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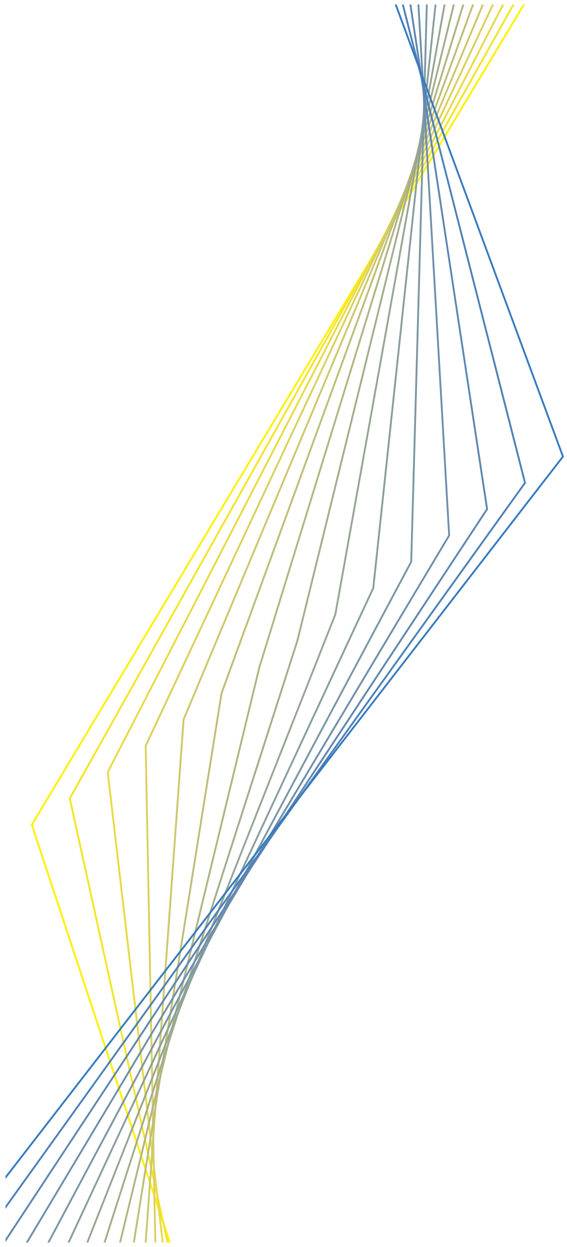

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INTEREST RATE REACTION FUNCTIONS AND THE TAYLOR RULE IN THE EURO AREA[1]

BY PETRA GERLACH-KRISTEN[2]

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Contents

Abstract

Traditional Taylor rules, which are estimated using a level specification linking the short-term interest rate to inflation and the output gap, are unstable when estimated on euro area data and forecast poorly out of sample. We present an alternative reaction function which takes the non-stationarity of the data into account. The estimated interest rate rule is stable and forecasts well. In contrast to the traditional Taylor rule, we find a significant role for the long rate, which we argue reflects shifts in the public's perception of the long-run inflation objective.

Keywords: ECB, Taylor rule, cointegration.

JEL Classification: C22, E52

Non-technical summary

"Interest rate reaction functions and the Taylor rule in the euro area"

This paper studies the behaviour of short-term interest rates in the euro area, which is an important issue both from a central bank and an academic perspective. For central bank purposes, empirical reaction functions illustrate how, given economic conditions, interest rates were set in the past, which may provide background information for future policy decisions. From an academic perspective, reaction functions are attractive because they capture the main considerations underlying a central bank's interest rate setting.

Previous work suggests that a so-called Taylor rule, which relates the short-term interest rate to its past values, inflation and the output gap, fits euro area data surprisingly well. However, that work has ignored the non-stationarity of the data. We show that traditional Taylor rules display signs of instability and appear mis-specified for euro area data over the period 1988 to 2002.

This paper estimates interest rate reaction functions under the hypothesis that interest rates, inflation and the output gap have a unit root. We account for this non-stationarity by using a cointegration approach to capture the movements of short-term nominal interest rates. In a first specification, the cointegrating vector links the nominal short interest rate to inflation, the output gap and the long interest rate. In a second specification, we impose a unit coefficient on inflation, so that in the long run the real short-term rate responds to the output gap and the long rate.

The main finding is that interest rate reaction functions estimated using the cointegration approach are, in contrast to traditional Taylor rules, stable in sample and forecast better out of sample. This model thus provides a superior description of the time series properties of the data and may yield more reliable forecasts. Interestingly, the specification using the real instead of the nominal short rate in the long-run relationship performs best.

A result of subsidiary interest is that the data suggest that short-term interest rates respond to long rates. We show that long rates capture shifts in long-run inflation expectations and argue that, in this sense, interest rate setting in the euro area has been forward-looking.

1 Introduction

Since the publication of John Taylor's seminal paper on the interest rate setting by the Federal Reserve (Taylor [31]), it has become common practice to describe monetary policy using reaction functions which link the level of the nominal short-term interest rate to inflation and economic activity (see e.g. Clarida, Gali and Gertler [7], Levin, Wieland and Williams [22] and Orphanides [25]). Such Taylor rules (TRs) are of interest both from a central bank and an academic perspective. For central bank purposes, TRs illustrate how, given economic conditions, interest rates would have been set in the past, which may provide background information for policy decisions. From an academic perspective, TRs are attractive because they provide an extremely simple model that captures the main considerations underlying central banks' interest rate setting.

The aim of this paper is to study how best to model the behaviour of short-term interest rates in the euro area. Previous work by Gerlach and Schnabel [15] and Gerdesmeier and Roffia [14] suggests that a specification of the TR relating the short-term interest rate to its own lagged value, inflation and the output gap fits euro area data surprisingly well.[1] However, these studies ignore the non-stationarity of the data, as is common in the empirical literature on reaction functions. We explore the econometric properties of this traditional model of TR using euro area data over the period 1988 to 2002 and find signs of instability and mis-specification. This paper therefore employs an alternative approach which takes the unit root behaviour of the variables into account. The main finding is that interest rate rules estimated using the cointegration approach are, in contrast to the traditional TR, stable in sample and forecast better out of sample. Thus, our model provides a superior description of the time series properties of the data than the traditional specification of the TR.

A result of subsidiary interest is that the data suggest that policymakers react to the long interest rate. We show that this variable captures shifts in long-run inflation

[1] Estimates of reaction functions for the euro area are also available in Breuss [5], Clausen and Hayo [8] and Peersman and Smets [26]. See Alesina, Blanchard, Gali, Giavazzi and Uhlig [1] and Begg, Canova, De Grauwe, Fatas and Lane [3] for comparisons of actual euro area interest rates with those implied by simulated reaction functions.

expectations, which implies that the interest rate setting in the euro area appears to be forward-looking.

The rest of the paper is structured as follows. Section 2 discusses the time series used in the estimation and presents evidence of the non-stationarity of the data. Section 3 estimates the traditional level specification of the TR. Section 4 argues that unit roots render the inference drawn from this traditional formulation unreliable and suggests that the TR should be estimated using a cointegration approach. We establish that there is evidence of one cointegrating vector linking the short and long-term interest rate, inflation and the output gap and fit it using Hamilton's [18] single-equation approach. We then study alternative interpretations of the estimated vector and proceed to estimate the remaining coefficients of the error-correction model for the short-term interest rate. Section 5 shows that the cointegration specification appears, in contrast to the traditional TR, stable. In particular, it passes a number of standard diagnostic tests and forecasts well. Section 6 shows why the long interest rate can be used as a proxy for the market perception of the long-run inflation objective, and Section 7 concludes.

