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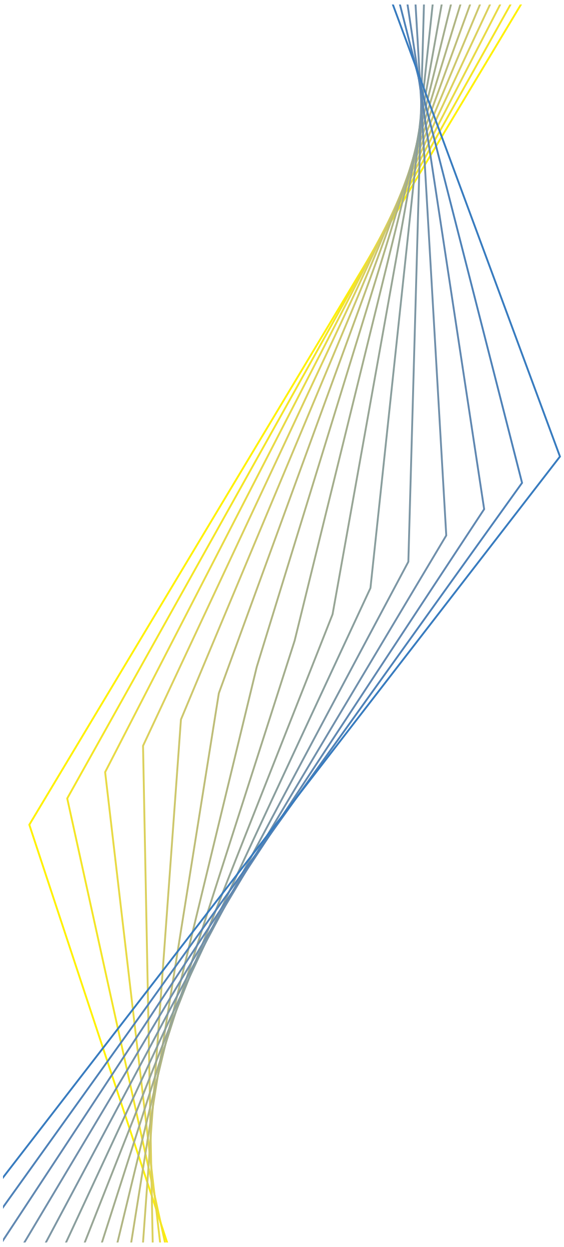

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INFLATION PERSISTENCE AND ROBUST MONETARY POLICY DESIGN[1]

BY GÜNTER COENEN[2]

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Contents

Abstract

This paper investigates the performance of optimised interest rate rules when there is uncertainty about a key determinant of the monetary transmission mechanism, namely the degree of persistence characterising the inflation process. The paper focuses on the euro area and utilises two variants of an estimated small-scale macroeconomic model featuring distinct types of staggered contracts specifications which induce quite different degrees of inflation persistence. The paper shows that a cautious monetary policy-maker is well-advised to design and implement interest rate policies under the assumption that inflation persistence is high when uncertainty about the prevailing degree of inflation persistence is pervasive.

JEL Classification System: E31, E52, E58, E61

Keywords: macroeconomic modelling, staggered contracts, inflation persistence, monetary policy rules, robustness, euro area

Non-technical summary

This paper investigates the performance of monetary policy rules when the monetary policymaker is faced with uncertainty about the degree of persistence characterising the inflation process. The degree of inflation persistence represents a key determinant of the monetary transmission mechanism and has important implications for the ability of monetary policy to stabilise inflation relative to output. Hence, monetary policy rules should ideally be designed to perform reasonably well under a range of alternative models of inflation determination which differ with respect to the degree of persistence that they induce.

To examine the consequences of different degrees of inflation persistence for the performance of monetary policy rules, we concentrate on the euro area for which such an examination seems particularly relevant as the single monetary policy of the European Central Bank (ECB) has to focus on the euro area as a whole being a new and relatively unexplored territory. We utilise two variants of the small-scale euro area model developed by Coenen and Wieland (2003) which feature different types of staggered contracts specifications: the nominal wage contracting specification due to Taylor (1980) and the relative real wage contracting specification originally proposed by Buiter and Jewitt (1981) and adapted to empirical work by Fuhrer and Moore (1995). Coenen and Wieland show that both types of specification describe historical euro area data reasonably well.

In terms of methodology, the paper builds on recent work by Levin, Wieland and Williams (1999, 2003) evaluating the performance and robustness of simple monetary policy rules across five different models of the U.S. economy. This methodology involves implementing simple reaction functions describing the response of the short-term nominal interest rate to inflation and the output gap, either observed or forecast, and then optimising over the respective response coefficients. The performance of these optimised interest rate rules is then evaluated with regard to their ability to stabilise inflation and output around their targets, while avoiding undue fluctuations in the nominal interest rate itself.

Unlike the papers by Levin, Wieland and Williams, this paper focuses on one particular determinant of the monetary transmission mechanism, namely the degree of inflation persistence that is induced by alternative models of inflation determination. Thus, while Levin, Wieland and Williams consider a larger set of models which exhibit substantial differences in theoretical specification, in degree of aggregation, in estimation sample and in estimation methodology, we control for all differences except for the different degrees of inflation persistence induced by the two distinct staggered contracts specifications. As a result, any differences in our findings can be attributed to the different degrees of inflation persistence induced by the two staggered contracts specifications.

Following the methodology proposed by Levin, Wieland and Williams, we first evaluate the stabilisation performance of both outcome and forecast-based interest rate rules that are designed for each of the two staggered contracts specifications separately. We then examine

the robustness of these optimised interest rate rules in a situation when the monetary policy-maker does not know which of the two staggered contracts specifications represents the "true" model of the inflation process. Specifically, we consider two different scenarios. In the first scenario, the policy-maker is faced with uncertainty regarding the choice of the forecasting model needed to implement a given forecast-based interest rate rule. In the second scenario, the policy-maker faces the even more profound uncertainty as to which of the two contracting specifications to rely upon when designing interest rate rules.

Based on our analysis, we conclude that it may be dangerous to rely too heavily on interest rate rules which are implemented and/or designed under the assumption that the degree of inflation persistence is low. Following the prescriptions of such rules may result in disastrous stabilisation outcomes if the true inflation process turns out to be much more persistent. In contrast, rules which are implemented and/or designed under the assumption that the degree of inflation persistence is relatively high also perform reasonably well if inflation is considerably less persistent. Hence, a cautious monetary policy-maker is well-advised to take monetary policy decision under the assumption that the inflation process is characterised by a high degree of persistence until strong evidence in favour of a low-persistence regime has emerged. In this context, we illustrate that using pooled forecasts rather than relying on a single model's inflation forecast can serve as a simple means to insure the policy-maker at least against the risks arising from the use of the wrong forecasting model, regardless of the prevailing degree of inflation persistence.

Finally, we identify the key operating characteristics of simple interest rate rules that are robust to the different degrees of inflation persistence induced by the two staggered contracts specifications under investigation. To this end, we optimise the simple interest rate rules across the alternative staggered contracts specifications simultaneously. Our results confirm previous findings by Levin, Wieland and Williams: robust rules respond to inflation and output gap forecasts with horizons that do not extend too far into the future and also incorporate a substantial degree of interest rate inertia. Specifically, we find that a first-difference rule which relates changes in the short-term nominal interest rate to the one-year ahead forecast of inflation and the current output gap already goes a long way towards making monetary policy robust to the different degrees of inflation persistence that are induced by the two types of staggered contracts specifications. To the extent that such a rule performs remarkably well under both staggered contracts specifications and in light of the large uncertainty about how to model euro area inflation, we tentatively conclude that such a rule may serve as a useful benchmark for model-based evaluations of monetary policy in the euro area.

1 Introduction

There is an active and rapidly growing literature on the evaluation of structural models of inflation determination.[1] While theoretical models, starting with the staggered contracts models of Taylor (1980) and Calvo (1983), propose that current inflation depends on future inflation and a measure of current excess demand, recent empirical research has highlighted that these models, in their simplest specification, typically fail to explain the degree of inflation persistence observed in the data. This failure has been documented most prominently by Fuhrer and Moore (1995) who rejected Taylor's nominal wage contracting model for U.S. inflation data and found strong empirical evidence in favour of the relative real wage contracting model originally proposed by Buiter and Jewitt (1981) which induces a considerably higher degree of inflation persistence.

More recently, Taylor (2000) and Cogley and Sargent (2001) have observed that the degree of persistence in U.S. inflation has been drifting downward in the 1980s and 1990s as inflation has come under control.[2] Taylor (2000) suggests that the diminished degree of inflation persistence may be due to changes in the orientation of monetary policy. In a low-inflation regime with credible monetary policy, inflation expectations may become contained and, hence, price and wage setters may be less inclined to change their contracts in response to shocks. Similarly, Brayton, Roberts and Williams (1999) argue that globalisation has increased competition in the products markets, thereby squeezing mark-ups and yielding reductions in prices. Although Staiger, Stock and Watson (2001) do not find empirical evidence in favour of such theories that place considerable weight on changes in price and wage-setting behaviour when revisiting U.S. wage and price inflation in the 1990s, more favourable evidence may emerge as data from the low-inflation regime accumulate.

In the light of the ongoing controversy about the appropriate specification of structural

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[1] See for example the evaluations by Galí and Gertler (1999), Sbordone (2002) and Rudd and Whelan (2002) for the United States and the studies by Galí, Gertler and López-Salido (2001) and Coenen and Wieland (2003) for the euro area.

[2] In line with this observation, recent work by Guerrieri (2002) suggests that even Taylor-style contracts are not rejected for U.S. data once the estimation period is extended to the more recent past.

models of inflation determination and more recent indications that the law of motion for inflation may have altered, this paper investigates the performance of simple monetary policy rules when the monetary policy-maker is faced with uncertainty about the degree of persistence characterising the inflation process. The degree of inflation persistence represents a key determinant of the monetary transmission mechanism and has important implications for the ability of monetary policy to stabilise inflation relative to output. Hence, monetary policy rules should ideally be designed to perform reasonably well under a range of alternative models of inflation determination which differ with respect to the degree of inflation persistence that they induce.

To examine the consequences of different degrees of inflation persistence for the performance of monetary policy rules, we concentrate on the euro area for which such an examination seems particularly relevant as the single monetary policy of the European Central Bank (ECB) has to focus on the euro area as a whole being a new and relatively unexplored territory. We utilise two variants of the small-scale euro area model developed by Coenen and Wieland (2003) which feature different types of staggered contracts specifications: the nominal wage contracting specification due to Taylor (1980) and the relative real wage contracting specification originally proposed by Buiter and Jewitt (1981) and adapted to empirical work by Fuhrer and Moore (1995).[3] Both types of contracting specification are found to describe historical euro area data reasonably well.

