parameters. Here, $\Delta i_t \equiv i_t - i_{t-1}$. The parameters $\lambda > 0$ and $\mu > 0$ represent the policymaker's preferences for reducing the variability of the output gap and of changes in the interest rate relative to inflation variability, respectively. Since there is no consensus in the literature on the correct order of magnitude of λ, we consider values of $\lambda \in \{0.1, 0.5, 1\}$ representing a wide range

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[9] Levin et al. (1999) consider four alternative macroeconomic models of the US economy and show that in each of them the optimized policy rule that incorporates the four-quarter average inflation rate dominates the rule that incorporates the quarter-to-quarter inflation rate even though the policymaker's objective is to stabilize the latter.

[10] Strictly speaking, average-inflation targeting also introduces history dependence. Consider a two-period average inflation rate entering the policy rule. A one-period inflation rate above target in period t forces the policymaker to aim for an inflation rate below target in the subsequent period. Inflation expectations of forward-looking agents will thus fall, thereby mitigating the initial impact of the inflationary shock. Nessen and Vestin (2005) show that when the Phillips curve has forward-looking elements, average inflation targeting improves the policymaker's short-run tradeoff compared to one-period inflation targeting.

of possible preferences. The weight on the variability of the change in the interest rate is fixed at $\mu = 0.1$, a value that has been widely used in similar exercises.

Table 1 reports the optimized response coefficients under the two different classes of monetary policy rules for the three euro area models and table 2 lists the corresponding unconditional variances of annualized quarter-to-quarter inflation, the output gap and the change in the interest rate under each rule. The upper panel of both tables reports the results for the IT rules and the lower panel for the PLT rules.[11]

We observe several similarities between both types of optimized rules. For all three models, under both classes of rules, the response coefficient to inflation / the price level is decreasing and the response coefficient to the output gap is increasing with rising weight on the output gap, λ, in the policymaker's loss function. Furthermore, if $\lambda > 0.1$, the size of the response coefficient to the output gap, β_j, $j \in \{\pi, p\}$, in a particular model is relatively similar under the optimized IT and PLT rule for a given output gap weight in the loss function. The size of the interest-rate-smoothing parameter is smaller in the more backward-looking model than in the forward-looking models for both classes of policy rules. In the case of the SW model the optimized coefficient equals 1, suggesting that a first-difference rule is optimal. This result concurs with the finding of Levin et al. (1999) that first-difference rules perform quite well in a relatively wide range of rational expectations models. Interestingly, the optimality of a coefficient of unity on the lagged interest rate in the SW model also holds true for the PLT rule. In this regard, the optimal simple PLT rule in the SW model is similar to the "quasi-optimal" PLT rule proposed by Giannoni (2010), a slightly simplified version of the rule that implements the optimal commitment solution in the standard New Keynesian model. More generally, in all three models the role of the lagged interest rate does not deteriorate once one considers PLT policy rules.

Comparing the policymaker's loss, L, under the optimized IT and PLT rules for a given model and a given weight on the output gap, we observe that in the SW model and in the CW model the rule reacting to changes in the price level dominates the rule reacting to changes in the inflation rate. In contrast, in the backward-looking AW model the optimal simple IT rule outperforms the optimal simple PLT rule. Hence, the improved tradeoff between inflation and output stabilization under a price-level targeting regime in the standard New Keynesian model continues to hold when one moves to a more

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[11] Optimized IT rules for all three models have been considered previously by Adalid et al. (2005) and Kuester and Wieland (2010).