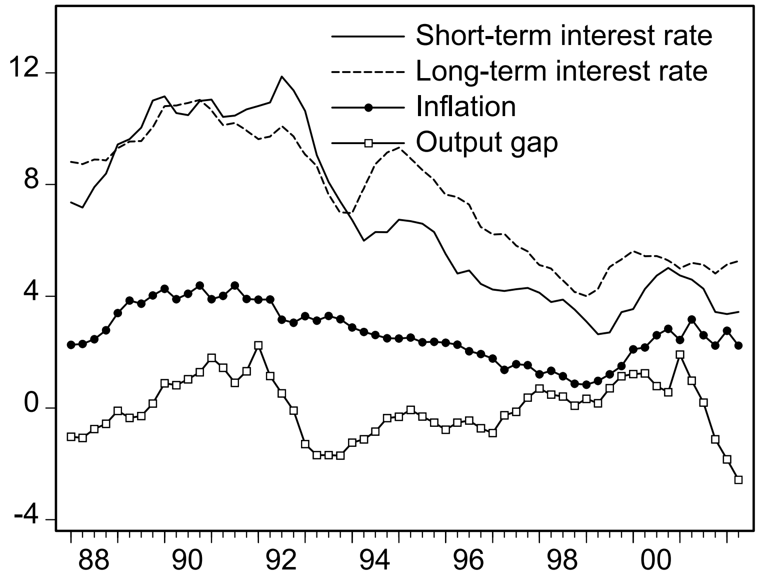
2 Data

We analyse the interest rate setting in the euro area using quarterly data spanning 1988:1 to 2002:2.[2] Since there was no single policy interest rate before 1999, we use a weighted average of national three-month money market rates, r_t, as measure of the stance of monetary policy.[3] The short-term interest rate, the long-term rate, l_t, which is measured by the yield on ten-year government bonds, inflation, π_t, and the output gap, y_t, are taken or computed using time series for the euro area available from the ECB data base. Inflation is calculated as the change over four quarters of the seasonally adjusted harmonised index of consumer prices and the output gap is measured by the residuals of a regression of the logarithm of GDP on a third-order polynomial in time.[4]

[2] While data before 1988 are available, we focus on the period after the European disinflation.

[3] This variable is also used in Brand and Cassola [4], Coenen and Wieland [10], Fagan, Henry and Mestre [12] and Gerdesmeier and Roffia [14].

Figure 1: Data (in percentage points)



As a first step of the analysis it is useful to briefly review the data. Figure 1 shows that inflation and interest rates move closely together in the period under consideration. This suggests the presence of one nominal trend. The inflation rate rose at the end of the 1980s, declined continuously from 1990 to 1998 and increased from 1999 to 2000 before falling again. Both the short and long-term interest rate move in similar ways, with the exception of a peak in 1994/95 that followed a tightening of monetary policy in the US in the spring of 1994. The output gap shows major declines at the time of the ERM crisis in 1992/1993 and from 2001 onwards.

A number of authors have argued that interest rate setting is forward-looking (see e.g. Clarida, Gali and Gertler [7], Faust, Roger and Wright [13] and Taylor [32]). Goodfriend [17] suggests that forward-looking monetary policy ought to react to movements in the

[4] As is well known there are several methods to estimate the output gap. The main reason for using this polynomial in time is that it generates somewhat more significant parameter estimates than alternative measures in the analysis below.

long-term interest rate since this variable is an indicator for "inflation scares".[5] We provide an analysis of the information contained in the long rate in Section 6; for the time being we assume that l_t can be used as a proxy for long-run inflation expectations.

Given that the time series properties of the data will play an important role in the discussion below, it is worth noting that all series display unit root characteristics. Table 1 shows Phillips-Perron test statistics for the level and the change of r_t, l_t , π_t and y_t (the table also shows the test statistics for $\pi_\infty^{(t)}$, which we define in Section 6). The unit root hypothesis is rejected for the first differences of these variables, but not for their levels, whether or not we include a time trend. While interest rates, inflation and the output gap are likely to be stationary in large samples, the results in Table 1 suggest that, in order to draw correct statistical inference, it is desirable to treat them as non-stationary in the relatively short sample studied here. Since it seems plausible that the evidence of unit roots may disappear as more data for the euro area are accumulated, this study therefore ought to be considered in its historical context.

Table 1: Phillips-Perron tests

	without time trend				
	r_t	l_t	π_t	y_t	$\pi_\infty^{(t)}$
level	-0.626	-0.784	-1.354	-1.925	-1.552
change	-4.327***	-4.091***	-7.822***	-5.433***	-5.008***
	with time trend				
	r_t	l_t	π_t	y_t	$\pi_\infty^{(t)}$
level	-2.510	-2.460	-2.252	-1.751	-2.398
change	-4.400***	-4.070**	-7.792***	-5.624***	-5.011***

Note: Phillips-Perron tests, including a constant and a truncation lag of three, for the sample period 1988:1-2002:2 (1994:1-2002:2 for $\pi_\infty^{(t)}$). */**/*** denotes significance at the ten / five / one percent level.

[5] See, however, Woodford [33] for a discussion of self-fulfilling expectations.

3 The traditional Taylor rule

Having reviewed the data, we next turn to the traditional TR. The original specification of the TR takes the form

$$r_t = \rho + \pi^* + k_\pi(\pi_t - \pi^*) + k_y y_t, \tag{1}$$

where ρ denotes the (by assumption constant) real interest rate and π^* the central bank's inflation objective. Taylor [31] suggested that the coefficients $\rho = 2$, $\pi^* = 2$, $k_\pi = 1.5$ and $k_y = 0.5$ captured the interest rate setting of the FOMC over the period 1987 to 1992 quite well.

Typically, empirical studies assume that the inflation objective is constant. However, the public's perception of π^* may vary, and policymakers might wish to react to the market perception of the long-run inflation objective. Goodfriend [17] discusses episodes in which the Federal Reserve raised interest rates in a reaction to such "inflation scares". We allow for shifts in long-run inflation expectations in Section 4 below by including the long interest rate in the reaction function and discuss the link between l_t and the inflation objective in Section 6.

Svensson [30] shows that the traditional TR is the optimal reaction function for a central bank which targets inflation in a simple backward-looking two-equation model of the economy, with the coefficients k_π and k_y being convolutions of policymakers' preferences and the parameters in the IS and the Phillips curves. One interesting finding of this model is that policymakers react to the output gap even if they are strict inflation targeters since y is useful in forecasting future π. A second result is that monetary policy responds to forecasted values of inflation and the output gap if future expectations of these variables enter in the IS and Phillips curves. A third characteristic, which is regarded as critical for empirical specifications of the TR, is that $k_\pi > 1$. This condition, known as the "Taylor principle", implies that the nominal interest rate is moved in response to an increase in inflation sufficiently to raise the real interest rate (see e.g. Taylor [32]). In other words, the real interest rate is assumed to be increased whenever inflation or the output gap rise.

Empirical estimates of the TR typically relate the current level of the short-term rate to its own lag and to the current levels of inflation and the output gap, where the significance of the coefficient on r_{t-1} is attributed to interest rate smoothing (e.g. Amato and Laubach [2] and Clarida, Gali and Gertler [7]; see also Rudebusch [27]). As a starting point for the analysis of interest rate setting in the euro area we therefore estimate the traditional formulation of the TR as

$$r_t = (1 - k_r)(k_0 + k_\pi \pi_t + k_y y_t) + k_r r_{t-1} + u_t, \tag{2}$$

over the period 1988:1 to 2002:2, where the constant k_0 is defined as $\rho + (1 - k_\pi)\pi^*$ and where we include a dummy for 1992:3 to capture the ERM crisis.[6] Since this equation in level terms implicitly assumes that the data are stationary, we refer to it as the I(0) specification of the TR.

The non-linear least squares estimates in Table 2 indicate that short-term interest rates in the euro area were raised in reaction to increased inflation and a positive output gap. We estimate $\widehat{k_\pi} = 2.73$ and $\widehat{k_y} = 1.44$ and reject Taylor's original suggestions of $k_\pi = 1.5$ and $k_y = 0.5$ in a joint Wald test (p-value of 0.04). The estimate of k_0, which is insignificantly different from zero , allows us to infer a confidence interval for the real interest rate. Assuming $\pi^* = 2$ and applying the delta method, we find that the 95% confidence interval for ρ is given by $[-0.85,\ 5.48]$ and thus rather broad. The coefficient on the lagged short rate is fitted as $\widehat{k_r} = 0.88$, and the $\overline{R}^2$ with 0.98 is high. From an econometric point of view, the finding that both the lagged dependent variable and the $\overline{R}^2$ are close to unity suggests, as already indicated by the unit root tests, that the variables in the analysis are likely to be non-stationary.

As will be shown in Section 5, the I(0) specification of the TR for the euro area is subject to serious econometric shortcomings. In particular, it displays signs of instability and mis-specification. We therefore now proceed to estimate an alternative model of interest rate setting.