Comparing the euro area results to those obtained for France, Germany and Italy separately, Coenen and Wieland (2003) show that the relative real wage contracting specification does quite well in countries which transitioned out of a high inflation regime such as France and Italy, while the nominal wage contracting specification describes German data better

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[3] Thus, the estimated small-scale euro area model belongs to the class of New-Keynesian models which have gained increased popularity in macroeconomic modelling over the recent years. This class of models includes most of the smaller-scale models currently used for research on monetary policy (see for example the backward-looking model of Rudebusch and Svensson (1999), the models with rational expectations and nominal rigidities of Fuhrer and Moore (1995), Fuhrer (1997) and Orphanides and Wieland (1998)) and the models with optimising agents of Rotemberg and Woodford (1997, 1999) and McCallum and Nelson (1999)), as well as large-scale policy models such as the Federal Reserve Board's FRB/U.S. model (see Brayton and Tinsley (1996)), the ECB's Area-Wide Model (see Fagan, Henry and Mestre (2001)) or the multi-country model of Taylor (1993a).

which exhibit a substantially lower degree of inflation persistence. This finding may be attributed to different degrees of nominal rigidity in the price and wage-setting behaviour across economies, but it may also reflect different degrees of credibility of the respective monetary regimes over the estimation period. The estimation results with German data also provide indirect empirical support for the thesis that the degree of inflation persistence is lower in a stable monetary regime with low average inflation, because of the reduced pricing power of firms as suggested by Taylor (2000).

Thus, as far as the future of the European Monetary Union (EMU) is concerned, the estimation based on historical euro area data may overstate the case for the relative real wage contracting model. In this case, nominal rigidities à la Taylor may provide a better description of the inflation process than Fuhrer-Moore-type rigidities and, in terms of evaluating alternative monetary policy strategies, a policy-maker who is optimistic about the output losses associated with stabilising inflation may prefer to use the nominal wage contracting specification, while a pessimist may prefer the relative real wage contracting specification. Given the high degree of uncertainty about the determination of euro area inflation in the future, however, a robust monetary policy strategy for the euro area should perform reasonably well under both contracting specifications.[4]

In terms of methodology, this paper builds on recent work by Levin, Wieland and Williams (1999, 2003) – henceforth referred to as LWW (1999, 2003) – evaluating the performance and robustness of simple monetary policy rules across five different models of the U.S. economy.[5] This methodology involves implementing simple reaction functions describing the response of the short-term nominal interest rate to inflation and the output gap, either observed or forecast, and then optimising over the respective response coefficients.

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[4] Another hypothesis, though with similar consequences, is that due to heterogeneity in the persistence of the national inflation rates in the countries that form the countries of the euro area, the use of aggregated euro area inflation data induces an upward bias in the estimated degree of inflation persistence. The latter would be an empirical artefact and therefore considered misleading as regards the evaluation of alternative monetary policy strategies.

[5] There are alternative approaches to analysing the consequences of uncertainty about the structure of the economy (see for example Giannoni (2002), Hansen and Sargent (2002), Onatski and Stock (2002), Onatski and Williams (2003) and Tetlow and von zur Muehlen (2001)). This coexistence of alternative approaches reflects that there has not yet emerged a consensus on how to address the issue of model uncertainty.

The performance of these optimised interest rate rules is then evaluated with regard to their ability to stabilise inflation and output around their targets, while avoiding undue fluctuations in the nominal interest rate itself.[6]

Unlike the papers by LWW, this paper focuses on one particular determinant of the monetary transmission mechanism, namely the degree of inflation persistence that is induced by alternative models of inflation determination. Thus, while LWW consider a larger set of models which exhibit substantial differences in theoretical specification, in degree of aggregation, in estimation sample and in estimation methodology, we control for all differences except for the different degrees of inflation persistence induced by the two distinct staggered contracts specifications. As a result, any differences in our findings can be attributed to the different degrees of inflation persistence induced by the two contracting specifications.[7]

We start our analysis by comparing the characteristics of inflation and output gap dynamics under the two staggered contracts specifications with an empirical benchmark policy rule imposed. To this end, we report the responses of inflation and the output gap to an unexpected tightening of monetary policy to illustrate the differences in the transmission of monetary policy. Our subsequent analysis proceeds in two steps. Following the methodology proposed by LWW, we first evaluate the stabilisation performance of both outcome and forecast-based interest rate rules which are designed for each of the two staggered contracts specifications separately. We then examine the robustness of these optimised interest rate rules in a situation when the monetary policy-maker does not know which of the two staggered contracts specifications represents the "true" model of the inflation process. Specifically, we consider two different scenarios. In the first scenario, the policy-maker is faced with uncertainty regarding the choice of the forecasting model needed to implement a given forecast-based interest rate rule. In the second scenario, the policy-maker faces the

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[6] Earlier studies of the performance of interest rate rules across a range of macroeconomic models of the U.S. economy are provided in Bryant, Hooper and Mann (1993) and Taylor (1999).

[7] Our study is related to recent work by Jääskelä (2002) on the implications of inflation persistence for the design of optimal monetary policy. However, while we evaluate the performance of both outcome and forecast-based interest rate rules in an empirically estimated model of the euro area with two distinct supply-side specifications, Jääskelä focuses on the performance of outcome-based interest rate rules in a highly-stylised calibrated model with a hybrid Phillips curve.

even more profound uncertainty as to which of the two contracting specifications to rely upon when designing interest rate rules.

Based on our analysis, we conclude that it may be dangerous to rely too heavily on interest rate rules which are implemented and/or designed under the assumption that the degree of inflation persistence is low. Following the prescriptions of such rules may result in disastrous stabilisation outcomes if the true inflation process turns out to be much more persistent. In contrast, rules which are implemented and/or designed under the assumption that the degree of inflation persistence is relatively high also perform reasonably well if inflation is considerably less persistent. Hence, a cautious monetary policy-maker is well-advised to take monetary policy decision under the assumption that the inflation process is characterised by a high degree of persistence until strong evidence in favour of a low-persistence regime has emerged. In this context, we illustrate that using pooled forecasts rather than relying on a single model's inflation forecast can serve as a simple means to insure the policy-maker against risks arising from the use of the wrong forecasting model, regardless of the prevailing degree of inflation persistence.

Finally, we identify the key operating characteristics of simple interest rate rules that are robust to the different degrees of inflation persistence induced by the two staggered contracts specifications. To this end, we optimise the simple interest rate rules across the alternative staggered contracts specifications simultaneously. Our results confirm previous findings by LWW: robust rules respond to inflation and output gap forecasts with horizons that do not extend too far into the future and also incorporate a substantial degree of interest rate inertia. Specifically, we find that a first-difference rule which relates changes in the short-term nominal interest rate to the one-year ahead forecast of inflation and the current output gap already goes a long way towards making monetary policy robust to the different degrees of inflation persistence that are induced by the two types of staggered contracts specifications. To the extent that such a rule performs remarkably well under both types of staggered contracts specifications and in the light of the large uncertainty about how to model euro area inflation, we tentatively conclude that such a rule may serve as a useful benchmark for model-based evaluations of monetary policy in the euro area.

The remainder of this paper is organised as follows. Section 2 outlines the behavioural equations of the euro area model with the two distinct staggered contracts specifications and illustrates the implied differences in inflation and output gap dynamics under an estimated benchmark rule. Section 3 briefly describes the methodology used for evaluating the performance of simple interest rate rules and provides a set of optimised benchmark rules for each of the two staggered contracts models. Section 4 evaluates the robustness of these optimised rules when there is uncertainty about the forecasting and/or the rule-generating model, while Section 5 identifies the operating characteristics of simple interest rate rules that are robust to different degrees of inflation persistence. Section 6 reports additional sensitivity analysis and Section 7 concludes.

2 Two Models of Inflation Determination

To analyse the robustness of monetary policy rules when there is uncertainty about the degree of inflation persistence, we utilise two variants of the small-scale euro area model developed by Coenen and Wieland (2003). The first variant employs the nominal wage contracting specification due to Taylor (1980), and the second the relative real wage contract specification originally proposed by Buiter and Jewitt (1981) and adapted to empirical work by Fuhrer and Moore (1995). These two contracting specifications differ with respect to the degree of inflation persistence that they induce, because relative real wage contracts give more weight to past inflation.[8]

2.1 The Behavioural Equations

The behavioural equations of the small-scale euro area model are indicated in **Table 1**. As shown in model equation (M-1), the aggregate price level p_t is determined as a weighted

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[8] There are other mechanisms which have been proposed in the literature as a means to induce lag-dependent inflation dynamics. For example, Galí and Gertler (1999) allow for a fraction of backward-looking firms in the staggered nominal contracts model of Calvo (1983), which are assumed to follow a “rule of thumb” when changing prices, while Christiano, Eichenbaum and Evans (2001) assume that nominal contracts are indexed to past prices.

average of staggered nominal wage contracts signed over the past year, x_{t-i} $(i = 0, 1, 2, 3)$, which are still in effect in period t.[9] Following Fuhrer and Moore (1995), the weights f_i on contract wages from different periods are assumed to be a downward-sloping linear function of contract length. This function depends on a single parameter, the slope s.

Table 1: A Small-Scale Euro Area Model with Staggered Wage Contracts

Price level	$p_t = f_0\, x_t + f_1\, x_{t-1} + f_2\, x_{t-2} + f_3\, x_{t-3}$,	(M-1)
	where $f_i = 0.25 + (1.5 - i)\, s,\ s \in (0,\ 1/6]$	
Contract wage		
a) Taylor	$x_t = \mathrm{E}_t \left[\sum_{i=0}^{3} f_i\, p_{t+i} + \gamma \sum_{i=0}^{3} f_i\, y_{t+i} \right] + \epsilon_t^x$	(M-2a)
b) Fuhrer-Moore	$x_t - p_t = \mathrm{E}_t \left[\sum_{i=0}^{3} f_i\, v_{t+i} + \gamma \sum_{i=0}^{3} f_i\, y_{t+i} \right] + \epsilon_t^x$,	(M-2b)
	where $v_t = \sum_{i=0}^{3} f_i\, (x_{t-i} - p_{t-i})$	
Aggregate demand	$y_t = \delta_1\, y_{t-1} + \delta_2\, y_{t-2} + \phi\, (r_{t-1}^l - r^*) + \epsilon_t^d$,	(M-3)
	where $y_t = q_t - q_t^*$	
Term structure	$i_t^l = \mathrm{E}_t \left[\frac{1}{8} \sum_{i=0}^{7} i_{t+i}^s \right]$	(M-4)
Fisher equation	$r_t^l = i_t^l - \mathrm{E}_t \left[\frac{1}{8} \sum_{i=1}^{8} \pi_{t+i} \right]$,	(M-5)
	where $\pi_t = 4\, (p_t - p_{t-1})$	

Notes: p: aggregate price level; x: nominal contract wage; y: output gap; ϵ^x: contract wage shock; v: real contract wage index; r^l: long-term real interest rate; r^*: equilibrium real interest rate; ϵ^d: aggregate demand shock; q: actual output; q^*: potential output; i^l: long-term nominal interest rate; i^s: short-term nominal interest rate; π: one-quarter inflation. Prices, wages and output are expressed in logarithmic form, and interest rates and inflation are expressed at annualised rates.

