Abstract
We estimate a Taylor rule for the euro area using a model that allows to differentiate between policy inertia and serially correlated shocks. In contrast to most previous research, we employ real-time expectations for inflation and output growth. Our estimates lend support to both policy inertia and serially correlated errors in ECB Taylor rules. Our results also show that the ECB takes expected inflation and expected output growth into account in setting interest rates.

Key words: Taylor rule, ECB, policy inertia, serial correlation, real-time data

JEL classification: C22, E52

Corresponding author: Jakob de Haan, Faculty of Economics, University of Groningen, PO Box 800, 9700 AV Groningen, The Netherlands, Tel. 31-(0)50-3633706; Fax 31-(0)50-3633720; email: jakob.de.haan@rug.nl.
1 Introduction

Taylor (1993) showed that a simple monetary policy rule relating the nominal short-term interest rate to inflation and the output gap accurately describes US monetary policy over the period 1987-1992. Although the Taylor rule may be too simplistic to fully capture monetary policy-making (Svensson, 2003), it has been used extensively ever since. The Taylor rule seems to be a satisfactory approximation of central bank behaviour all over the world. As the Taylor rule should be extended with dynamics, most studies include the lagged interest rate as explanatory variable in the model (see e.g. Clarida et al., 1998). The theoretical underpinning of this modification of the rule as proposed by Taylor is that central banks dislike jumps in the short-term interest rate and prefer interest rate smoothing. The estimated degree of partial adjustment has typically been very high, suggesting monetary policy inertia.

However, Rudebusch (2002) questions monetary policy inertia arguing that the significance of the lagged interest rate may be caused by serially correlated errors. Omitted shocks in the estimated policy rule, like financial crises, will give rise to serially correlated errors. English et al. (2003) suggest a framework that allows distinguishing between policy inertia and serially correlated errors. Their results – based on quarterly U.S. data over 1987-2001 – suggest the presence of both serial correlation and partial adjustment.

In this paper we estimate a Taylor rule for the euro area using the 1990.I-2003.II (quarterly data) and 1998.6-2003.6 (monthly data) periods. Since the European Central Bank (ECB) was only created in the summer of 1998, we follow most previous studies and include pre-euro years in our first sample period. However, we also employ a sample period that starts after the creation of the ECB. Hayo and Hofmann (2006) report that the

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1 Furthermore, monetary policy inertia implies that the term structure should predict future interest rate movements, which turns out not to be the case (see e.g. Campbell and Schiller, 1991).

2 Similarly, Gerlach-Kristen (2004) assumes monetary authorities to react to both the lagged interest rate and an unobserved first-order serially correlated variable. Using quarterly U.S. data over 1987-99 and Kalman filtering, this author finds support for serial correlation and policy inertia. We use the model of English et al. instead of the model of Gerlach-Kristen (2004) since the former does not require Kalman filtering.
reaction functions of the Bundesbank and the ECB are not the same, so that a sample period that includes pre-ECB years may give non-representative results. In contrast to most previous research, we employ real-time expectations for inflation and output growth in our Taylor rule model for the ECB.\(^3\) It is well known that central banks are forward-looking, taking forecasts of inflation and output growth into account.\(^4\) However, authors often use ex post data when estimating Taylor rule models, be it as explanatory variables (thereby neglecting the forward-looking character of monetary policy) or as input to generate expectations. When ex post data are used, it is assumed that the data available to the central bank at the time the decision was taken are the same as those used by the researcher who models central bank behaviour. However, Orphanides (2001) has shown that the use of real-time instead of ex post data leads to very different estimated coefficients in Taylor rule models for the Federal Reserve. Likewise, Sauer and Sturm (2003) find that Taylor rule models for the ECB that use survey information, and therefore combine a forward-looking aspect with the use of real-time data, result in by far the best fit.\(^5\) We therefore use real-time expectations in our model for the ECB. Our estimates lend support to both policy inertia and serially correlated errors in ECB Taylor rules. Our evidence also suggests that the ECB takes expected inflation and output growth into account in setting interest rates.

The remainder of the paper is structured as follows. The next section reviews different Taylor rules, including the model of English et al. (2003). Section 3 discusses the variables used in our estimations and Section 4 contains estimates of several Taylor rule models. Finally, Section 5 offers some concluding comments.

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\(^3\) Previous recent studies include Gerlach and Schnabel (2002), Gerdesmeier and Roffia (2003), Surico (2003), Sauer and Sturm (2003), Carstensen and Colavecchio (2004), and Fourçans and Vranceanu (2004). See De Haan et al. (2005) for a discussion of the ECB’s policies and Gerlach (2004a) for a critique.

\(^4\) See, for instance, Clarida et al. (1999) for a theoretical justification for such a forward-looking behaviour within a New Keynesian model.