elaborated DSGE model like the one of Smets and Wouters (2003). In addition, price-level targeting can also dominate inflation targeting in models that are not based on rigorous microfoundations.[12] Here, the outcome seems to depend on the weight assigned to forward-looking behavioral elements. If agents are mainly backward looking, as in the AW model, then an IT rule may lead to better outcomes because the expectations channel of history-dependent monetary policy shuts down. However, in general, the differences in the performance of the optimized IT and PLT rules remain modest.[13] For instance, in the case of $\lambda = 0.1$, the gain from PLT compared to IT measured in terms of the equivalent change in the unconditional standard deviation of inflation amounts to 0.033 percentage points (pp) in the SW model, 0.021 pp in the CW model and -0.024 pp in the AW model, respectively. Table 3 reports the results for the case of annualized quarter-to-quarter inflation entering the IT rule. Similar to the results of Levin et al. (1999) we find that this type of IT rule is dominated by IT rules that employ the annual inflation rate instead.

4 The Performance of Optimized Rules under Model Uncertainty

Next, we analyze to what extent rules optimized for a given reference model of the euro area are robust to model uncertainty and whether there are differences between the two considered types of rules. Specifically, the degree of robustness of a rule optimized for a given model X is analyzed by evaluating the performance of this policy rule in a competing model Y. If a policy rule optimized for model X also performs reasonably well in competing models, then this policy rule is argued to be robust.

Table 4 reports the results of this comparison exercise. Each optimized rule identified in the previous section is evaluated in the two competing models of the euro area by determining the implied policymaker's loss. Beginning with the rules optimized for the SW model, we observe that they perform reasonably well in the CW setting. For instance, in the case of $\lambda = 0.5$, the policymaker's loss in the CW model amounts to 3.01 under the optimal IT-SW rule and to 2.93 under the optimal PLT-SW

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[12] See also Williams (2003) who finds that in the large-scale FRB/US model already for moderate output weights in the policymaker's loss function a simple PLT rule is superior to a simple IT rule which responds to the annual inflation rate in stabilizing inflation and output.

[13] Kryvtsov et al. (2008) come to a similar result when comparing PLT and IT under discretion in the standard New Keynesian model. In contrast, Cateau (2008) finds relatively large differences in the stabilization performance of PLT rules and IT rules in the Bank of Canada's ToTEM model.

rule, reflecting in each case a loss increase of eleven percent compared to the model-specific optimal rule of the respective type. For all three values of λ, the PLT-SW rule dominates the IT-SW rule in the CW model. However, the SW rules lack robustness with respect to the AW model. Under the IT rule there is no stable equilibrium for the case of $\lambda = 0.1$, while under the PLT rule the central bank's loss is tremendous, being 497 percent higher than under the optimal AW-PLT rule. For higher values of λ unique equilibria exist and the relative performance measure improves, but losses are still fairly large. Interestingly, while the optimal model-consistent AW-IT rule dominates the corresponding PLT rule, this does not hold once one considers the SW rules. In fact, for all three values of λ considered in the exercise, the PLT-SW rule outperforms the IT-SW rule in the AW model.

Turning to the evaluation of the rules optimized for the CW model, table 4 documents that the SW model exhibits only minor additional losses under the CW rules compared to the optimal model-consistent rules. Furthermore, in the SW model the PLT-CW rules outperform the IT-CW rules. Like the SW rules, the CW rules fail to establish robustness with respect to the AW model for $\lambda = 0.1$. However, for higher values of λ the performance under the CW rules improves compared to the performance under the SW rules. The policymaker's loss is now only between 30 and 35 percent higher than under the optimal model-specific rule. In all cases, the IT-CW rules dominate the PLT-CW rules in the AW model.

Finally, the AW rules are shown to perform fairly well in the SW and CW settings with losses never exceeding the benchmark loss by more than 25 percent. In both models there are only minor differences in the performance of PLT-AW and IT-AW rules.

Overall, in the majority of cases the PLT rules optimized for a certain model lead to better outcomes in the competing models than the corresponding IT rules, however, in many cases the difference in the loss implied by the IT rule and the respective PLT rule is relatively small. Those models, admitting a non-negligible role for forward-looking behavior, seem to be less prone to disastrous outcomes in response to deviations from the optimal rule than the models that exhibit predominantly backward-looking behavior.