The staggered contracts models of Taylor and Fuhrer-Moore induce nominal rigidities, because workers negotiate long-term contracts and compare the contract wage to past contracts that are still in effect and future contracts that will be negotiated over the life of this

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[9] Thus, like Fuhrer and Moore (1995), we treat the aggregate price and aggregate wage indices interchangeably, which is consistent with a fixed mark-up. For recent studies considering wage and price stickiness separately, see Taylor (1993a), Erceg, Henderson and Levin (2000) and Amato and Laubach (2000).

contract. As a result only a subset of nominal wage contracts are adjustable at a given point in time. The distinction between Taylor and Fuhrer-Moore-type wage contracts concerns the definition of the wage indices that form the basis of this comparison.

Under Taylor's specification defined by equation (M-2a), the nominal wage contract x_t is negotiated with reference to the price level that is expected to prevail over the life of the contract, p_{t+i}, as well as the expected output gap over this period, y_{t+i}. The operator $\mathrm{E}_t[\,\cdot\,]$ indicates the model-consistent expectation of a particular variable conditional on all information available in period t.[10] Since the price indices p_{t+i} reflect contemporaneous and preceding contract wages, (M-2a) implies that wage setters look at an average of nominal contract wages negotiated in the recent past and expected to be negotiated in the near future when setting the current contract wage. In other words, they take into account nominal wages that apply to overlapping contracts. If wage setters expect the output gap to be positive, $y_{t+i} > 0$, they adjust the current contract wage upwards relative to overlapping contracts. The sensitivity of contract wages to the output gap is measured by γ. The contract wage shock ϵ_t^x is assumed to be serially uncorrelated.

Under the Fuhrer-Moore specification defined by equation (M-2b), workers negotiating their nominal wage compare the implied real wage expected to prevail over the life of their contract with the real wages on overlapping contracts in the recent past and near future. This specification implies that the expected real wage under contracts signed in the current period is set with reference to an average of real contract wage indices expected to prevail over the current and the next three quarters, v_{t+i}.[11] Thus, the Fuhrer-Moore contracts should not be understood as reflecting real wage rigidity, but rather as representing an alternative nominal rigidity.

Equations (M-1) and (M-2a, M-2b) represent rules for price and contract wage-setting

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[10] We employ the AIM algorithm of Anderson and Moore (1985), which uses the Blanchard and Kahn (1980) method for solving linear rational expectations models, to compute model-consistent expectations.

[11] Here we follow Fuhrer and Moore (1995) and use the current price level in the definition of the real contract wage instead of using the average price level expected to prevail over the life of the contract, which would be theoretically preferable. For a more detailed discussion of variations of relative real wage contracts see Coenen and Wieland (2003).

that are not explicitly derived from a framework with optimising agents. However, they need not necessarily be inconsistent with such a framework. More recently, Taylor-style staggered contracts have been analysed within more fully fleshed-out dynamic general equilibrium models (see for example Chari, Kehoe and McGrattan (2000) or King and Wolman (1999)). Starting with a representative agent model with monopolistically competitive firms these studies add the constraint that *prices*, rather than *wages* are set in a staggered fashion for a fixed number of periods. A log-linear approximation of a stripped-down version of these equilibrium models then implies a contract price equation that coincides with Taylor's contract wage equation (M-2a) with the parameter γ being a function of deeper technology and preference parameters. The Fuhrer-Moore contracting model, however, has typically been criticised for lacking such microeconomic foundations.

To complete our macroeconomic model of the euro area, it remains to specify aggregate demand and the transmission of monetary policy. As regards the determination of aggregate demand, equation (M-3) relates the output gap, i.e. the deviation of actual output from its potential, $y_t = q_t - q_t^*$, to two lags of itself and to the lagged ex-ante long-term real interest rate, r_{t-1}^l. Since our analysis is focused on the implications of different types of staggered contracts specifications we assume for simplicity that potential output q_t^* is exogenous. In the short run, actual output q_t may deviate from its long-run potential due to the nominal rigidities arising from the staggering of contracts. The demand shock ϵ_t^d is assumed to be serially uncorrelated. The rationale for including lags of the output gap is to account for habit formation in consumption as well as adjustment costs and accelerator effects in investment. We use the lagged instead of the contemporaneous value of the long-term real interest rate to allow for a transmission lag of monetary policy.

Two equations relate the long-term real interest rate r_t^l to the short-term nominal interest rate i_t^s which is assumed to be the principal instrument of monetary policy. First, as to the determination of the long-term nominal interest rate i_t^l defined by equation (M-4), we rely on the accumulated forecasts of the short-term interest rate over two years. These accumulated forecasts will coincide with the long-term interest rate forecast for this horizon under the expectations hypothesis of the term structure. The term premium is assumed to be constant and equal to zero. And second, according to the Fisher relation defined by equation (M-5), we obtain the ex-ante long-term real interest rate r_t^l by subtracting inflation expectations over the following two years, with $\pi_{t+i} = 4\,(p_{t+i} - p_{t+i-1})$ denoting the annualised one-quarter inflation rate.

Table 2: The Parameter Estimates of the Small-Scale Euro Area Model

Aggregate supply $^{(a)}$	s	γ		p-value $^{(c)}$
a) Taylor	0.0456 (0.0465)	0.0115 (0.0053)		0.3186 [2]
b) Fuhrer-Moore	0.0742 (0.0245)	0.0212 (0.0048)		0.2602 [2]
Aggregate demand $^{(b)}$	δ_1	δ_2	ϕ	p-value $^{(c)}$
	1.1807 (0.1006)	-0.2045 (0.1065)	-0.0947 (0.0333)	0.2307 [5]

Notes: $^{(a)}$ Simulation-based indirect estimates using a VAR(3) model for the annualised one-quarter inflation rate and the output gap as auxiliary model. Standard errors in parentheses. $^{(b)}$ GMM estimates using a constant, lagged values of the output gap, the annualised one-quarter inflation rate and the short-term nominal interest rate as instruments. Standard errors in parentheses. $^{(c)}$ Probability value associated with the test of overidentifying restrictions. Number of overidentifying restrictions in brackets.

Estimates of the model's parameters are taken from Coenen and Wieland (2003) and summarised in **Table 2**. The upper panel of the table shows the estimated parameters of the alternative price and wage setting specifications that form the supply side of the model. As indicated by the p-values for the tests of overidentifying restrictions that were imposed when estimating the staggered contracts specifications, neither Taylor nor Fuhrer-Moore-type contracts can be rejected on statistical grounds. Taylor-type contracts, however, are favoured somewhat by a higher p-value. The lower panel of the table shows the estimated parameters of the aggregate demand equation. The coefficients on the two lags of the output gap exhibit an accelerator pattern and the interest rate sensitivity of aggregate demand is sizeable. For further details on the estimation of the model's supply-side specifications and its demand side we refer the reader to Coenen and Wieland (2003).

2.2 Implications for the Transmission of Monetary Policy

In principle, the estimated staggered contracts specifications together with the estimated aggregate demand equation would be sufficient to evaluate the stabilisation performance and robustness of alternative monetary policies. However, if we wish to know how the different contracting specifications would have affected the transmission of monetary policy historically we also need to specify an empirical benchmark. We could do so by estimating a policy reaction function which captures the historical path of the euro area short-term nominal interest rate.

Since (GDP-) weighted averages of European interest rates preceding the formation of European Monetary Union in 1999 seem unlikely to be appropriate as a measure of the euro area-wide historical monetary policy stance, however, we resort to estimating a reaction function for the German interest rate (that we already used in estimating the aggregate demand equation discussed above). After all, movements in German interest rates eventually had to be mirrored by the other European countries to the extent that they intended to maintain exchange rate parities within the European Monetary System (EMS).[12]

The benchmark rule that we estimate is a forecast-based interest rate rule which relates short-term nominal interest rates to variations of the one-year-ahead forecast of annual inflation in deviation from the policy-maker's target π^* and the current output gap and also allows for interest rate inertia, i.e. "smoothing".[13] We estimate a generalised form of such a forward-looking rule allowing for up to two lags of the short-term nominal interest

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[12] Clarida, Galí and Gertler (1998) also argue that German monetary policy had a strong influence on interest rate policy in the U.K., France and Italy throughout the EMS period. More recently, Faust, Rogers and Wright (2001) estimate an interest rate reaction function for Germany and use it to predict the interest rate the ECB would be setting, were it to behave like the Bundesbank.

[13] Work by Clarida and Gertler (1997) and Clarida, Galí and Gertler (1998) suggests that German interest rate policy since 1979 is summarised quite well by such a forecast-based interest rate rule.

rate using quarterly German data (standard errors in parentheses):

$$\begin{aligned} i^s_t \;=\;& \underset{(0.0271)}{1.0670}\, i^s_{t-1} - \underset{(0.0320)}{0.2764}\, i^s_{t-2} + (1 - 1.0670 + 0.2764)\,(\, r^* + \mathrm{E}_t[\tilde{\pi}_{t+4}]\,) \\ & + \underset{(0.0241)}{0.1778}\,(\,\mathrm{E}_t[\tilde{\pi}_{t+4}] - \pi^*\,) + \underset{(0.0169)}{0.0388}\, y_t + \epsilon^{i^s}_t . \end{aligned}$$

Here, i^s_t corresponds to the three-month money market rate, the annual inflation rate $\tilde{\pi}_t = p_t - p_{t-4}$ is the annual change in the log-level of the GDP deflator and the output gap measure y_t has been constructed using quarterly real GDP data and annual output gap estimates reported in OECD (2002). r^* again denotes the equilibrium real interest rate and π^* reflects the monetary policy-maker's inflation target. The term $\epsilon^{i^s}_t$ captures unexpected shocks to monetary policy. Motivated by earlier work of Clarida, Galí and Gertler (1998), the estimation period was chosen to start in the second quarter of 1979 with the formation of the European Monetary System; it ends in the fourth quarter of 1998, prior to the launch of the euro in January 1999.[14]

The estimated short-run response coefficients in the interest rate rule capture the pattern of stabilisation policy during the 1980s and 1990s in Germany. Not surprisingly, the coefficient on the one-year-ahead inflation forecast is sizeable, implying a long-run coefficient of about 1.85. This ensures determinacy and stability of the rational expectations equilibrium, when solving the model under either of the wage contracting specifications.[15] The coefficient on the current output gap is a good bit smaller but positive; and the estimated degree of interest rate smoothing turns out to be relatively high.

In the deterministic steady state of the model the output gap is zero and the short and real interest rate equal its equilibrium value r^*. Since the alternative staggered contracts specifications do not impose any restriction on the steady-state inflation rate, the latter is

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[14] The interest rate rule has been estimated by the Generalised Method of Moments (GMM) using lags up to order three of the interest rate, one-quarter inflation and the output gap as instruments. In addition, the current value and lags up to order two of the ratio of government expenditure to potential output have been used to account for demand pressures in the aftermath of German reunification which were at least partly due to fiscal measures.