[6] Gerlach and Schnabel [15] also use dummies for the period 1992:4 to 1993:3. However, these were insignificant in our estimation and were therefore not included in the analysis.

Table 2: The traditional I(0) specification of the TR

$$r_t = (1 - k_r)(k_0 + k_\pi \pi_t + k_y y_t) + k_r r_{t-1} + e_t$$

k_0	-1.228
	(1.593)
k_π	2.733***
	(0.546)
k_y	1.443*
	(0.759)
k_r	0.884***
	(0.043)
$\overline{R}^2$	0.976

Note: Non-linear least squares estimates, sample period 1988:1-2002:2. Dummy for 1992:3 included but not reported here, standard errors in parentheses (), */**/*** denotes significance at the ten / five / one percent level.

4 A cointegration approach to the Taylor rule

We next present a formulation of the TR which takes the non-stationarity of the data into account and which thereby captures the dynamics of the interest rates, inflation and the output gap better.[7] As a first step, we test for the number of cointegrating vectors in the data.

4.1 The number of cointegrating vectors

In order to assess the number n of cointegrating vectors linking the short and long-term interest rates, inflation and the output gap, we perform Johansen cointegration tests on a system with a lag length of four.[8] Table 3 shows the trace and the maximum

[7] In related work (Gerlach-Kristen [16]), an I(1) specification of the TR results from a general-to-specific modelling strategy.

[8] We started out with a model of six lags and then reduced the number of lags one by one using F-tests to assess the validity of the restrictions. The first test to reject was that comparing a system of four lags to one of three.

eigenvalue statistics for the hypotheses that $n = 0$ and $n \leq 1$ to 3. Using the large sample critical values, we reject the hypothesis of no cointegrating relationship, but accept that of $n \leq 1$.[9,10] This indicates that there appears to be only one level relationship between r_t, l_t, π_t and y_t, which we interpret below as an interest rate reaction function.

Table 3: Johansen tests for the number of cointegrating vectors

	trace statistics		max. eigenvalue statistics	
	test statistics (small sample)	95% critical value	test statistics (small sample)	95% critical value
$n = 0$	29.8** (20.1)	27.1	49.8** (35.0)	47.2
$n \leq 1$	13.3 (9.4)	21.0	20.0 (14.0)	29.7
$n \leq 2$	6.0 (4.2)	14.1	6.7 (4.7)	15.4
$n \leq 3$	0.6 (0.4)	3.8	0.6 (0.5)	3.8

Note: Johansen tests for n cointegrating vectors, 1989:1 - 2002:2. ** denotes significance at the five percent level.

It is worth noting that the discussion in Section 6 implies that we would expect a second cointegrating vector which links the long interest rate and long-run inflation. Our failure to find evidence of this second cointegrating relationship, however, may not be surprising given the short sample period. Johansen tests rely on asymptotics, which implies that the test results in Table 3 should not be over-interpreted.

4.2 Estimating the cointegrating vector

Usually, the next step in the analysis would be to estimate the full vector error-correction model. This system would in our case consist of four equations, each describing the

[9] As usual in the literature we also report the small sample test statistics, even though the merits of this correction are unclear (see Doornik and Hendry [11]).

[10] Johansen tests including only r_t, π_t and y_t detect no evidence of any cointegrating vector. It thus appears that the long rate plays a crucial role in the analysis.

reaction of Δr_t, Δl_t, $\Delta \pi_t$ and Δy_t, respectively, to deviations from the cointegrating relationship. However, the number of parameters to be fitted under this approach is too large given the short data sample. In particular, if we were to estimate a vector error-correction model with four lags, we would be required to estimate 75 coefficients on 58 data points.[11] We therefore instead follow the single-equation approach discussed by Hamilton [18] to estimate the cointegrating vector. This approach allows us to focus on one variable, which in our case is the short-term interest rate, and thereby reduces the number of parameters to be estimated drastically. Moreover, and in contrast to standard OLS based estimates of the cointegrating vector, this technique does not require the right-hand side variables to be weakly exogenous.

The cointegrating vector is given by

$$r = b_l l + b_\pi \pi + b_y y, \tag{3}$$

where the normalisation has been chosen such that the coefficient on the short-term interest rate is unity. Note that equation (3) coincides with the original TR if $b_l = 0$, $b_\pi = 1.5$ and $b_y = 0.5$.

Since any of the four variables might adjust to disequilibria in the cointegrating vector, a correction for the potential endogeneity bias which arises in the estimation of b_l, b_π and b_y is necessary.[12] Hamilton suggests estimating equation (3) by including the current, past and future changes of the right-hand side variables. We then fit

$$r_t = a + b_l l_t + b_\pi \pi_t + b_y y_t + \sum_{p=-1}^{1} (a_{lp} \Delta l_{t+p} + a_{\pi p} \Delta \pi_{t+p} + a_{yp} \Delta y_{t+p}) + v_t. \tag{4}$$

Hamilton argues that the residuals v_t are likely to be serially correlated and proposes applying a GLS technique originally due to Stock and Watson [29] to correct the standard errors. We assume an AR(1) structure for v_t to arrive at the estimates presented in Table 4.[13] For brevity, we only present the estimates of the b coefficients and not of the auxiliary a parameters.

[11] Of these parameters, four are constants, 64 describe the reaction of Δr_t, Δl_t, $\Delta \pi_t$ and Δy_t to their lagged values, three capture the cointegrating vector and another four are the feedback coefficients.

[12] See Maddala and Kim [24] for alternative approaches to correct this bias.

[13] Estimations assuming an AR(2) process for v_t lead to very similar results. We set $p = -1$ to 1 since preliminary estimations with two lags and leads yielded insignificant coefficient estimates for the variables with $p = -2$ and 2.

Table 4: Estimation of the cointegrating vector

$$r_t = a + b_l l_t + b_\pi \pi_t + b_y y_t + \sum_{p=-1}^{1} (a_{lp}\Delta l_{t+p} + a_{\pi p}\Delta \pi_{t+p} + a_{yp}\Delta y_{t+p}) + v_t$$

and

$$\rho_t = \widetilde{a} + \widetilde{b}_l l_t + \widetilde{b}_y y_t + \sum_{p=-1}^{1} (\widetilde{a}_{lp}\Delta l_{t+p} + \widetilde{a}_{yp}\Delta y_{t+p}) + \widetilde{v}_t$$

	equation (4)		equation (5)
b_l	0.827*** (0.174)	$\widetilde{b}_l$	0.771*** (0.146)
b_π	0.900** (0.365)	$\widetilde{b}_\pi$	1.000 (restricted)
b_y	0.358* (0.207)	$\widetilde{b}_y$	0.437** (0.209)
$\overline{R}^2$	0.648	$\overline{R}^2$	0.460

Note: GLS estimates, sample 1988:3-2002:1. Standard errors in parentheses (), */**/*** denotes significance at the ten / five / one percent level. Estimates of auxiliary coefficients a and $\widetilde{a}$ not reported.

Interestingly, the coefficient estimate on the output gap is with 0.36 close to the value of 0.5 originally suggested by Taylor, while the sum of the parameters fitted for l_t and π_t $(0.83 + 0.90 = 1.73)$ is close to the coefficient of 1.5 proposed for inflation. We define the error-correction term as $ec_t^r = r_t - 0.83 l_t - 0.90\pi_t - 0.36 y_t$ and will use it in Section 4.4 to assess how Δr_t adapts to disequilibria. First, however, we study the cointegrating vector more carefully.

4.3 Interpreting the cointegrating vector

In the estimation of equation (3) we obtain coefficients on the inflation rate and the output gap which are close to those originally suggested by Taylor. A Wald test does not reject

$$\text{Hypothesis 1}: \; b_\pi = 1.5, \, b_y = 0.5$$

and yields a p-value of 0.20 (see Table 5). However, interpreting the cointegrating vector as the original TR would imply ignoring the role of the long-term interest rate.

Table 5: Hypothesis tests for the cointegrating vector

$$r = b_l l + b_\pi \pi + b_y y$$

Hypothesis	p-value
1: $b_\pi = 1.5$, $b_y = 0.5$	0.198
2: $b_\pi = 1.0$	0.785
3: $b_\pi = 1$, $b_l = b_y = 0.5$	0.164

Note: Coefficient on r_t is normalised to unity.