5 Robust Monetary Policy under Model Uncertainty

Until now, the design of the optimized rules has relied on a single reference model, respectively. This section determines robust simple rules taking model uncertainty explicitly into account. We then evaluate the performance of these rules in the case of small perturbations to the optimized policy rule parameters.

5.1 Designing Robust Rules

We assume that the policymaker takes a Bayesian perspective on the design of robust rules. Following Levin, Wieland and Williams (1999, 2003), the central bank aims to minimize a weighted sum of the losses from the individual models, where the weights represent her priors over these models:

$$\tilde{L} = \omega_{SW} L_{SW} + \omega_{CW} L_{CW} + \omega_{AW} L_{AW}, \tag{5}$$

where L_i denotes the policymaker's loss realized in model i, $i \in \{SW, CW, AW\}$, and ω_i is the weight attached to that model. Here, we assume that the policymaker has flat priors over the three models, $\omega_{SW} = \omega_{CW} = \omega_{AW} = \frac{1}{3}$. The problem is solved numerically via grid search. Table 5 reports the results when the policymaker minimizes the aggregated loss $\tilde{L}$ by choosing the interest rate response coefficients of IT and PLT types of rules. Columns 3 to 5 list the optimized policy parameters, column 6 reports the aggregated loss and columns 7 to 9 report the model-specific losses under the respective robust benchmark rule.

The Bayesian robust IT rules are characterized by a response coefficient to the lagged interest rate in the narrow range from 0.62 to 0.64, being close to the value of 0.66 showing up in the estimated Gerdesmeier-Roffia rule. Response coefficients to inflation and the output gap range from 0.41 to 0.79 and 1.04 to 2.80, respectively. Corresponding coefficients to the lagged interest rate and the output gap in the Bayesian robust PLT rules are relatively similar to those under the IT rules. For the price level, the response coefficient varies between 0.11 and 0.14.

Comparing the model-specific losses under the Bayesian robust rule with those obtained under the model-specific optimal rule, one observes that the costs of achieving robustness are in fact very small under both types of rules, i.e. IT and PLT rules. The percentage increase in the loss compared to the optimal simple rule (IT for the AW model, PLT for the SW and CW model) always remains below 16 percent in case of the IT rules, and below 10 percent in case of the PLT rules. In the SW model and the CW model the Bayesian robust PLT rule performs slightly better than the Bayesian robust IT rule, while the opposite holds true in the AW model.

The aggregate loss is somewhat lower in case of the Bayesian robust PLT rule than under the IT rule. Hence, given her priors over the models, the policymaker would prefer the PLT rule, however, the quantitative difference in the aggregated losses is small. Similarly, if we compare the performance of the Bayesian IT and PLT rules in each of the three models, we observe that the change in the unconditional standard deviation of inflation equivalent to the difference in the policymaker's loss under IT and PLT never exceeds 0.04 percentage points.