[15] See Woodford (2000) for a detailed discussion of the conditions regarding the size of the interest rate response coefficients on current or expected inflation in order to guarantee uniqueness of the rational expectations equilibrium in a standard New-Keynesian sticky-price model.

determined by monetary policy alone and equals the policy-maker's target rate π^* in the interest rate rule.

Figure 1: Responses to an Unexpected Policy Tightening (50 Basis Points)

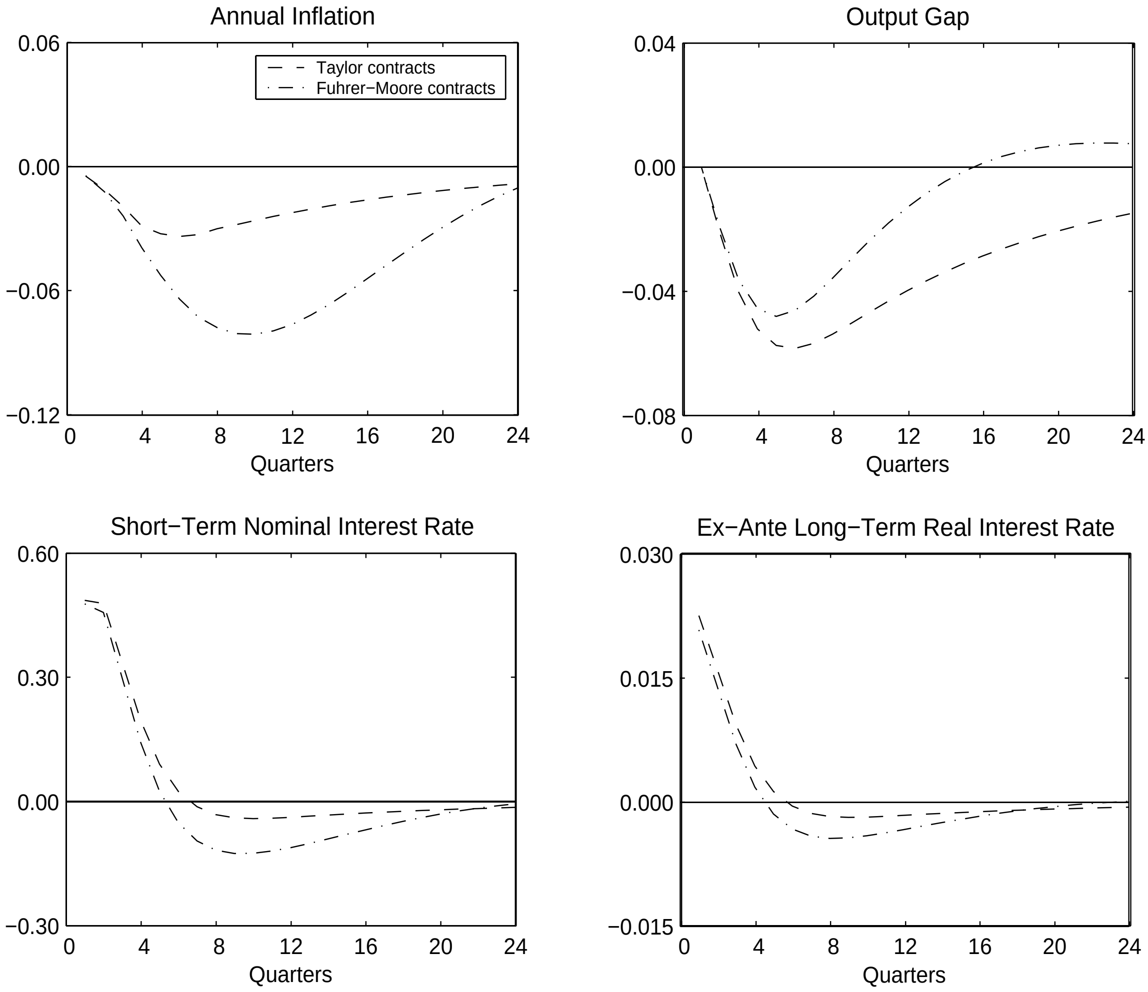

Figure 1 provides a comparison of the effects of an unexpected tightening of monetary policy by 50 basis points under the two different wage contracting specifications. The upper two panels depict the responses of annual inflation and the output gap, while the lower two panels show the responses of the short-term nominal interest rate and the ex-ante long-term real interest rate. The dashed lines refer to the responses under Taylor's wage contracting

specification, while the dash-dotted lines correspond to the responses under the contracting specification due to Fuhrer and Moore. Both the equilibrium real interest rate and the policy-maker's inflation target have been normalised to zero.

Qualitatively, the tightening of policy has the same consequences under the two wage contracting specifications. As the nominal interest rate rises unexpectedly, demand falls short of potential and inflation falls below target, with the dynamic adjustment being drawn out lastingly. Quantitatively, however, the responses exhibit some noticeable differences. Most importantly, the disinflation effect is considerably larger under Fuhrer-Moore-type contracts with the timing of the peak effect on inflation noticeably delayed relative to that on demand. By contrast, the decline in inflation is less pronounced under Taylor-type contracts and the timing of the peak effects on inflation and output is almost identical. These differences reflect that expectations regarding future inflation drop more sharply and are much more persistent under Fuhrer-Moore contracts than under Taylor contracts, as discussed in more detail in Coenen and Wieland (2003). With the nominal interest rate being set in response to expectations of future inflation, the empirical benchmark rule prescribes to lower the nominal interest rates under Fuhrer-Moore contracts more decisively than under Taylor contracts. As a result, ex-ante long-term real interest rates rise more strongly under the latter, inducing a more pronounced decline in demand.

Based on the documented patterns of the impulse response functions, we summarise that a given monetary policy rule may perform quite differently in terms of inflation and output gap stabilisation, depending on the type of staggered contracts. Hence, it is evident why monetary policy-makers should be concerned about the model of inflation determination when designing policies.

3 Evaluating the Performance of Monetary Policy Rules

We now proceed to describe the methodology which we will use to evaluate the stabilisation performance of alternative monetary policies in the presence of uncertainty about the true model of inflation determination. Our starting point is an evaluation of simple interest rate rules which respond to outcomes or forecasts of annual inflation and the output gap and allow for inertia due to dependence on the lagged short-term nominal interest rate.

3.1 The Methodology

Following the approach in LWW (2003), we consider a parametric family of simple interest rate rules,

$$i_t^s \;=\; \rho\, i_{t-1}^s + (1-\rho)\,(\, r^* + \mathrm{E}_t\,[\, \tilde{\pi}_{t+\theta}\,]\,) + \alpha\, \mathrm{E}_t\,[\, \tilde{\pi}_{t+\theta} - \pi^*\,] + \beta\, \mathrm{E}_t\,[\, y_{t+\kappa}\,]\,,$$

where again i_t^s denotes the short-term nominal interest rate, r^* is the equilibrium real interest rate, $\tilde{\pi}_t = p_t - p_{t-4}$ is the annual inflation rate, π^* denotes the inflation target, and y_t is the output gap. Under rational expectations, the operator $\mathrm{E}_t[\,\cdot\,]$ indicates the model-consistent forecast of a particular variable, using information available in period t. The parameters θ and κ denote the length of the forecast horizons for inflation and the output gap respectively. This specification accommodates both forecast-based rules (with forecast horizons $\theta, \kappa > 0$) and outcome-based rules ($\theta = \kappa = 0$) and simplifies to the one proposed by Taylor (1993b) if $\theta = \kappa = 0$ and $\rho = 0$. For fixed inflation and output gap forecast horizons θ and κ, the above family of policy rules is defined by the triplet of response coefficients ρ, α and β.

In our evaluation of the stabilisation performance of particular versions of the parametric family of policy rules, we assume that the policy-maker has a standard loss function equal to the weighted sum of the unconditional variances of inflation, the output gap and changes in the short-term nominal interest rate,

$$\mathcal{L} \;=\; \mathrm{Var}[\,\pi_t\,] + \lambda\, \mathrm{Var}[\,y_t\,] + \mu\, \mathrm{Var}[\,\Delta i_t^s\,].$$

Here, inflation is measured by the annualised one-quarter inflation rate, $\pi_t = 4\,(p_t - p_{t-1})$. The weight $\lambda \geq 0$ refers to the policy-maker's preference for reducing output variability relative to inflation variability, and the weight $\mu \geq 0$ on the variability of changes in the short-term nominal interest rate, $\Delta i_t^s = i_t^s - i_{t-1}^s$, reflects a desire to avoid undue fluctuations in the nominal interest rate itself. Establishing this loss function is consistent with the assumption that the policy-maker aims at stabilising inflation around the inflation target π^* and actual output around potential, with the concern regarding excessive interest rate variability justified by financial stability considerations or the risk of hitting the zero-interest-rate bound.[16,17]

For fixed inflation and output gap forecast horizons θ and κ, the parametric family of interest rate rules defined above is optimised by minimising the policy-maker's loss function $\mathcal{L}$ with respect to the triplet of coefficients ρ, α and β. In this context, in order to evaluate the policy-maker's loss function, we repeatedly need to compute the unconditional variances of the model's endogenous variables for a particular interest rate rule. In preparation for these computations, we first identify the series of historical structural shocks that would be consistent with the alternative contracting specifications under rational expectations with the estimated benchmark for historical monetary policy imposed.[18] Based on the covariance matrix of the structural shocks, it is then possible to calculate the unconditional covariance matrix of the endogenous variables for a given interest rate rule by applying standard methods to the reduced-form solution of the model including that rule.

In the subsequent analysis, we will consider four alternative values for the relative weight on output gap variability, namely $\lambda = 0, 1/2, 1, 2$. Regarding the weight on the variability of interest rate changes, we concentrate the analysis on a fixed value of $\mu = 1$. This weight is relatively high, but avoids extreme and counterfactual interest rate variability under the optimised rules. In the sensitivity analysis at the end of the paper we report additional results for a lower weight of $\mu = 0.1$ on interest rate variability. There, we will also briefly

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[16] For an explicit derivation of the policy-maker's loss function $\mathcal{L}$ from quadratic intertemporal preferences the reader is referred to Rudebusch and Svensson (1999). In Svensson's (1999) terminology, the case of $\lambda = \mu = 0$ corresponds to "strict" inflation targeting, while "flexible" inflation targeting is characterised by $\lambda, \mu > 0$.

[17] It is recognised that it would be beneficial to use a welfare criterion derived as an approximation of the representative agent's utility function (see for example Rotemberg and Woodford (1997)). The weights in this approximate welfare criterion would be functions of the parameters of the structural model itself. However, to the extent that the model used in this paper is lacking full micro-foundations, a well-defined welfare criterion does not exist.