We argue in Section 6 that movements in l_t capture shifts in the public's perception of the long-run inflation objective. If this is the case, equation (3) represents a forward-looking version of the TR since the short-term rate tends to be raised in reaction to expected future long-run inflation. It seems natural to ask why both the current rate of inflation and the public's long-run expectation of it should enter the reaction function. One possible explanation is that policymakers set r_t such that the *real* short-term nominal interest rate responds to long-run inflation expectations and the output gap. We therefore next test whether π_t can be restricted to have a unit coefficient in the cointegrating vector, i.e. whether

$$\text{Hypothesis 2} : b_\pi = 1.0,$$

and obtain a p-value of 0.78. This results leads us to consider as restricted I(1) specification of the TR the model for which the error-correction term is obtained from

$$\rho_t = \widetilde{a} + \widetilde{b}_l l_t + \widetilde{b}_y y_t + \sum_{p=-1}^{1} (\widetilde{a}_{lp} \Delta l_{t+p} + \widetilde{a}_{yp} \Delta y_{t+p}) + \widetilde{v}_t. \tag{5}$$

The second column of Table 4 shows that $\widetilde{b}_l$ is somewhat smaller than b_l in equation (4) and that $\widetilde{b}_y$ is larger than b_y.[14] We define the error-correction term resulting from this specification of the TR as $ec_t^\rho = \rho_t - 0.77 l_t - 0.44 y_t$.

[14] However, a test of the joint hypothesis $\widetilde{b}_l = b_l$ and $\widetilde{b}_y = b_y$ does not reject (p-value of 0.89).

It is noteworthy that this restricted cointegrating vector resembles the original TR. In fact, a test imposing in equation (4)

$$\text{Hypothesis 3}: b_\pi = 1.0,\ b_l = b_y = 0.5,$$

which matches Taylor's original coefficient suggestions of 1.5 for inflation and 0.5 for the output gap, is not rejected (p-value = 0.16).

Next we estimate the complete reaction function of the short-term interest rate. In particular, we consider two alternative specifications. The first of these uses the unrestricted error-correction term $ec_t^r = r_t - 0.83l_t - 0.90\pi_t - 0.36y_t$. The second specification applies the error-correction term obtained when the real interest rate is imposed in the cointegrating vector, $ec_t^\rho = \rho_t - 0.77l_t - 0.44y_t$.

4.4 The I(1) specification of the TR

After having fitted the cointegrating vector we next complete the estimation of our interest rate reaction function by analysing the feedback of the error-correction term to the short-term interest rate.[15] We estimate the unrestricted I(1) version of the TR, which uses the error-correction term ec_{t-1}^r, as

$$\Delta r_t = c + \sum_{p=0}^{1} (c_{lp}\Delta l_{t-p} + c_{\pi p}\Delta\pi_{t-p} + c_{yp}\Delta y_{t-p}) + c_r\Delta r_{t-1} + c_e ec_{t-1}^r + w_t, \tag{6}$$

where we again include a dummy for the ERM crisis. Equation (6) captures how movements of the short rate depend on the current and lagged changes of the long rate, inflation and the output gap, on its own past change and on the deviation of the level of r in the last quarter from its long-run equilibrium.[16] We expect c_e to be negative since such deviations should lead to offsetting interest rate movements. We estimate equation (6) with two-stage least squares using lagged changes of the long rate as instruments in order to account for potential simultaneity between Δr_t and Δl_t.[17] The regression output is presented in the left panel of Table 6.

[15] For the remaining three system equations, the data suggest a feedback of the error-correction term to inflation, but not to the long rate or the output gap. In the interest of brevity, we do not discuss these results here.

[16] Preliminary estimations with up to three lags of the changes of r, l, π and y did not yield significant coefficient estimates for any of these variables.

[17] Instrumenting with the long rate from the US yields similar results.

The restricted I(1) specification of the TR, which uses ec^{ρ}_{t-1} instead of ec^{r}_{t-1}, is given by

$$\Delta r_t = \widetilde{c} + \sum_{p=0}^{1} (\widetilde{c}_{lp} \Delta l_{t-p} + \widetilde{c}_{\pi p} \Delta \pi_{t-p} + \widetilde{c}_{yp} \Delta y_{t-p}) + \widetilde{c}_r \Delta r_{t-1} + \widetilde{c}_e ec^{\rho}_{t-1} + w_t. \tag{7}$$

The regression results are shown in the right panel of the table. Next we drop insignificant variables and obtain the final specifications

$$\Delta r_t = c + c_{\pi 0} \Delta \pi_t + c_{y0} \Delta y_t + c_r \Delta r_{t-1} + c_e ec^{r}_{t-1} + w_t \tag{8}$$

and

$$\Delta r_t = \widetilde{c} + \widetilde{c}_{\pi 0} \Delta \pi_t + \widetilde{c}_{y0} \Delta y_t + \widetilde{c}_r \Delta r_{t-1} + \widetilde{c}_e ec^{\rho}_{t-1} + w_t, \tag{9}$$

the regression output for which also is reported in Table 6. The constants in equations (8) and (9) are negative, which suggests that interest rates in the euro area tended to decline between 1988 and 2002. This might capture the convergence of European interest rates. Furthermore, changes in the interest rate seem to be autocorrelated and to react to movements of inflation and the output gap as well as to the error-correction term. As expected, a deviation of the level of the short-term interest rate from its long-run equilibrium appears to cause offsetting future interest rate changes.

It is notable that the current change of the long rate does not seem to impact on Δr_t. However, this is compatible with the interpretation of l_t as a proxy for the market perception of the long-run inflation objective. As we show in Section 6, a better measure of this perception, which is available only for a short sample period, is effectively uncorrelated with changes in the short-term rate.

Lastly, Table 6 indicates that the restricted I(1) specification of the TR, which explores the possibility that short-term interest rates respond to the real rate and which therefore uses ec^{ρ}_t, fits the data virtually as well as its unrestricted counterpart, which applies ec^{r}_t. Having estimated two versions of the TR using the cointegration approach, we next demonstrate that these I(1) specifications capture the interest rate setting in the euro area better than the traditional model.

Table 6: Cointegration specification of the TR

	unrestricted I(1)			restricted I(1)	
	equation (6)	equation (8)		equation (7)	equation (9)
	TSLS	OLS		TSLS	OLS
c	-0.377*** (0.105)	-0.418*** (0.104)	$\widetilde{c}$	-0.342*** (0.098)	-0.378*** (0.096)
c_{l0}	0.362 (0.615)	-	$\widetilde{c}_{l0}$	0.335 (0.602)	-
c_{l1}	-0.066 (0.373)	-	$\widetilde{c}_{l1}$	-0.043 (0.363)	-
$c_{\pi 0}$	0.473 (0.311)	0.628*** (0.151)	$\widetilde{c}_{\pi 0}$	0.486 (0.307)	0.629*** (0.151)
$c_{\pi 1}$	0.192 (0.163)	-	$\widetilde{c}_{\pi 1}$	0.187 (0.162)	-
c_{y0}	0.190* (0.110)	0.266*** (0.089)	$\widetilde{c}_{y0}$	0.203* (0.109)	0.278*** (0.089)
c_{y1}	-0.029 (0.106)	-	$\widetilde{c}_{y1}$	-0.030 (0.106)	-
c_r	0.351** (0.139)	0.370*** (0.091)	$\widetilde{c}_r$	0.339** (0.136)	0.361*** (0.091)
c_e	-0.171*** (0.051)	-0.189*** (0.049)	$\widetilde{c}_e$	-0.165*** (0.048)	-0.183*** (0.048)
$\overline{R}^2$	0.617	0.578	$\overline{R}^2$	0.619	0.576
AIC	-	0.755	AIC	-	0.758
BIC	-	0.972	BIC	-	0.975

Note: TSLS and OLS estimates, sample 1988:4-2002:2 and 1988:3-2002:2, respectively. Instruments are lagged changes of the long rate. Standard errors in parentheses (), */**/*** denotes significance at the ten / five / one percent level, AIC the Akaike criterion, BIC the Schwarz criterion. Dummy for 1992:3 included but not reported here.