5.2 Policy Rule Fault Tolerance

We now examine whether small perturbations of the Bayesian rules still exhibit a near-optimal stabilization performance under both types of monetary policy regimes. Since simple policy rules in practice are only used as guidelines, small persistent deviations from the policy prescribed by a particular rule may easily happen. In order to address this question, we employ fault tolerance analysis. Following Kuester and Wieland (2010), the fault tolerance of a policy rule is studied by evaluating the performance implications of deviations for each policy rule parameter from its optimized value, holding the other parameters constant, respectively. A policy rule is fault tolerant if small variations in its policy parameters have no significant impact on its stabilization performance across the set of macroeconomic models. Arguably one would want a rule used for the conduct of monetary policy in practice to possess this attribute. Figure 2 displays the fault tolerance of the Bayesian rules in the case of $\lambda = 1$. Specifically, we plot the percentage increase in the policymaker's loss compared to the outcome when all parameters are set to their model-specific optimal value. The benchmark value of the policy rule parameter is marked by a solid vertical line, respectively. We find that the Bayesian PLT rule (right column) is reasonably robust to deviations in each of the three policy rule parameters. Small perturbations do neither lead to surges in the central bank's loss nor to indeterminacy. In contrast, fault tolerance analysis of the IT rule (left column) draws a markedly different picture. Already minor deviations in either the coefficient on the lagged interest rate or the coefficient on inflation lead to indeterminacy in the CW model. Clearly, the Bayesian IT rule lacks stability robustness. To get some intuition it is useful to determine the long-run response coefficient to inflation $\overline{\alpha}_{\pi} \equiv \frac{\alpha_{\pi}}{1-\rho_{\pi}}$. For the Bayesian IT rule $\overline{\alpha}_{\pi} = 1.14$. Therefore, slightly smaller responses to the lagged interest rate or to the inflation rate lead to long-run response coefficients to inflation below 1, violating the generalized Taylor principle.[14]

Assuming that a desirable monetary policy rule should be immune to minor deviations in its parameters, we conclude that only the Bayesian PLT rule succeeds in guaranteeing a reasonable stabilization performance for the considered set of models.

6 Conclusion

We compare the performance and robustness of simple PLT and IT rules across three distinct macroeconomic models of the euro area.[15] Assuming that the policymaker chooses policy rule parameter values that minimize the weighted sum of the unconditional variances of inflation, the output gap, and changes in the short-term nominal interest rate, we find that in the SW model and in the CW model optimized model-specific PLT rules perform better than the corresponding IT rules. On the other hand, the IT rule dominates PLT in the primarily backward-looking AW model. While the three models differ along several dimensions, the fact that in models with non-negligible forward-looking behavioral elements history dependence enables policymakers to steer private agents' expectations more effectively is likely to contribute to the results. If the expectations channel is shut down due to largely backward-looking dynamics, PLT loses its advantage over IT. However, the quantitative difference in the performance of the two types of rules turns out to be rather small in all three models. Since in practice policymakers do not know the true model of the euro area, we continue to evaluate the performance of these optimized rules under model uncertainty. We find that neither the IT rules nor the PLT rules are necessarily robust. We therefore move to a Bayesian policy approach to design

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[14] The Bayesian IT rules for $\lambda = 0.1$ and $\lambda = 0.5$ are less prone to indeterminacy because of a larger long-run response coefficient to inflation. Note, however, that a relative weight on output gap stabilization of $\lambda = 1$ is not inordinately large. If we express the loss function in terms of non-annualized inflation and interest rates, this corresponds to a relative output gap weight of $1/16$.

[15] Additional aspects not considered in this paper may be relevant for a comparison of PLT and IT rules. For instance Gaspar et al. (2007) consider PLT in a model with learning, Kryvtsov et al. (2008) examine gains from switching to PLT under imperfect credibility, Walsh (2009) discusses the performance of PLT in the presence of the zero lower bound on the nominal interest rate.

rules that perform well across all three models. The costs of following these Bayesian rules in terms of stabilization performance turn out to be low. For the considered set of models the policymaker prefers the PLT rule but the quantitative difference in performance might be too small in order to convince central banks to abandon a well-established inflation-targeting strategy in favor of a not yet approved price-level target. However, fault tolerance analysis reveals that the Bayesian IT rule lacks stability robustness. Already very small perturbations in the policy parameters can lead to indeterminacy. In contrast, the Bayesian robust PLT rule remains potent in stabilizing the economy.

In summary, our model-based experiments suggest that the performance of PLT is robust to a range of alternative model assumptions. PLT continues to be superior to IT when we move from the standard New Keynesian model to medium-size forward-looking sticky-price models. Furthermore, even in elaborated predominantly backward-looking models PLT does not fall considerably short of IT. When we explicitly consider the stability robustness of policy rules, PLT turns out to be less prone to the risk of macroeconomic instability than IT.