[18] The historical structural shocks differ from the single-equation estimation residuals, because expectations of future variables are computed to be consistent with the complete model, including the empirical benchmark for monetary policy discussed in Section 2.2. The relevant sample period is 1979:Q2 to 1998:Q4, given the estimation period for the benchmark rule.

deal with the case of interest rate rules which do not allow for a direct response to the output gap. Such rules have been used as a proxy for actual policy in inflation-targeting countries that are widely perceived as setting interest rates in response to deviations of short to medium-term inflation forecasts from the target rate.[19]

3.2 Optimised Benchmark Rules

As a benchmark for evaluating the robustness of optimised interest rate rules under the two alternative staggered contracts models, **Table 3** reports the optimised response coefficients for a collection of outcome and forecast-based rules, together with an indication of the stabilisation performance of these rules. Regarding the choice of the forecast-based rules, we consider three different combinations of forecast horizons: one-quarter-ahead and four-quarter-ahead inflation forecasts combined with the current output gap, as used in many theoretical and empirical studies in the literature; and four-quarter-ahead forecasts of both inflation and the output gap. The last combination is motivated by **Figure 1** above which shows that a particular interest rate rule may lead to quite distinct profiles for the time paths of inflation and the output gap under the two different types of staggered contracts. As a result, choosing the forecast horizons for both inflation and the output gap may have important consequences for the stabilisation performance and robustness of interest rate rules.

The four columns in the middle of **Table 3** show the short-run response coefficients and a measure indicating the stabilisation performance of the optimised rules under Taylor-type contracts, while the four columns on the right show the corresponding results for Fuhrer-Moore-type contracts. Regardless of the policy-maker's preference for output stabilisation, we observe that the optimised rules are characterised by a substantial degree of interest rate smoothing under both types of staggered contracts, as indicated by the high coefficient on the lagged interest rate ρ. Interestingly, with the forecast horizons extending one year into the future, the magnitude of ρ tends to exceed unity, a feature which is known as

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[19] See Batini and Nelson (2001) for a model-based analysis of choosing the optimal forecast horizon within an inflation-targeting framework.

Table 3: The Stabilisation Performance of Optimised Interest Rate Rules

			Taylor contracts				Fuhrer-Moore contracts			
θ	κ	λ	ρ	α	β	$\%\Delta\mathcal{L}_{\mathrm{T}}$	ρ	α	β	$\%\Delta\mathcal{L}_{\mathrm{FM}}$
0	0	0	0.97	0.21	0.06	2.29	0.86	0.46	0.41	1.98
		1/2	0.86	0.03	0.40	3.62	0.85	0.41	0.53	1.80
		1	0.85	0.04	0.57	3.35	0.83	0.39	0.62	2.01
		2	0.85	0.06	0.78	3.42	0.82	0.36	0.78	2.56
1	0	0	0.98	0.23	0.05	2.90	0.89	0.45	0.35	2.16
		1/2	0.86	0.03	0.40	3.83	0.87	0.40	0.46	1.94
		1	0.85	0.04	0.56	3.36	0.86	0.38	0.55	2.19
		2	0.84	0.06	0.78	3.27	0.84	0.35	0.70	2.85
4	0	0	1.27	1.32	-0.09	5.47	0.99	0.77	0.20	4.96
		1/2	0.86	0.19	0.40	4.48	0.96	0.65	0.30	3.99
		1	0.84	0.11	0.57	3.38	0.93	0.58	0.39	4.02
		2	0.83	0.07	0.78	2.78	0.91	0.52	0.54	4.58
4	4	0	1.21	1.20	-0.09	5.58	1.07	1.00	0.37	4.92
		1/2	0.98	0.37	0.72	4.65	1.06	0.96	0.62	3.86
		1	1.00	0.33	1.21	3.80	1.07	0.96	0.87	3.82
		2	1.04	0.33	2.01	3.47	1.08	1.00	1.37	4.30

Notes: For each choice of the inflation and output gap forecast horizons (θ and κ), for each preference parameter (λ) and for each contracting specification (j), this table indicates the optimised interest rate response coefficients (ρ, α and β) and the percentage point change in the policy-maker's loss function ($\%\Delta\mathcal{L}_j$) compared with the loss under the fully optimal policy under commitment.

"super-inertia" in the interest rate. Not surprisingly, as the weight on output stabilisation λ increases, the coefficient on the output gap β rises while the short-run coefficient on the inflation gap α falls, albeit less dramatically for Fuhrer-Moore-type contracts. Furthermore, the coefficients under Fuhrer-Moore-type contracts are typically a good bit larger than under Taylor-type contracts. This reflects that, under Fuhrer-Moore contracts, the inflation process is much harder to control and that, as a result, the policy-maker has to respond more aggressively to any signs of rising inflation.

The stabilisation performance of the optimised interest rate rules is measured in relative terms as the percentage point change in the policy-maker's loss function, $\%\Delta\mathcal{L}_j$ ($j =$ T,FM), compared with the loss under the fully optimal policy under commitment.[20] Overall, we observe that the stabilisation performance of monetary policy does not deteriorate much when the policy-maker follows simple interest rate rules rather than fully optimal policies under commitment. Under both Taylor and Fuhrer-Moore contracts the value of the policy-maker's loss function never rises by more than 6 percent. Interestingly, there is no stabilisation gain from following forecast-based as opposed to outcome-based rules.[21]

Based on these results, one might conclude that relying on optimised interest rate rules rather than optimal policies under commitment does not compromise the overall stabilisation performance of monetary policy significantly and, hence, seems innocuous. However, our analysis thus far has assumed that the policy-maker knows the true model of inflation determination when designing and implementing simple interest rate rules. As we will see below, the stabilisation performance of these rules can deteriorate dramatically, if this assumption is invalid.

4 The Robustness of Optimised Monetary Policy Rules

In the previous section it was assumed that the policy-maker knows the "true" model of inflation determination as represented by either Taylor or Fuhrer-Moore contracts. For each of these two contracting specifications, we designed optimal interest rate rules which performed remarkably well in stabilising inflation and the output gap for given preferences of the policy-maker. In the case that the optimised rules prescribed to set the interest rate in response to forecasts of future inflation or the output gap, these forecasts happened to be consistent with the structure of the model.

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[20] See Finan and Tetlow (1999) for details on computing the optimal policy under commitment for large rational expectations models using AIM.

[21] In the sensitivity analysis at the end of the paper we consider forecast-based rules which do not allow for a direct response to the output gap. For such rules, it is found that extending the forecast horizon for inflation beyond one year leads to an improved stabilisation performance relative to outcome-based rules or rules that are confined to short inflation forecast horizons.

In the presence of uncertainty about the true model of inflation determination, however, two distinct sources of policy mistakes can be identified when implementing and designing interest rate rules. First, when implementing a forecast-based rule, the policy-maker may erroneously rely on forecasts which are obtained from the false model of inflation determination. And second, the policy-maker may already rely on the false model of inflation determination when designing the rule itself. We will refer to these two sources of policy mistakes as uncertainty about the forecasting model and uncertainty about the rule-generating model respectively. Of course, in the latter case the risks may even be heightened when also relying on the false forecasting model.

In the following we shall assess the robustness of optimised interest rate rules to uncertainty about the true model of inflation determination by evaluating the costs associated with these two distinct sources of policy mistakes.

4.1 Uncertainty about the Forecasting Model

Table 4 characterises the stabilisation performance of the optimised forecast-based policy rules reported in **Table 3** above under the assumption that the forecasts used when implementing these rules have been generated by the false model of the inflation process. Column four in **Table 4** refers to the model with Taylor contracts and indicates the percentage point change in the policy-maker's loss function when interest rates are set according to a rule which has been optimised under Taylor contracts (representing the true model of the inflation process) but implemented using inconsistent forecasts obtained from the model with Fuhrer-Moore contracts. Here, the comparison is made with respect to the loss under the optimised forecast-based rule that has been implemented with consistent forecasts. Vice versa, column five refers to the model with Fuhrer-Moore contracts and reports the relative loss when the correctly designed policy rule is implemented using inconsistent forecasts based on the model with Taylor contracts. In each case, the inconsistent forecast, $\mathrm{E}_t^j[\,\cdot\,]$ (j = T, FM), is computed under the forecast-based rule designed for the model which is supposed to be the true representation of the inflation process, i.e. the policy-maker happens

Table 4: The Robustness of Optimised Rules when the Forecasting Model Is Uncertain

			Inconsistent forecasts		Pooled forecasts	
θ	κ	λ	$\%\Delta\mathcal{L}_{\mathrm{T}}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}$	$\%\Delta\mathcal{L}_{\mathrm{T}}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}$
1	0	0	0.26	0.66	0.08	0.16
		1/2	0.09	0.55	0.09	0.13
		1	0.15	0.53	0.15	0.13
		2	0.19	0.55	0.19	0.12
4	0	0	20.21	70.87	3.07	6.89
		1/2	4.56	61.94	2.31	5.85
		1	3.13	69.43	1.95	5.98
		2	2.37	95.51	1.72	6.81
4	4	0	22.03	61.55	3.86	6.24
		1/2	4.25	42.15	1.20	5.27
		1	2.98	35.97	0.74	5.13
		2	2.28	29.80	0.42	5.19

Notes: For each choice of the inflation and output gap forecast horizons (θ and κ), for each preference parameter (λ) and for each contracting specification (j), this table indicates the percentage point change in the policy-maker's loss function ($\%\Delta\mathcal{L}_j$) when the optimised forecast-based rule is implemented using either model-inconsistent or pooled forecasts, compared with the loss under the optimised forecast-based rule implemented with model-consistent forecasts.

to choose the correct rule-generating model, but when implementing the optimal rule the policy-maker resorts to the incorrect forecasting model.

The comparison of the outcomes reported in columns four and five of **Table 4** reveals that the deterioration of monetary policy is less severe, if the policy-maker overestimates the degree of inflation persistence when implementing forecast-based policy rules (that is, if forecasts that are based on Fuhrer-Moore contracts are incorrectly used in the model with Taylor contracts.) In this case, the use of inconsistent forecasts leads to a percentage point increase in the policy-maker's loss function of up to 22 percent, depending on the length of the forecast horizons and the policy-maker's preferences. In contrast, if the policy-maker underestimates the degree of inflation persistence (that is, if inflation forecasts based on

Taylor contracts are erroneously implemented in the model with Fuhrer-Moore contracts), the deterioration in the performance of monetary policy is more dramatic. In this case, the loss increases by up to 71 percent. Overall, the deterioration is increasing in the length of the inflation-forecast horizon, and it is found to be particularly large if the monetary policy-maker puts no weight on output stabilisation. Interestingly, the deterioration in the performance of forecast-based rules with forecast horizons extending farther into the future seems to be alleviated at least somewhat if the horizon of the output gap forecast is synchronised with that of the inflation forecast.