5 Comparison of the models

Section 3 argued that the non-stationarity of interest rates, inflation and the output gap in the euro area might invalidate the conclusions drawn from the traditionally specified TR. We here present evidence of the econometric shortcomings of this model and compare it to the two I(1) specifications derived in Section 4. First, we present the results from a series of diagnostic tests. Second, we simulate the three versions of the TR in order to assess the responsiveness of the short-term interest rate to permanent shocks in inflation and the output gap. Third, we discuss the forecasting ability of the different reaction functions.

5.1 Diagnostic tests

Table 7 presents the test statistics for a number of standard diagnostic tests. Note that, while the residuals of the traditional I(0) formulation appear autocorrelated, both I(1) specifications pass tests for serial correlation in the residuals. This suggests that the traditionally specified TR fails to capture appropriately the dynamics of the data. We do not detect evidence of non-normality, ARCH, heteroskedasticity or model mis-specification, as defined in the reset test, for any of the three models.

Next we turn to the stability of the different models. Given that they are estimated over a sample which includes the convergence of the national economies before the introduction of the euro, one might expect parameter instability. Figure 2 presents the cusum and cusum of squares for the three models. While we detect signs of instability for the traditional specification of the TR, the I(1) models perform well.[18]

In order to test for structural breaks, we recursively calculate Chow breakpoint tests. Figure 3 shows that the test statistics for the I(1) specifications of the TR lie above the ten percent critical value and thus reveal no evidence of a structural break. Interestingly, there also is no sign of instability in 1999. The introduction of the euro thus does not seem to have altered interest rate setting significantly.[19] For the I(0) formulation, on the

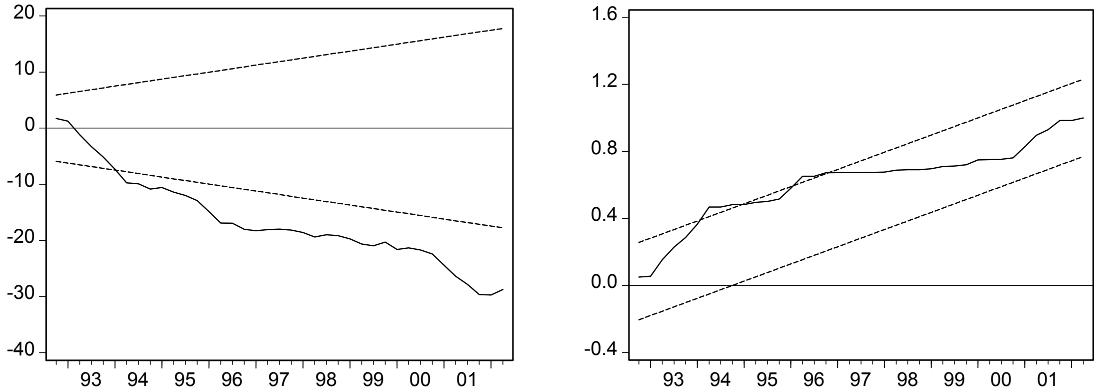
[18]Recursive coefficient estimates appear stable for all three specifications and are not reported for brevity.

[19]It could thus be argued that shifting the responsibility for monetary policy to the ECB did not

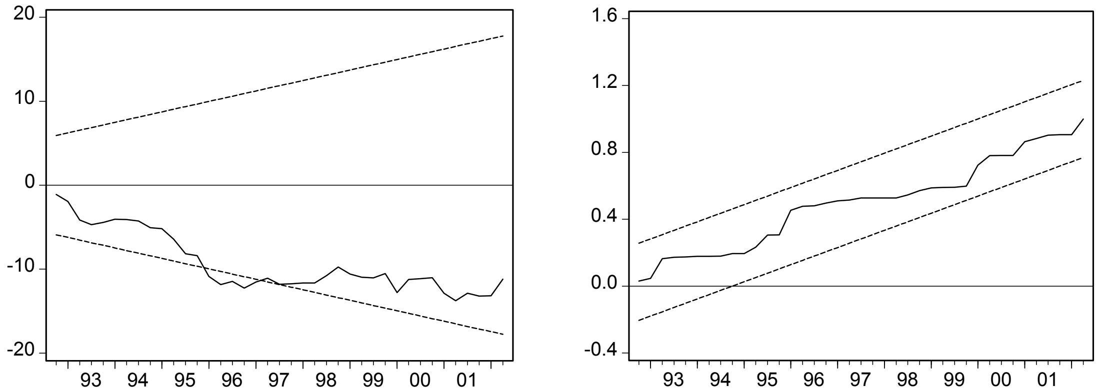
Figure 2: Cusum tests

Cumulated sum of residuals | Cumulated sum of squared residuals

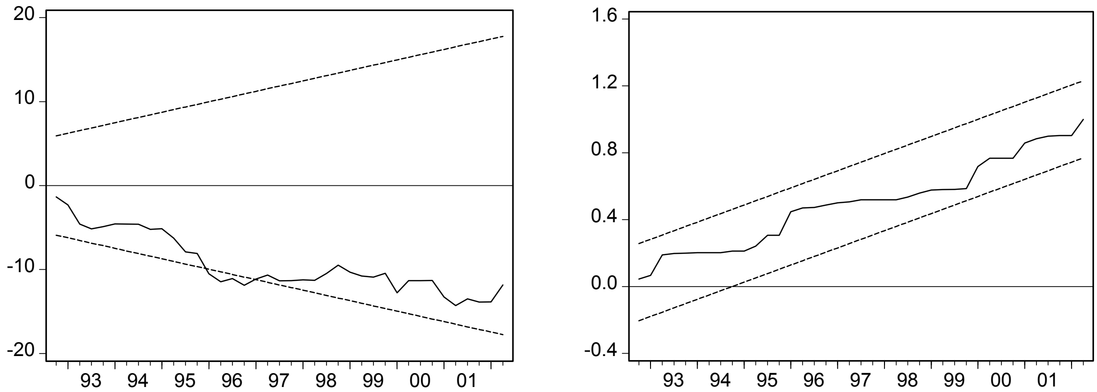
traditional I(0)



unrestricted I(1)



restricted I(1)



Note: Cumulated sums of simple and squared residuals with 95% confidence intervals.

Table 7: F-test statistics of diagnostic tests

Hypothesis (test)	Specification of TR: traditional I(0)	unrestricted I(1)	restricted I(1)
No AR(1) (Q-statistics)	14.657**	0.001	0.001
Normality (Jarque-Bera test)	1.297	0.015	0.038
No serial correlation (F-statistics LM(2))	9.334***	0.001	0.002
No ARCH (F-statistics LM(1))	1.726	0.113	0.100
No heteroskedasticity (F-statistics White test)	1.141	0.484	0.557
No mis-specification (F-statistics reset(1))	0.629	1.646	1.880

Note: Sample period for traditional I(0) specification of the TR 1988:2 - 2002:2, for the I(1) formulations 1988:3 - 2002:2. */**/*** denotes significance at the ten / five / one percent level.

other hand, the Chow tests indicate instability. It thus appears that the traditional model is not stable over the sample period, which suggests that it might forecast poorly.

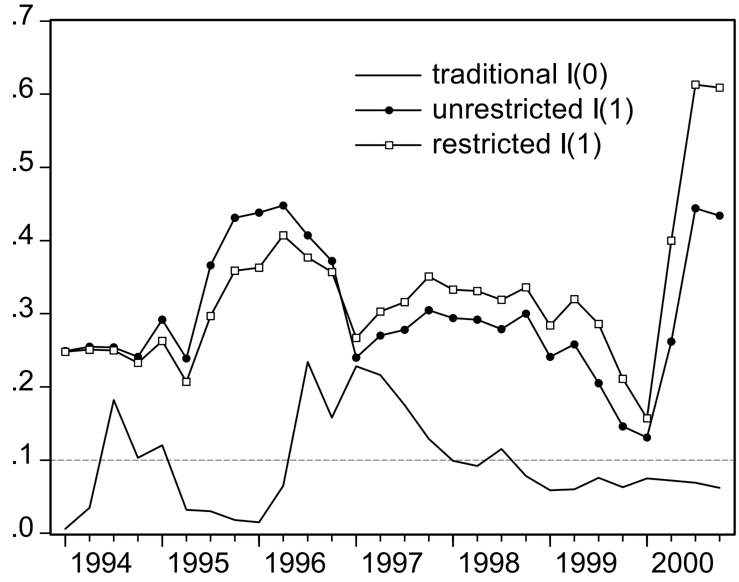
Overall, these results point to considerable econometric shortcomings of the standard formulation of the TR. It seems preferable to model interest rate setting in the euro area using the cointegration approach instead. However, and as mentioned above, the non-stationarity of the data and the problems arising in the estimation of the I(0) model may disappear as more observations for the euro area become available.