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Table 1: Characteristics and Performance of Optimized Simple Rules

Type	Model	λ	ρ_j	α_j	β_j	L
IT	SW	0.1	1.01	0.75	0.55	1.19
		0.5	1.00	0.56	2.00	1.38
		1	0.99	0.43	3.05	1.48
	CW	0.1	0.88	0.59	0.26	2.18
		0.5	0.81	0.42	1.11	2.72
		1	0.80	0.30	1.55	3.17
	AW	0.1	0.36	1.11	1.66	1.55
		0.5	0.40	0.84	2.84	2.15
		1	0.44	0.67	3.76	2.64
PLT	SW	0.1	1.00	0.54	0.85	1.12
		0.5	0.99	0.34	2.12	1.31
		1	0.99	0.27	3.12	1.42
	CW	0.1	0.85	0.40	0.61	2.12
		0.5	0.82	0.18	1.15	2.63
		1	0.80	0.12	1.54	3.09
	AW	0.1	0.51	0.07	1.60	1.61
		0.5	0.47	0.05	2.77	2.19
		1	0.48	0.00	3.67	2.67

This table reports the optimized interest-rate-rule response coefficients ρ_j, α_j and β_j, where $j \in \{\pi, p\}$, and the value of the policymaker's loss function (L) for the inflation-targeting and the price-level-targeting rule specification for each choice of the preference parameter on output gap stabilization (λ).

Table 2: Detailed Results for the Optimized Simple Rules

Type	Model	λ	$Var(\pi)$	$Var(x)$	$Var(\Delta i)$	L
IT	SW	0.1	1.04	1.17	0.32	1.19
		0.5	1.15	0.26	0.97	1.38
		1	1.17	0.16	1.46	1.48
	CW	0.1	1.90	2.43	0.37	2.18
		0.5	2.14	0.98	0.93	2.72
		1	2.18	0.83	1.59	3.17
	AW	0.1	1.19	1.98	1.71	1.55
		0.5	1.16	1.18	4.06	2.15
		1	1.16	0.84	6.46	2.64
PLT	SW	0.1	0.98	0.97	0.37	1.12
		0.5	1.06	0.29	1.00	1.31
		1	1.09	0.18	1.48	1.42
	CW	0.1	1.89	1.92	0.37	2.12
		0.5	2.03	1.02	0.96	2.63
		1	2.08	0.85	1.61	3.09
	AW	0.1	1.24	1.88	1.83	1.61
		0.5	1.20	1.15	4.19	2.19
		1	1.19	0.82	6.55	2.67

This table reports the unconditional variances of annualized quarter-to-quarter inflation (π), the output gap (x) and the first difference in the annualized nominal interest rate (Δi), as well as the value of the policymaker's loss function (L) for the optimized inflation-targeting and price-level-targeting rules for each choice of the preference parameter on output gap stabilization (λ).

Table 3: Results for the Optimized Simple Q-to-Q-Inflation-Targeting Rules

Model	λ	$Var(\pi)$	$Var(x)$	$Var(\Delta i)$	L
SW	0.1	1.07	1.17	0.36	1.22
	0.5	1.17	0.24	0.98	1.39
	1	1.18	0.16	1.47	1.49
CW	0.1	1.92	2.53	0.43	2.22
	0.5	2.17	0.95	0.93	2.74
	1	2.20	0.82	1.60	3.17
AW	0.1	1.19	1.97	1.85	1.58
	0.5	1.17	1.15	4.18	2.16
	1	1.16	0.83	6.53	2.65

This table reports the unconditional variances of annualized quarter-to-quarter inflation (π), the output gap (x) and the first difference in the annualized nominal interest rate (Δi), as well as the value of the policymaker's loss function (L) for the optimized Q-to-Q-inflation-targeting rules for each choice of the preference parameter on output gap stabilization (λ).