The remaining two columns in **Table 4** provide information on the stabilisation performance of optimised forecast-based rules if the policy-maker implements "pooled" forecasts, which are defined as a (simple) weighted average of the individual forecasts obtained under the two alternative wage contracting specifications, $\bar{\mathrm{E}}_t[\,\cdot\,] = 1/2\,(\,\mathrm{E}_t^{\mathrm{T}}[\,\cdot\,] + \mathrm{E}_t^{\mathrm{FM}}[\,\cdot\,]\,)$. In this case, the percentage point increase in the policy-maker's loss function is typically found to be lower when compared with the percentage point increase in the loss function resulting from the use of inconsistent forecasts. The relative improvement is found to be particularly large for the model with Fuhrer-Moore contracts. Hence, as far as the choice of the forecasting model is concerned, pooling forecasts rather than relying on any single model's forecast which may be largely misguiding can serve as a means to make forward-looking monetary policies more robust.

4.2 Uncertainty about the Rule-Generating Model

Table 5 summarises our findings regarding the robustness of optimised interest rate rules when there is uncertainty about the rule-generating model. We again consider the set of benchmark rules documented in **Table 3**. To assess the consequences of relying on the false model in the design of interest rate rules, we evaluate the stabilisation performance of interest rate rules that are optimised for either of the two models of inflation determination but then implemented in the alternative one which is supposed to represent the true model of the inflation process. The deterioration due to this policy mistake is measured by the

Table 5: The Robustness of Optimised Rules when the Rule-Generating Model Is Uncertain

			Consistent forecasts		Inconsistent forecasts		Pooled forecasts	
θ	κ	λ	$\%\Delta\mathcal{L}_{\mathrm{T}}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}$	$\%\Delta\mathcal{L}_{\mathrm{T}}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}$	$\%\Delta\mathcal{L}_{\mathrm{T}}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}$
0	0	0	20.96	224.30				
		1/2	8.04	70.01				
		1	7.83	83.02				
		2	7.40	86.10				
1	0	0	18.92	154.97	23.14	229.83	20.87	186.35
		1/2	6.95	82.63	10.22	ME	8.48	ME
		1	7.05	99.67	10.06	ME	8.47	ME
		2	6.86	103.44	9.53	ME	8.12	ME
4	0	0	8.93	58.94	33.23	558.68	16.44	88.10
		1/2	1.99	27.45	18.82	ME	7.44	ME
		1	3.09	47.06	18.10	ME	8.11	ME
		2	3.45	63.86	16.77	ME	8.04	ME
4	4	0	9.70	44.28	25.29	615.45	13.88	79.17
		1/2	1.49	20.41	18.92	ME	7.49	59.60
		1	2.22	30.83	17.74	ME	7.76	93.18
		2	2.62	34.95	15.93	ME	7.50	115.56

Notes: For each choice of the inflation and output gap forecast horizons (θ and κ), for each preference parameter (λ) and for each contracting specification (j), this table indicates the percentage point change in the policy-maker's loss function ($\%\Delta\mathcal{L}_j$) under the rule optimised for the "false" model, compared with the loss under the rule optimised for the "true" model. Each of the forecast-based rules optimised for the false model is implemented using consistent, inconsistent and pooled forecasts respectively. The notation "ME" indicates that the implemented rule yields multiple equilibria.

relative increase in the policy-maker's loss function compared with the loss that would occur under the correctly designed rule.

Starting with the optimised outcome-based rule in columns four and five of **Table 5** ($\theta = \kappa = 0$), we observe that the stabilisation performance deteriorates significantly under both types of wages contracts, with the performance being distorted most severely if the policy-maker puts zero weight on output stabilisation. However, as shown in column four, if outcome-based rules that are optimised under the assumption that the degree of inflation persistence is high (i.e. under Fuhrer-Moore contracts) are used in the low-persistence model (i.e. under Taylor contracts), the value of the loss function never rises by more than 21 percent. In contrast, as shown in column five, using outcome-based rules optimised under Taylor contracts within a model incorporating Fuhrer-Moore contracts results in distortions that are dramatically larger. In the extreme case, the value of the loss function is found to increase by about 225 percent.

We next turn to the forecast-based interest rate rules ($\theta > 0, \kappa \geq 0$). Here, we consider three alternative assumptions regarding the formation of forecasts, as in Section 4.1 above. First, we assume that the policy-maker uses forecasts obtained from the correct model of the inflation process. In this case, the forecasts are model-consistent but the implemented rule is poorly designed. As indicated in columns four and five of **Table 5**, using forecast-based rules that are optimised under the wrong assumption regarding the degree of inflation persistence results in a significant deterioration in the stabilisation performance of monetary policy, as has already been documented for the outcome-based rules above. Interestingly, the deterioration is found to diminish with the length of the inflation-forecast horizons. For the model with Taylor contracts, for example, the increase in the value of the loss function amounts to 19 percent if one-quarter-ahead inflation forecasts are used, while the loss rises by less than 9 percent when using one-year-ahead inflation forecasts. Comparing the results for the two distinct contracting specifications, we observe that the relative increase in the value of the loss function for the model with Fuhrer-Moore contracts is larger by an order of magnitude.

Second, we assume that the policy-maker not only follows a poorly designed rule but also relies on model-inconsistent forecasts when implementing this rule. By comparing the results in columns four and six of **Table 5**, we observe that the deterioration in the stabilisation performance of monetary policy continues to be relatively benign if forecast-based rules optimised under Fuhrer-Moore contracts are implemented in the model with Taylor contracts using forecasts that are based on Fuhrer-Moore contracts by mistake.

In contrast, as shown in column six, for the model incorporating Fuhrer-Moore contracts, implementing poorly designed rules together with inconsistent forecasts results in a dramatic deterioration of the stabilisation performance of policy. The value of the loss function increases dramatically. Even worse, in most cases the solution of the model turns out to be indeterminate, with non-fundamental shocks eventually contributing to the variance of economic fluctuations themselves.

Finally, the results reported in the last two columns of **Table 5** confirm that forecast pooling can in principle help to alleviate the distortions in the stabilisation performance of forecast-based rules, at least to the extent that those distortions arise from the use of inconsistent forecasts. The improvement however seems limited, in particular for the model with Fuhrer-Moore contracts, that is, when the true degree of inflation persistence is underestimated.

Overall, these results indicate that a cautious policy-maker who tries to avoid very poor outcomes is well-advised to design and implement monetary policies under the assumption that the degree of inflation persistence is substantial, as long as there is uncertainty regarding the true characteristics of the inflation process.

5 Designing Robust Monetary Policy Rules

Having documented the potential lack of robustness of optimised interest rate rules which rely on the assumption that either Taylor or Fuhrer-Moore-type staggered contracts correctly represent the inflation process, we finally proceed to identify the operating characteristics of interest rate rules which perform reasonably well under both types of staggered contracts.

In search of such robust policy rules we follow LWW (1999, 2003) and optimise the response coefficients of the parametric family of interest rate rules defined in Section 3.1 across the two contracting models simultaneously by minimising the (simple) weighted

Table 6: The Stabilisation Performance of Robustly Optimised Interest Rate Rules

θ	κ	λ	ρ	α	β	$\%\Delta\mathcal{L}_{\mathrm{T}}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}$
0	0	0	0.87	0.38	0.34	18.17	3.07
		1/2	0.86	0.33	0.48	9.06	2.44
		1	0.85	0.31	0.59	8.82	2.55
		2	0.84	0.30	0.76	8.62	3.03
1	0	0	0.90	0.39	0.29	17.59	3.11
		1/2	0.88	0.34	0.43	8.86	2.43
		1	0.86	0.32	0.54	8.61	2.63
		2	0.85	0.31	0.71	8.31	3.25
4	0	0	0.99	0.78	0.13	12.09	5.52
		1/2	0.94	0.63	0.31	6.03	4.11
		1	0.92	0.58	0.43	5.50	4.27
		2	0.89	0.53	0.61	4.77	4.93
4	4	0	1.03	0.91	0.21	12.56	5.59
		1/2	1.05	0.92	0.61	5.93	3.93
		1	1.06	0.95	0.94	5.60	3.94
		2	1.08	1.04	1.57	5.35	4.49

Notes: For each choice of the inflation and output gap forecast horizons (θ and κ) and for each preference parameter (λ), this table indicates the jointly optimised interest rate response coefficients (ρ, α and β) and the percentage point change in the contributions of the alternative contracting models to the policy-maker's overall loss function ($\%\Delta\mathcal{L}_j$) compared with the losses under the fully optimal policy under commitment for those models.

average of the associated loss functions,

$$\bar{\mathcal{L}} \;=\; \frac{1}{2}\left(\mathcal{L}_{\mathrm{T}} + \mathcal{L}_{\mathrm{FM}}\right).$$

Implicitly, the average loss function corresponds to the policy-maker's expected loss function when he has flat prior beliefs regarding which of these two models is the correct representation of the inflation process.

Table 6 reports the response coefficients of the jointly, i.e. *robustly* optimised interest rate rules and indicates the stabilisation performance of these rules in terms of the percentage point change in the loss functions that are associated with the two distinct staggered contracts models. Again, the comparison is made with the losses under the fully optimal policies under commitment. As shown in columns four to six of **Table 6**, the size of the response coefficients of the robustly optimised rules is quite similar to the size of the optimised response coefficients that were obtained for the model with Fuhrer-Moore contracts separately (see **Table 3** above). In particular, the degree of interest rate inertia is relatively high, and the short-run response coefficients, notably those on inflation, turn out to be relatively large.[22] As indicated in the final two columns of **Table 6**, the loss under Fuhrer-Moore contracts increases only slightly when implementing the robustly optimised rules, while the rise in the loss under Taylor contracts is somewhat higher, in particular, if the weight on output stabilisation is zero, although still benign. Obviously, this contrasts favourably with the lack of robustness of rules that have been optimised for a particular model of the inflation process (see **Table 5** above). Importantly, none of the robustly optimised rules yields indeterminate equilibria.

Table 7 indicates the stabilisation performance of the forecast-based versions of the robustly optimised rules reported in **Table 6** when these rules are implemented using either inconsistent or pooled forecasts. Here, the value of the policy-maker's loss function under the robustly optimised rule implemented with consistent forecasts is used as the benchmark for comparison again. Overall, the distortions due to the use of inconsistent forecasts are noticeable, in particular if the forecast horizon extends one year into the future. The results, however, still compare favourably with those reported in **Table 4**, that is when relying on rules that are optimised for the models separately. Notice, though, that using forecasts based on Taylor contracts yields indeterminate equilibria in the model with Fuhrer-Moore contracts if the policy-maker places either a very high weight on output stabilisation or none at all.

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[22] This is consistent with the findings in a study by Söderström (2002) who shows, by applying formal Bayesian analysis to a simplified version of the Rudebusch-Svensson (1999) model, that heightened responsiveness is optimal when there is uncertainty about the parameters characterising the degree of inflation persistence. The intuition is that a more aggressive response reduces uncertainty regarding the future path of inflation.