5.2 Simulations

Next we present the simulated reactions of the short-term interest rate to a permanent increase in inflation and the output gap, respectively. The purpose of this analysis is to compare the dynamics implied by the three specifications of the TR. In particular, we

expose interest rate setting in the euro area to the Lucas critique (Lucas [23]).

Figure 3: p-values of recursive Chow tests



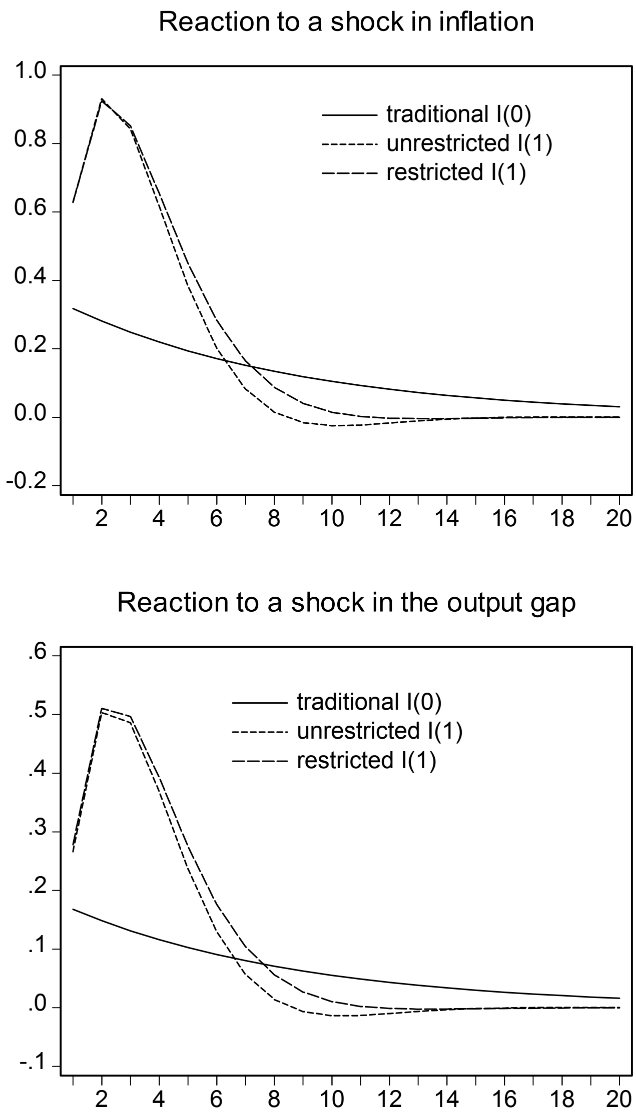
Note: p-values of recursive estimates of Chow breakpoint tests with 10% critical value.

examine whether the size and speed of interest rate responses are similar for all models or whether they suggest different degrees of responsiveness of monetary policy.

Figure 4 shows the interest rate reaction to a permanent unit increase in $t = 1$ of inflation (upper plot) and of the output gap (lower plot). The policy response under the traditional specification of the TR implies both for the inflation and the output gap shock a small immediate increase of the interest rate that is subsequently slowly undone. The I(1) formulations, by contrast, predict a large immediate response of the interest rate and a fast return to equilibrium.

The sharp differences in the estimated dynamic responses provide additional evidence that the traditional specification of the TR fails to capture fully the dynamics in the data. Moreover, they imply that if past patterns of interest rate setting are used to understand policy decisions by the ECB, it is important that the non-stationarity of the data be taken into account. In particular, assume that policy decisions are best described by the I(1) specification but that the researcher instead uses the traditional TR to forecast interest rate changes. In this situation, actual monetary policy is likely to be more activist than predicted by his model.

Figure 4: Simulated responses of the short-term interest rate



Note: Responses to a permanent unit increase of inflation at time $t = 1$ (upper plot) and of the output gap (lower plot).

5.3 Forecasts

As an alternative test for mis-specification we compare the forecasts of the three models. For this purpose, we re-estimate the three reaction functions up to 1998:4 and use the remaining observations to evaluate the out-of-sample forecasts. Choosing 1998:4 as end point of the sample allows us to test whether reaction functions estimated with data up to the introduction of the euro are able to capture the interest rate setting of the ECB.

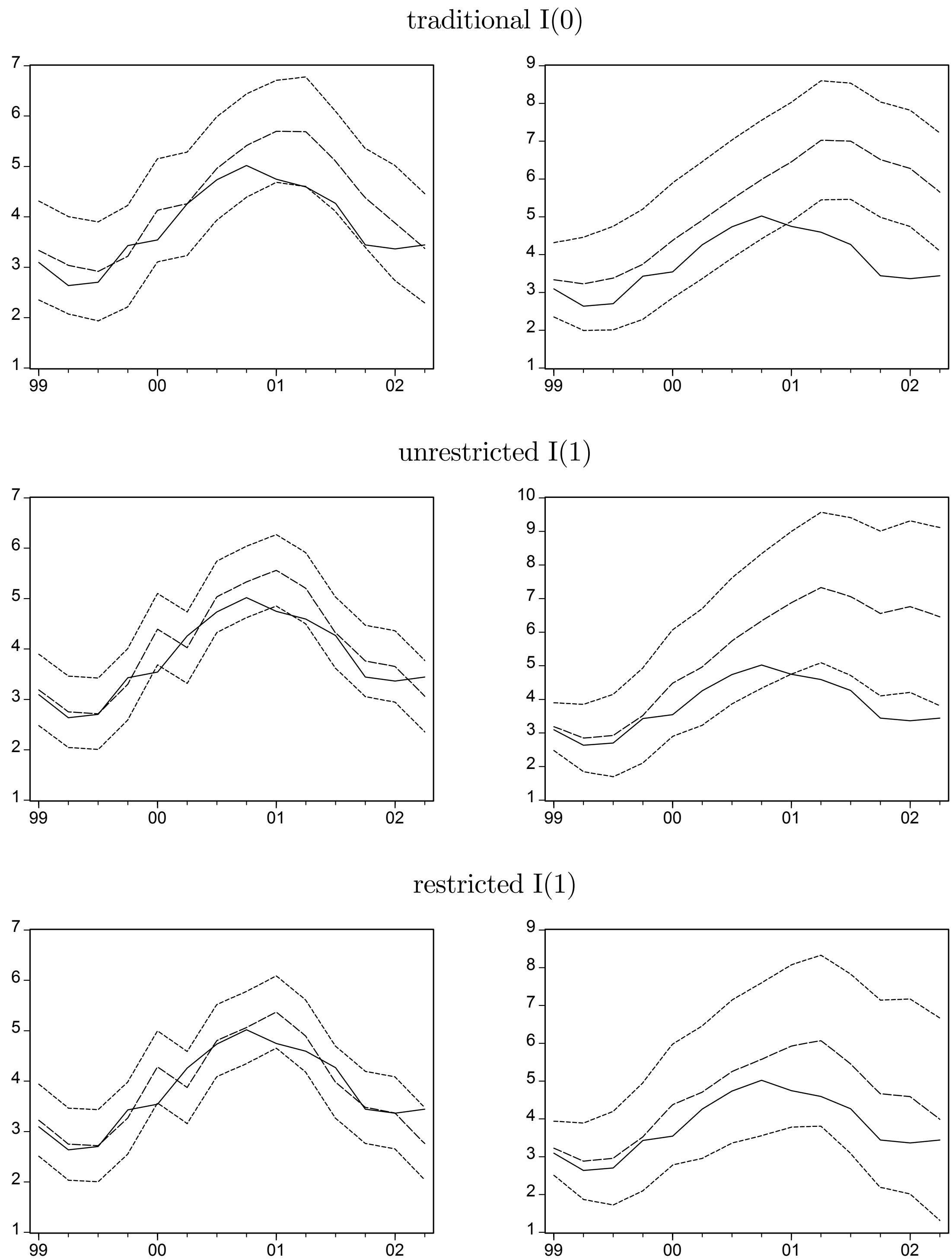
Figure 5 shows the static and dynamic forecasts of r_t for 1999:1 to 2002:2. The static forecast calculates the predicted short-term interest rate at time t using the actual lagged short-term rate, while the dynamic forecast uses past forecasts of r_t. Note that we always use the actual values of l_t, π_t and y_t.