Table 4: Performance of Optimized Simple Rules in Competing Models

Rule generating model	Type of rule	λ	Loss L		ΔL	
SW			CW	AW	CW	AW
	IT	0.1	2.29	unst.	5	unst.
		0.5	3.01	4.48	11	108
		1	3.74	4.71	18	78
	PLT	0.1	2.18	9.62	3	497
		0.5	2.93	4.13	11	89
		1	3.68	4.58	19	72
CW			SW	AW	SW	AW
	IT	0.1	1.24	7.53	4	384
		0.5	1.48	2.80	7	30
		1	1.64	3.48	11	32
	PLT	0.1	1.14	unst.	2	unst.
		0.5	1.40	2.90	7	33
		1	1.58	3.54	11	33
AW			SW	CW	SW	CW
	IT	0.1	1.37	2.37	16	8
		0.5	1.59	2.93	15	8
		1	1.71	3.50	16	11
	PLT	0.1	1.29	2.30	16	9
		0.5	1.53	2.87	17	9
		1	1.71	3.48	21	13

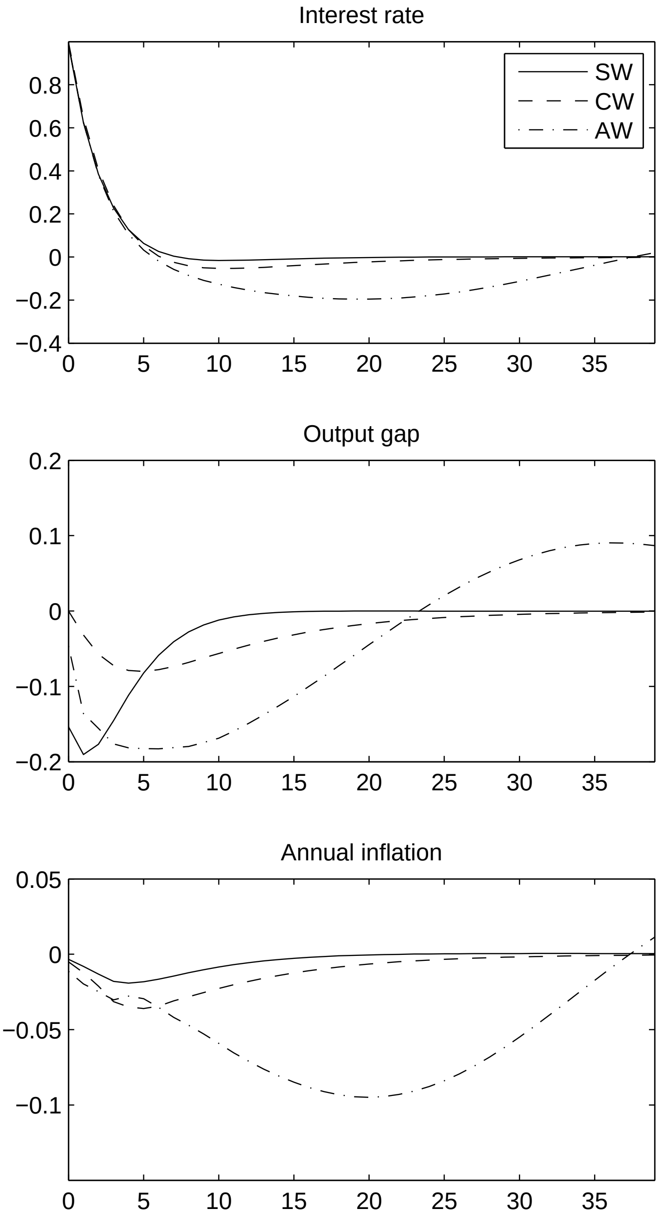
This table reports the value of the policymaker's loss function (L) and the percentage difference of the latter from the loss obtained under the optimized rule of this type (ΔL) for each choice of the preference parameter on output gap stabilization (λ) if the rule optimized for model X is evaluated in the competing model Y, where $Y \neq X$. Outcomes are shown for the inflation-targeting rules (IT) and the price-level-targeting rules (PLT). The entry *unst.* points to cases in which no stable equilibrium exists.