Table 7: The Stabilisation Performance of Robustly Optimised Rules when the Forecasting Model Is Uncertain

			Inconsistent forecasts		Pooled forecasts	
θ	κ	λ	$\%\Delta\mathcal{L}_{\mathrm{T}}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}$	$\%\Delta\mathcal{L}_{\mathrm{T}}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}$
1	0	0	2.83	1.76	1.31	0.69
		1/2	2.37	1.54	1.11	0.60
		1	2.26	1.54	1.07	0.60
		2	2.10	1.55	1.00	0.58
4	0	0	10.84	ME	7.42	12.62
		1/2	16.93	77.46	5.55	6.37
		1	15.64	100.55	5.34	6.98
		2	14.37	ME	5.02	8.17
4	4	0	22.89	116.66	7.30	10.86
		1/2	16.69	54.04	5.72	6.02
		1	15.09	55.66	5.39	6.10
		2	13.18	56.76	4.84	6.25

Notes: For each choice of the inflation and output gap forecast horizons (θ and κ), for each preference parameter (λ) and for each contracting specification (j), this table indicates the percentage point change in the policy-maker's loss function ($\%\Delta\mathcal{L}_j$) when the robustly optimised forecast-based rule is implemented using either model-inconsistent or pooled forecasts, compared with the loss under the robustly optimised rule implemented with model-consistent forecasts. The notation "ME" indicates that the implemented rule yields multiple equilibria.

As is evident from **Table 6**, one notable feature of the robustly optimised rules is the rather high degree of interest rate inertia, in particular if the interest rate is set in response to one-year-ahead inflation and/or output gap forecasts. This raises the possibility that first-difference rules that relate changes in the interest rate to inflation and output gap forecasts which do not extend too far into the future may already go a long way towards making policy rules robust to different degrees of inflation persistence.

Table 8 summarises the stabilisation performance of a first-difference rule which relates the change in the short-term nominal interest rate to the one-year-ahead forecast of annual

Table 8: The Stabilisation Performance of the Calibrated Forecast-Based First-Difference Rule

	Consistent forecasts		Inconsistent forecasts		Pooled forecasts	
λ	$\%\Delta\mathcal{L}_{\mathrm{T}}^{(1)}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}^{(1)}$	$\%\Delta\mathcal{L}_{\mathrm{T}}^{(2)}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}^{(2)}$	$\%\Delta\mathcal{L}_{\mathrm{T}}^{(2)}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}^{(2)}$
0	17.11	5.20	20.63	69.34	6.20	6.98
1/2	9.00	5.60	17.16	51.73	5.44	3.95
1	14.58	9.23	15.23	40.68	5.02	2.04
2	26.33	18.40	13.15	27.58	4.56	-0.21

Notes: For each preference parameter (λ) and each contracting specification (j), this table indicates the percentage point change in the policy-maker's loss function ($\%\Delta\mathcal{L}_j$) under the calibrated forecast-based first-difference rule. The first-difference rule is implemented using consistent, inconsistent and pooled forecasts respectively. The superscript "(1)" indicates the comparison with the loss under the fully optimal policy under commitment, whereas the superscript "(2)" indicates the comparison with the loss under the first-difference rule implemented with consistent forecasts.

average inflation and the current output gap,

$$\Delta i_t^s \quad = \quad 0.75\,\mathrm{E}_t[\,\tilde{\pi}_{t+4} - \pi^*\,] + 0.25\,y_t,$$

with the response to the expected inflation gap calibrated to be somewhat stronger than to the current output gap.

Evidently, the calibrated first-difference rule performs remarkably well across the two models of inflation determination, in particular when the policy-maker puts a modest weight on output stabilisation. Also, the implementation of inconsistent forecasts always yields determinate solutions, with pooled forecasts providing insurance against the adverse consequences of choosing the incorrect forecasting model.

6 Sensitivity Analysis

Now we briefly summarise some additional sensitivity analysis regarding the results presented above. First, we consider the implications of changing the weight μ on the variability of interest rate changes in the policy-maker's loss function. For the preceding analysis we have chosen a weight of $\mu = 1.0$ which, as noted in Section 3.1, implies that the variability of interest rate changes under the optimised simple rules is of the same order of magnitude as the variability implied by the estimated benchmark rule. As shown in **Table A-1** in the appendix, with a weight of $\mu = 0.1$ on interest rate variability, the relative stabilisation performance of optimised rules is not significantly affected when compared to the baseline results reported in **Table 3** above. Similarly, we observe by comparing **Table A-2** in the appendix with **Table 4** that the results regarding the robustness of optimised rules change very little if the weight on interest rate variability is lowered to $\mu = 0.1$. The costs of making a policy mistake when the inflation process is in reality less persistent are not as high as the costs when the inflation process turns out to be more persistent. Finally, as documented in **Table A-3**, robustly optimised interest rate rules are yet again found to perform amazingly well across the two alternative models of inflation determination.

Second, it is worthwhile to consider the stabilisation performance and robustness of interest rate rules that respond to forecasts of inflation but do not allow for an explicit response to the output gap. Such inflation-forecast-based rules have been widely used to proxy the decision-making frameworks of central banks in inflation-targeting countries that are widely perceived as setting interest rates in response to deviations of short to medium-term inflation forecasts from the targeted rate. In these frameworks, information on the output gap is only used to the extent that it helps to form forecasts of future inflation. **Table B-1** in the appendix indicates that the performance of such rules tends to improve with increasing inflation-forecast horizon. In fact, extending the length of the inflation forecast horizon to roughly two years leads to rules that perform best within the restricted class of inflation-forecast-based rules under investigation. However, the costs of relying on inflation forecasts based on the incorrect model of the inflation process is increasing with the length of the forecast horizon as well. Most importantly, for the Fuhrer-Moore model the use of inconsistent one-year-ahead and two-year-ahead forecasts yields either indeterminate equilibria or explosive solution paths, regardless of the weight on output stabilisation. As documented in **Table B-2**, optimised rules which only respond to inflation forecasts also lack robustness in the presence of uncertainty regarding the correct model of the inflation process. Surprisingly, though, they tend to be less prone to yielding indeterminate equilibria if the degree of inflation persistence is underestimated. Finally, as shown in **Table B-3**, optimising inflation-forecast-based rules jointly across the two models of inflation determination again helps to make them more robust, as long as the forecast horizon does not extend too far into the future and the weight on output stabilisation is relatively low.

7 Conclusion

This paper examined the robustness of simple monetary policy rules to the different degrees of inflation persistence generated by two distinct staggered contracts specifications within an estimated small-scale macroeconomic model of the euro area. Our central conclusion is that rules assuming a high degree of inflation persistence are more robust. More specifically, we find that it may be dangerous to rely too heavily on rules that are designed and/or implemented under the assumption that inflation persistence is low. These rules may result in disastrous stabilisation outcomes if the inflation process turns out to be considerably more persistent. In contrast, rules designed and/or implemented under the assumption that the degree of inflation persistence is relatively high also perform reasonably well if inflation persistence turns out to be low. Hence, a cautious monetary policy-maker is well-advised to take monetary policy decision under the assumption that the economy is characterised by a substantial degree of inflation persistence until strong evidence in favour of a low-inflation regime has emerged. In this context, we also find that using pooled forecasts rather than relying on a single model's forecast can serve as a means to insure the policy-maker against risks arising from the use of the wrong forecasting model when there is uncertainty on how to model the inflation process.

Regarding the key characteristics of simple monetary policy rules that are designed to be robust to different degrees of inflation persistence, we confirm earlier findings by LWW: robust rules respond to inflation and output gap forecasts with a horizon that does not extend too far in the future. Furthermore, such rules also incorporate a substantial degree of interest rate inertia. Thus, first-difference rules which relate changes in the short-term nominal interest rate to medium-term forecasts of inflation and the current output gap may already go a long way towards making monetary policy robust to uncertainty regarding the degree of inflation persistence. To the extent that such rules are found to perform remarkably well under both types of staggered contracts specifications and given that the uncertainty about inflation determination in the euro area looms large, we tentatively conclude that they may serve as a useful benchmark for model-based evaluations of monetary policy in the euro area.

There are several directions in which the analysis presented in this paper could be extended. First, while this paper has focused on the robustness of optimised interest rate rules, it would be interesting to also investigate the robustness of the fully optimal policies under commitment which were solely used as a benchmark for evaluating the stabilisation performance of optimised interest rate rules. A first attempt in this direction has been undertaken in Angeloni, Coenen and Smets (2003), though a more rigorous analysis using techniques developed in Giannoni and Woodford (2002) is left for future research. Second, in the light of the good performance of first-difference rules under both types of staggered contracts, it would be interesting to compare the robustness of rules which target the price level instead of the inflation rate, or a combination of both. Using simpler theoretical frameworks, initial studies relevant to this have been provided by Jääskelä (2002) and Batini and Yates (2002). Third, one could approach the robustness analysis using different methodologies. For example, one could design interest rate rules using an explicit minimax criterion to avoid the worst possible outcome under either of the two staggered contracts specifications. At least implicitly, part of the analysis in this paper has been following this idea, and one may form a conjecture that a more formal analysis along this line would also lead to favouring Fuhrer-Moore contracts over Taylor contracts. An example of a formal analysis using the minimax approach is Giannoni (2002) who uses a stylised New-Keynesian model though. Last, but not least, it would be important to check if the central conclusion from the paper is sensitive to alternative models of inflation determination. This could essentially be achieved by replicating the same kind of analysis using a larger set of empirical models of the inflation process. The analysis presented in Angeloni, Coenen and Smets (2003) is encouraging in this respect.

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Table A-1: The Stabilisation Performance of Interest Rate Rules that Are Optimised with a Lower Weight of $\mu = 0.10$ on Interest Rate Variability

			Consistent forecasts		Inconsistent forecasts		Pooled forecasts	
θ	κ	λ	$\%\Delta\mathcal{L}_{\mathrm{T}}^{(1)}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}^{(1)}$	$\%\Delta\mathcal{L}_{\mathrm{T}}^{(2)}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}^{(2)}$	$\%\Delta\mathcal{L}_{\mathrm{T}}^{(2)}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}^{(2)}$
0	0	0	1.55	1.87				
		1/2	4.41	1.57				
		1	3.74	2.33				
		2	3.29	3.61				
1	0	0	2.14	2.10	0.23	0.48	0.07	0.10
		1/2	4.66	1.89	0.09	0.33	0.03	0.07
		1	3.84	2.92	0.04	0.33	0.01	0.06
		2	3.31	4.59	0.01	0.35	0.00	0.05
4	0	0	4.75	4.92	28.26	ME	10.37	4.31
		1/2	5.38	3.39	3.89	33.85	0.94	3.41
		1	4.14	4.51	2.79	48.18	0.68	4.18
		2	3.42	6.60	2.10	75.45	0.52	5.68
4	4	0	4.82	4.91	17.98	53.20	3.84	4.00
		1/2	5.50	3.17	2.07	26.19	0.46	3.36
		1	4.52	4.12	1.21	28.54	0.28	3.61
		2	4.05	5.98	0.79	27.93	0.18	3.77

Notes: For each choice of the inflation and output gap forecast horizons (θ and κ), for each preference parameter (λ) and for each contracting specification (j), this table indicates the percentage point change in the policy-maker's loss function ($\%\Delta\mathcal{L}_j$) under the optimised rule. Each forecast-based rule is implemented using consistent, inconsistent and pooled forecasts respectively. The superscript "(1)" indicates the comparison with the loss under the fully optimal policy under commitment, whereas the superscript "(2)" indicates the comparison with the loss under the optimised rule implemented with consistent forecasts. The notation "ME" indicates that the implemented rule yields multiple equilibria.