For the I(0) formulation of the TR the actual interest rate lies within the 95% confidence band of the static forecast, but deviates significantly from the dynamic forecast from 2001 onwards. This casts doubt on the forecasting ability of the traditional specification of the TR. The same conclusion is reached for the unrestricted I(1) model, the forecasts of which resemble those of the I(0) specification. By contrast, the restricted I(1) formulation appears to predict actual policy well. The short-term interest rate lies outside the 95% confidence interval of the static forecast only once, and it stays within the confidence region of the dynamic prediction for the entire forecast period. Thus, this specification of the TR seems to reflect interest rate setting before and after the introduction of the euro well.

Table 8 shows the root mean squared errors of the different forecasts. The restricted cointegration model yields the smallest errors for both the static and the dynamic method, while the traditional I(0) formulation of the TR displays the worst performance in the static and the unrestricted I(1) specification in the dynamic forecast. Conditional on the caveat that the non-stationarity of the data series studied here might disappear in the years to come, it appears that the restricted I(1) model of the TR describes interest rate setting in the euro area best.

Figure 5: Interest rate forecasts (in percent)

One-step-ahead static forecast s One-step-ahead dynamic forecasts



Note: Static and dynamic out-of-sample forecasts. Solid lines show the actual interest rate.

Table 8: Root mean squared errors

Specification of the TR	static forecast	dynamic forecast
traditional I(0)	0.585	1.745
unrestricted I(1)	0.411	1.970
restricted I(1)	0.357	0.841

Note: RMSEs of the static and the dynamic forecasts over the period 1999:1 to 2002:2.

6 Interpreting the long rate

The analysis above rested on the assumption that the long rate is a good proxy for the public's perception of long-run inflation. However, this interpretation may be disputed since the expectations hypothesis (EH) holds that l_t is determined by current and expected future short-term rates and, potentially, a constant term premium.[20] Thus, movements in long interest rates may be largely due to changes in market participants' expectations of monetary policy in the near term. Here we provide evidence suggesting that the long rate does in fact also contain information on long-run inflation expectations and that, if anything, the impact of near-term expectations on monetary policy is limited.

As a preliminary it is useful to note that the EH is typically rejected by the data, especially when the hypothesis that the slope of the yield curve predicts future changes in long rates is tested (see e.g. Hardouvelis [19]).[21] While it often is assumed that time-varying term premia account for this finding, Kozicki and Tinsley [20] and [21] argue that the EH is rejected because the long rate is critically influenced also by market participants' expectations for the short rate in the distant future, which are related to their perceptions of policymakers' long-run inflation objective. Hence, shifts in market participants' views of the long-run inflation rate (or of the credibility of monetary policy) may be an important determinant of l_t.

Kozicki and Tinsley operationalise this concept by defining an "endpoint" of the short-term rate process. This endpoint, which they denote as $r_\infty^{(t)}$ (we follow their notation

[20] Cochrane [9] contains an excellent overview of the EH.

[21] Regressing the change in the long rate on the spread between the long and the short rate (using compounded rates) yields an insignificant parameter estimate also for the euro area.

below), need not be closely correlated with the current stance of monetary policy, and is constructed from the observed term structure as

$$r_{\infty}^{(t)} = \frac{D_T l_{T,t} - D_\tau l_{\tau,t}}{D_T - D_\tau}, \tag{10}$$

where D denotes the duration and where T and τ are the maturities of two underlying long-run investments ($T > \tau$).[22] It should be noted that $r_{\infty}^{(t)}$ is identical to the implied forward rate between $t + \tau$ and $t + T$ obtained from the coupon-bearing term structure (see Campbell, Lo and MacKinley [6] p. 408, equation (10.1.20)). Goodfriend [17] argues that movements of the long end of the term structure, which impact on this forward rate, are useful in diagnosing "inflation scares", implying that policymakers may wish to react to l_t.

Kozicki and Tinsley [20] link $r_{\infty}^{(t)}$ and the market expectation of long-run inflation using the Fisher equation. They denote the public's perception of the long-run inflation objective as $\pi_{\infty}^{(t)}$ and argue that the endpoint of the short rate process is given by

$$r_{\infty}^{(t)} = \rho_{\infty}^{(t)} + \pi_{\infty}^{(t)},$$

where $\rho_{\infty}^{(t)}$ is the endpoint of the short-term real interest rate. Assuming, as in the quote above, that $\rho_{\infty}^{(t)}$ is constant, it follows that movements in $\pi_{\infty}^{(t)}$ are directly reflected in $r_{\infty}^{(t)}$. We therefore construct $\pi_{\infty}^{(t)}$ for the euro area with T = ten years and τ = seven years.[23] Since the seven-year bond yield for the euro area is available from 1994:1 onwards, we only have data on $\pi_{\infty}^{(t)}$ for the period 1994:1 to 2002:2.

We first investigate the correlations between the changes of l_t, $\pi_{\infty}^{(t)}$ and r_t and then present regressions involving l_t and $\pi_{\infty}^{(t)}$.[24] Reporting correlations of first-differenced data, Table 9 shows that the long rate is correlated both with the short rate and the expected level of long-run inflation. This indicates that the use of l_t as a measure of long-run inflation may be correct, but also that it is contaminated by the current short rate. By contrast, $\pi_{\infty}^{(t)}$ is essentially uncorrelated with r_t. We thus reach two important conclusions.

[22] D_T is given by $(1 - B^T)/(1 - B)$ with $B \equiv 1/(1 + \overline{l_{T,t}})$.

[23] We calculate $r_{\infty}^{(t)}$ using equation (10) and set $\pi_{\infty}^{(t)}$ equal to this variable. Given the assumption of a constant $\rho_{\infty}^{(t)}$ this does not distort the estimates of the parameter on $\pi_{\infty}^{(t)}$ below.

[24] We concentrate on changes since all variables appear non-stationary (see Table 1).

First, movements in the long rate seem due to two factors, $\pi_\infty^{(t)}$ and r_t. Second, the changes in $\pi_\infty^{(t)}$ and r_t appear orthogonal. Thus, there seem to be two distinct sources of movements in the long rate.

Table 9: Correlations

	Δl_t	$\Delta\pi_\infty^{(t)}$
$\Delta\pi_\infty^{(t)}$	0.378	1
Δr_t	0.215	0.113

Note: Sample period 1994:1-2002:2.

We can test the hypothesis that l_t is significant in the cointegrating vector because of $\pi_\infty^{(t)}$ by replacing the long rate with the endpoint of inflation in equation (4). Due to the short data sample, we exclude insignificant led and lagged changes from equation (4) and estimate

$$r_t = a + b'_\infty \pi_\infty^{(t)} + b'_\pi \pi_t + b'_y y_t + a'_\infty \Delta\pi_\infty^{(t)} + a'_\pi \Delta\pi_t + a'_y \Delta y_t + v'_t. \tag{11}$$

For comparison, we also fit

$$r_t = a + b_l l_t + b_\pi \pi_t + b_y y_t + a_l \Delta l_t + a_\pi \Delta\pi_t + a_y \Delta y_t + v_t. \tag{12}$$

Table 10 shows the regression output.[25] We find that the estimate of b'_∞ is smaller than b_l, which seems due to the fact that $\pi_\infty^{(t)}$ is more volatile than l_t (the standard deviations are 3.24 and 1.56, respectively). While therefore $\overline{R}^2$ is smaller for equation (11) as well, long-run inflation is clearly significant in the cointegrating vector. A further interesting result is that, while the estimate of b'_y is roughly the same as in equation (12), b'_π is larger and has a smaller p-value than b_π. This might be due to multicollinearity between l_t and π_t. Those two variables have a correlation of 0.28, while the correlation between $\pi_\infty^{(t)}$ and π_t is -0.04. Using $\pi_\infty^{(t)}$ instead of l_t might allow for a more precise identification of the role of current inflation in the TR. It is striking that we do not reject that b'_π equals unity, which can be interpreted as support for the restricted I(1) model.