Table 5: Characteristics and Performance of Bayesian Robust Rules

Type	λ	ρ_j	α_j	β_j	$\tilde{L}$	L_{SW}	L_{CW}	L_{AW}
IT	0.1	0.63	0.79	1.04	1.73	1.30	2.29	1.61
	0.5	0.62	0.56	2.11	2.18	1.50	2.81	2.23
	1	0.64	0.41	2.80	2.56	1.62	3.30	2.75
PLT	0.1	0.67	0.13	1.14	1.70	1.22	2.22	1.67
	0.5	0.65	0.14	2.07	2.14	1.42	2.72	2.28
	1	0.65	0.11	2.78	2.53	1.57	3.23	2.79

This table reports the optimized interest-rate-rule response coefficients ρ_j, α_j and β_j, where $j \in \{\pi, p\}$, and the value of the aggregated loss ($\tilde{L}$) for the robust inflation-targeting and price-level-targeting rules, as well as the implied model-specific losses (L_i) for each choice of the preference parameter on output gap stabilization (λ).

Figure 1: Impulse Responses to Monetary Policy Shock

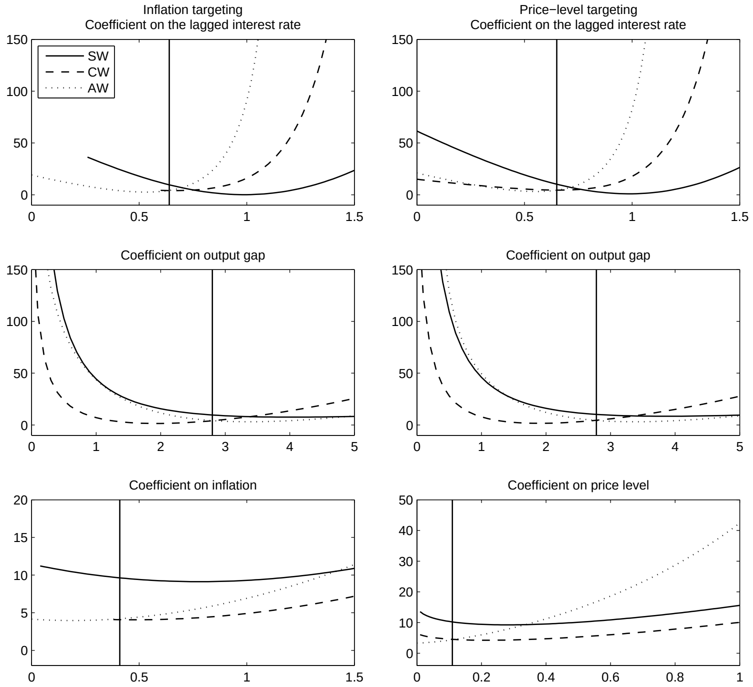

Interest rate

Output gap

Annual inflation

Shown are impulse responses in the SW, CW and AW model to an unexpected temporary 100 basis points increase in the annualized short-term nominal interest rate under the Gerdesmeier and Roffia (2004) rule given by equation (1). All variables are expressed in percentage deviations from steady state.

Figure 2: Fault Tolerances of Bayesian Policy Rules



Fault-tolerance analysis of the Bayesian IT rule (left column) and PLT rule (right column) for $\lambda = 1$. In each of the subplots one policy parameter is varied, holding the other parameters constant at their optimized value. The fault (in)tolerance is measured as the percentage increase in the policymaker's loss compared to the outcome when all parameters are set to their model-specific optimal value. The optimal Bayesian policy rule parameter is marked by a solid vertical line, respectively.