Table A-2: The Robustness of Rules that Are Optimised with a Lower Weight of $\mu = 0.10$ on Interest Rate Variability when the Rule-Generating Model Is Uncertain

			Consistent forecasts		Inconsistent forecasts		Pooled forecasts	
θ	κ	λ	$\%\Delta\mathcal{L}_{\mathrm{T}}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}$	$\%\Delta\mathcal{L}_{\mathrm{T}}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}$	$\%\Delta\mathcal{L}_{\mathrm{T}}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}$
0	0	0	14.66	67.37				
		1/2	8.11	53.19				
		1	9.41	106.72				
		2	9.43	285.81				
1	0	0	13.29	50.90	16.07	64.48	14.57	57.03
		1/2	7.38	58.12	10.14	75.21	8.70	65.83
		1	8.98	111.16	11.76	153.25	10.32	129.03
		2	9.08	257.93	11.75	ME	10.37	ME
4	0	0	8.14	36.87	22.50	37.88	11.66	11.88
		1/2	3.37	25.23	16.15	ME	7.92	61.54
		1	5.17	35.21	18.10	ME	10.00	91.22
		2	5.24	39.63	18.08	ME	10.04	115.63
4	4	0	9.27	38.24	23.37	94.86	12.94	41.42
		1/2	2.62	30.17	16.82	188.38	7.94	61.59
		1	4.44	47.79	18.43	308.81	9.91	91.65
		2	5.15	57.55	18.25	ME	10.41	109.62

Notes: For each choice of the inflation and output gap forecast horizons (θ and κ), for each preference parameter (λ) and for each contracting specification (j), this table indicates the percentage point change in the policy-maker's loss function ($\%\Delta\mathcal{L}_j$) under the rule optimised for the "false" model, compared with the loss under the rule optimised for the "true" model. Each of the forecast-based rules optimised for the false model is implemented using consistent, inconsistent and pooled forecasts respectively. The notation "ME" indicates that the implemented rule yields multiple equilibria.

Table A-3: The Stabilisation Performance of Rules that Are Robustly Optimised with a Lower Weight of $\mu = 0.10$ on Interest Rate Variability

			Consistent forecasts		Inconsistent forecasts		Pooled forecasts	
θ	κ	λ	$\%\Delta\mathcal{L}_{\mathrm{T}}^{(1)}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}^{(1)}$	$\%\Delta\mathcal{L}_{\mathrm{T}}^{(2)}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}^{(2)}$	$\%\Delta\mathcal{L}_{\mathrm{T}}^{(2)}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}^{(2)}$
0	0	0	11.48	3.24				
		1/2	9.75	2.35				
		1	10.48	3.07				
		2	10.27	4.27				
1	0	0	11.14	3.40	1.84	1.35	0.84	0.56
		1/2	9.83	2.54	1.95	1.28	0.93	0.52
		1	10.42	3.60	2.12	1.33	1.01	0.53
		2	9.94	5.23	2.15	1.33	1.03	0.53
4	0	0	10.64	5.65	13.98	33.31	1.54	5.03
		1/2	7.80	3.69	12.97	40.76	4.58	4.34
		1	7.09	5.07	13.96	58.45	5.13	5.70
		2	5.77	7.22	14.07	82.13	5.14	7.05
4	4	0	10.42	6.05	14.20	33.74	3.75	5.17
		1/2	7.72	3.32	13.07	30.05	4.85	4.45
		1	7.95	4.42	13.17	31.73	5.13	4.92
		2	7.88	6.31	12.23	29.18	4.92	4.95

Notes: For each choice of the inflation and output gap forecast horizons (θ and κ), for each preference parameter (λ) and for each contracting specification (j), this table indicates the percentage point change in the policy-maker's loss function ($\%\Delta\mathcal{L}_j$) under the robustly optimised rule. Each forecast-based rule is implemented using consistent, inconsistent and pooled forecasts respectively. The superscript "(1)" indicates the comparison with the loss under the fully optimal policy under commitment, whereas the superscript "(2)" indicates the comparison with the loss under the robustly optimised rule implemented with consistent forecasts.

Table B-1: The Stabilisation Performance of Interest Rate Rules that Are Optimised without Allowing for a Response to the Output Gap

		Consistent forecasts		Inconsistent forecasts		Pooled forecasts	
θ	λ	$\%\Delta\mathcal{L}_{\mathrm{T}}^{(1)}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}^{(1)}$	$\%\Delta\mathcal{L}_{\mathrm{T}}^{(2)}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}^{(2)}$	$\%\Delta\mathcal{L}_{\mathrm{T}}^{(2)}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}^{(2)}$
0	0	8.66	35.50				
	1/2	56.73	43.82				
	1	85.80	50.40				
	2	122.14	61.37				
1	0	6.84	27.73	-0.37	3.15	-0.33	1.04
	1/2	47.96	35.39	-0.68	2.80	-0.58	0.92
	1	74.20	41.84	-0.51	2.75	-0.54	0.89
	2	107.59	52.13	-0.34	2.69	-0.47	0.84
4	0	6.52	8.88	17.60	∞	4.67	10.39
	1/2	16.77	11.81	34.33	ME	10.80	9.56
	1	27.79	15.53	44.31	ME	14.55	9.58
	2	43.41	22.66	53.20	ME	18.03	10.43
8	0	15.44	5.68	40.95	∞	-0.49	16.78
	1/2	6.10	4.48	230.02	∞	63.89	14.22
	1	7.19	5.27	338.89	∞	97.40	12.86
	2	10.32	8.37	459.93	∞	135.77	11.90

Notes: For each choice of the inflation forecast horizon (θ), for each preference parameter (λ) and for each contracting specification (j), this table indicates the percentage point change in the policy-maker's loss function ($\%\Delta\mathcal{L}_j$) under the optimised rule. Each forecast-based rule is implemented using consistent, inconsistent and pooled forecasts respectively. The superscript "(1)" indicates the comparison with the loss under the fully optimal policy under commitment, whereas the superscript "(2)" indicates the comparison with the loss under the optimised rule implemented with consistent forecasts. The notation "ME" indicates that the implemented rule yields multiple equilibria; the notation "∞" indicates that the implemented rule results in instability.

Table B-2: The Robustness of Rules that Are Optimised without Allowing for a Response to the Output Gap when the Rule-Generating Model Is Uncertain

		Consistent forecasts		Inconsistent forecasts		Pooled forecasts	
θ	λ	$\%\Delta\mathcal{L}_{\mathrm{T}}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}$	$\%\Delta\mathcal{L}_{\mathrm{T}}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}$	$\%\Delta\mathcal{L}_{\mathrm{T}}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}$
0	0	32.08	180.81				
	1/2	7.82	14.66				
	1	4.43	5.53				
	2	2.68	2.71				
1	0	24.88	126.26	33.46	193.07	28.76	154.11
	1/2	4.98	10.60	8.60	20.82	6.44	14.92
	1	2.23	3.25	4.30	8.98	2.90	5.56
	2	1.73	1.85	2.42	4.50	1.67	2.76
4	0	4.01	25.88	16.42	416.35	8.43	52.76
	1/2	1.47	3.56	18.96	58.45	4.82	1.79
	1	4.14	8.86	14.42	31.66	3.57	-0.38
	2	9.72	17.28	11.32	13.40	3.96	0.98
8	0	-0.80	177.03	21.65	∞	1.17	9.43
	1/2	9.57	66.46	17.33	ME	3.83	12.59
	1	17.79	104.71	16.85	ME	7.08	24.40
	2	29.14	148.59	17.84	ME	12.02	39.50

Notes: For each choice of the inflation forecast horizon (θ), for each preference parameter (λ) and for each contracting specification (j), this table indicates the percentage point change in the policy-maker's loss function ($\%\Delta\mathcal{L}_j$) under the rule optimised for the "false" model, compared with the loss under the rule optimised for the "true" model. Each of the forecast-based rules optimised for the false model is implemented using consistent, inconsistent and pooled forecasts respectively. The notation "ME" indicates that the implemented rule yields multiple equilibria; the notation "∞" indicates that the implemented rule results in instability.

Table B-3: The Stabilisation Performance of Rules that Are Robustly Optimised without Allowing for a Response to the Output Gap

		Consistent forecasts		Inconsistent forecasts		Pooled forecasts	
θ	λ	$\%\Delta\mathcal{L}_{\mathrm{T}}^{(1)}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}^{(1)}$	$\%\Delta\mathcal{L}_{\mathrm{T}}^{(2)}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}^{(2)}$	$\%\Delta\mathcal{L}_{\mathrm{T}}^{(2)}$	$\%\Delta\mathcal{L}_{\mathrm{FM}}^{(2)}$
0	0	31.80	37.70				
	1/2	62.63	45.11				
	1	88.85	51.41				
	2	123.96	62.19				
1	0	25.21	29.33	5.15	5.00	2.30	2.13
	1/2	51.93	36.12	2.18	4.17	0.79	1.57
	1	75.88	42.30	1.08	3.56	0.22	1.29
	2	108.77	52.63	0.09	2.70	-0.31	0.89
4	0	10.07	9.03	28.70	154.65	5.99	20.11
	1/2	17.90	11.95	19.70	150.19	4.45	7.26
	1	31.02	16.03	15.53	ME	2.11	4.70
	2	50.84	24.24	11.29	ME	-0.39	1.39
8	0	14.49	5.69	23.31	∞	-5.63	16.16
	1/2	14.31	4.97	13.66	∞	-2.87	9.44
	1	21.47	6.47	9.99	∞	-5.05	5.83
	2	32.80	10.76	6.73	∞	-7.22	1.74

Notes: For each choice of the inflation forecast horizon (θ), for each preference parameter (λ) and for each contracting specification (j), this table indicates the percentage point change in the policy-maker's loss function ($\%\Delta\mathcal{L}_j$) under the robustly optimised rule. Each forecast-based rule is implemented using consistent, inconsistent and pooled forecasts respectively. The superscript "(1)" indicates the comparison with the loss under the fully optimal policy under commitment, whereas the superscript "(2)" indicates the comparison with the loss under the robustly optimised rule implemented with consistent forecasts. The notation "ME" indicates that the implemented rule yields multiple equilibria; the notation "∞" indicates that the implemented rule results in instability.

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