Finally, it ought to be noted that the significance of the long rate in this study arguably depends on the choice of sample period. Monetary policy ought to react to movements

[25] We drop insignificant current changes in order to improve the fit of the remaining parameters.

Table 10: Sensitivity analysis of the long rate

$$r_t = a + b'_\infty \pi_\infty^{(t)} + b'_\pi \pi_t + b'_y y_t + a'_\infty \Delta\pi_\infty^{(t)} + a'_\pi \Delta\pi_t + a'_y \Delta y_t + v'_t$$

and

$$r_t = a + b_l l_t + b_\pi \pi_t + b_y y_t + a_l \Delta l_t + a_\pi \Delta\pi_t + a_y \Delta y_t + v_t$$

	equation (11)		equation (12)
b'_∞	0.105^{**}	b_l	0.570^{***}
	(0.043)		(0.097)
b'_π	0.760^{***}	b_π	0.502^{**}
	(0.225)		(0.207)
b'_y	0.230^{*}	b_y	0.134
	(0.117)		(0.117)
$\overline{R}^2$	0.304	$\overline{R}^2$	0.775

Note: GLS estimates, sample 1994:1-2002:2. Standard errors in parentheses (), $^*/^{**}/^{***}$ denotes significance at the ten / five / one percent level. Equation (11) is estimated without a'_∞ and a'_y, for equation (12) we drop all current changes.

in the long rate only if they reflect movements in $\pi_\infty^{(t)}$. If the ECB successfully stabilises the public's perception of the long-run inflation objective, the long rate should cease to be significant in the TR for the euro area.

7 Conclusions

In this paper we compare the traditional formulation of the Taylor rule, which is estimated on level data, to an interest rate reaction function which takes into account the non-stationarity of the data. We show that for the euro area the traditional model displays signs of instability and mis-specification. We estimate the Taylor rule using a cointegration approach and demonstrate that, by contrast, this yields a stable reaction function. The cointegrating vector of this unrestricted I(1) model comprises the nominal short and long-term interest rates, inflation and the output gap. We demonstrate that the long rate can be seen as a proxy for the public's perception of long-run inflation, which implies that interest rate setting in the euro area has in that sense been forward-looking.

We also consider a restricted version of the I(1) model of the Taylor rule in which a unit coefficient on inflation is imposed. Under this specification the real short-term interest rate is raised in reaction to an increased output gap and if markets seem to expect a higher future inflation. Thus, monetary policy is set such that the so-called Taylor principle is met. The resulting reaction function passes the standard specification tests and yields better out-of-sample forecasts than the traditional Taylor rule and the unrestricted I(1) model.

References

[1] Alesina, Alberto, Olivier Blanchard, Jordi Gali, Francesco Giavazzi and Harald Uhlig (2001), Defining a macroeconomic framework for the euro area: Monitoring the European Central Bank (3), CEPR, London.

[2] Amato, Jeffery D. and Thomas Laubach (1999), "The value of interest-rate smoothing: How the private sector helps the Federal Reserve", Federal Reserve Bank of Kansas City Economic Review 84 (3), pp. 47-64.

[3] Begg, David, Fabio Canova, Paul De Grauwe, Antonio Fatas and Philip Lane (2002), Surviving the slowdown: Monitoring the European Central Bank (4), CEPR, London.

[4] Brand, Claus and Nuno Cassola (2000), "A money demand system for euro area M3", ECB Working Paper 39.

[5] Breuss, Fritz (2002), "Is ECB's monetary policy optimal already?", mimeo, Vienna University.

[6] Campbell, John Y., Andrew W. Lo and A. Craig MacKinlay (1997), The econometrics of financial markets, Princeton University Press, Princeton.

[7] Clarida, Richard, Jordi Gali and Mark Gertler (1998), "Monetary policy rules in practice: Some international evidence", European Economic Review 42, pp. 1033-1067.

[8] Clausen, Volker and Bernd Hayo (2002), "Monetary policy in the euro area – Lessons from the first years", ZEI Working Paper B02-09.

[9] Cochrane, John H. (2001), Asset pricing, Princeton University Press, Princeton.

[10] Coenen, Günter and Volker Wieland (2000), "A small estimated euro area model with rational expectations and nominal rigidities", ECB Working Paper 30.

[11] Doornik, Jurgen A. and David F. Hendry (1997), Modelling dynamic systems using PcFiml 9.0 for Windows, International Thomson Business Press, London.

[12] Fagan, Gabriel, Jérôme Henry and Ricardo Mestre (2001), "An area-wide model (AWM) for the euro area", ECB Working Paper 42.

[13] Faust, Jon, John H. Rogers and Jonathan H. Wright (2001), "An empirical comparison of Bundesbank and ECB monetary policy rules", Board of Governors of the Federal Reserve System International Finance Discussion Paper 705.

[14] Gerdesmeier, Dieter and Barbara Roffia (2003), "Empirical estimates of reaction functions for the euro area", ECB Working Paper 206.

[15] Gerlach, Stefan and Gert Schnabel (2000), "The Taylor rule and interest rates in the EMU area", Economics Letters 67, pp. 165-171.

[16] Gerlach-Kristen, Petra (2002), "A Taylor rule for the euro area", working paper, University of Basel.

[17] Goodfriend, Marvin (1998), "Using the term structure of interest rates for monetary policy", Federal Reserve Bank of Richmond Economic Quarterly 84 (3), pp. 13-30.

[18] Hamilton, James D. (1994), Time series analysis, Princeton University Press, Princeton.

[19] Hardouvelis, Gikas A. (1994), "The term structure spread and future changes in long and short rates in the G7 countries – Is there a puzzle?", Journal of Monetary Economics 33, pp. 255-283.

[20] Kozicki, Sharon and P.A. Tinsley (2001), "Shifting endpoints in the term structure of interest rates", Journal of Monetary Economics 47, pp. 613-652.

[21] Kozicki, Sharon and P.A. Tinsley (2001), "Term structure views of monetary policy under alternative models of agent expectations", Journal of Economic Dynamics and Control 25, pp. 149-184.

[22] Levin, Andrew, Volker Wieland and John C. Williams (1999), "Robustness of simple monetary policy rules and model uncertainty"; in: John B. Taylor, ed., Monetary policy rules, Chicago University Press, Chicago.

[23] Lucas, Robert E. Jr (1976), "Econometric policy evaluation: A critique", Carnegie-Rochester Conference Series on Public Policy 1, pp. 19-46.

[24] Maddala, G.S. and In-Moo Kim (2000), Unit roots, cointegration, and structural change, Cambridge University Press, Cambridge.

[25] Orphanides, Athanasios (2000), "The quest for prosperity without inflation", ECB Working Paper 15.

[26] Peersman, Gert and Frank Smets (1999), "The Taylor rule: A useful monetary benchmark for the euro area?", International Finance 2 (1), pp. 85-116.

[27] Rudebusch, Glenn D. (2002), "Term structure evidence on interest-rate smoothing and monetary policy inertia", Journal of Monetary Economics 49, pp. 116-1187

[28] Sack, Brian (1998), "Uncertainty, learning, and gradual monetary policy", Federal Reserve Board Finance and Economics Discussion Series Paper 34.

[29] Stock, James H. and Mark W. Watson (1993), "A simple estimator of cointegrating vectors in higher order integrated systems", Econometrica 61, pp. 783-820.

[30] Svensson, Lars E.O. (1999), "Inflation targeting: Some extensions," Scandinavian Journal of Economics 101 (3), pp. 337-361.

[31] Taylor, John B. (1993), "Discretion versus policy rules in practice", Carnegie-Rochester Conference Series on Public Policy 39, pp. 195-214.

[32] Taylor, John B. (1998), "The robustness and efficiency of monetary policy rules as guidelines for interest rate setting by the European Central Bank", IIES Seminar Paper 649.

[33] Woodford, Michael (1994), "Nonstandard indicators for monetary policy: Can their usefulness be judged from forecasting regressions?", in: N. Gregory Mankiw, ed., Monetary policy, University of Chicago Press and NBER, Chicago.

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