\(^5\) Sauer and Sturm (2003) also do not find support for the claim by Faust et al. (2001) that the ECB puts a much higher weight on the output gap relative to inflation than the Bundesbank did.
2 Taylor rule dynamics

Taylor (1993) proposed the following rule:

\[ \hat{i}_t = r^* + \pi^* + k_\pi (\pi_t - \pi^*) + k_y y_t, \]  

(1)

where \( \hat{i}_t \) is the nominal interest rate in period \( t \), \( r^* \) is the equilibrium real interest rate, \( \pi_t - \pi^* \) is the deviation of inflation in period from the inflation target \( \pi^* \) and \( y_t \) is the output gap in period \( t \). Taylor suggested the following values for the coefficients: \( r^* = 2, \pi^* = 2, k_\pi = 1.5 \) and \( k_y = 0.5 \).\(^6\)

This simple policy rule described the Fed’s monetary policy over the period 1987 to 1992 surprisingly well.

Svensson (1999) derives Equation (1) as the theoretically optimal reaction function for a central bank that targets inflation, using a simple model of the economy consisting of an IS curve and a Philips curve. It follows from Svensson’s analysis that even inflation targeting central banks react to a change in the output gap, because it is useful in forecasting future inflation.

In empirical studies, Taylor’s rule is typically modified by including a smoothing parameter, \( \lambda \), to account for monetary policy inertia. To see how this adjusted Taylor rule relates to Taylor’s original rule, we decompose the adjusted model in two equations. Equation (2a) is identical to the original Taylor rule, while Equation (2b) fits it in a partial adjustment framework.

\[ \hat{i}_t = r^* + \pi^* + k_\pi (\pi_t - \pi^*) + k_y y_t \]  

(2a)

\[ i_t = (1 - \lambda)\hat{i}_t + \lambda i_{t-1} + u_t, \]  

(2b)

\(^6\) According to the so called “Taylor principal” \( k_\pi \) should be greater than one to avoid dynamic instability. Only when \( k_\pi > 1 \) the nominal short-term interest rate moves sufficiently in response to inflation to increase the real short-term interest rate (see e.g. Taylor, 2000 and Woodford, 2001).
where \( \hat{i}_t \) is referred to as the Taylor-rule rate in period \( t \), \( i_{t-1} \) is the one-period lagged nominal interest rate and \( u_t \) is an independent identically distributed error term.

Gerlach and Schnabel (2000) and Gerdesmeier and Roffia (2003) show that this partial adjustment model fits euro area data quite well. However, these studies may be criticized on various grounds. First, they do not use real-time data thereby neglecting the Orphanides (2001) critique. Furthermore, these studies ignore that monetary policy is forward-looking and they do not take the non-stationarity of various variables into account.

Rudebusch (2002) criticizes the partial adjustment Taylor rule and proposes an alternative equation which includes a first-order serially correlated error instead of a partial adjustment parameter.

\[
\begin{align*}
\hat{i}_t &= r^* + \pi^* + k_s(\pi_t - \pi^*) + k_y y_t \\
i_t &= \hat{i} + v_t \\
v_t &= \rho v_{t-1} + u_t,
\end{align*}
\]

where \( v \) is a serially correlated error term, \( \rho \) is the serial correlation parameter and the other variables are defined as in Equations (2a) and (2b).

English et al. (2003) combine the partial adjustment model and the serial correlation model to obtain a nested model:

\[
\begin{align*}
\hat{i}_t &= r^* + \pi^* + k_s(\pi_t - \pi^*) + k_y y_t \\
i_t &= (1 - \lambda)\hat{i}_t + \lambda i_{t-1} + v_t \\
v_t &= \rho v_{t-1} + u_t,
\end{align*}
\]

\(^7\) See Gerlach (2004b) for a discussion of other studies estimating a Taylor rule model for the euro area.
where all variables and parameters are defined as above. When Equations (4a), (4b) and (4c) are combined and written in first differences, it becomes possible to distinguish empirically between hypotheses of partial adjustment and serially correlated errors:

\[
\Delta i_t = (1 - \lambda)\Delta \hat{i}_t + (1 - \rho)(\hat{i}_{t-1} - i_{t-1}) + \lambda \rho \Delta i_{t-1} + u_t. \tag{5}
\]

Equation (5) shows that the change in the nominal short-term interest rate is captured by the most recent change in the Taylor-rule rate, \(\Delta \hat{i}_t\), the existing gap between the Taylor-rule interest rate and the actual interest rate in the previous period, \(\hat{i}_{t-1} - i_{t-1}\), and the change in the nominal interest rate one period earlier, \(\Delta i_{t-1}\). Especially the first term on the right-hand-side, \((1 - \lambda)\Delta \hat{i}_t\), is of special importance to our research as it facilitates distinguishing between partial adjustment and serial correlation in the dynamics of the short-term interest rate.\(^8\)

As far as we know, only Castelnuovo (2003) has employed the framework of English et al. (2003). While he cannot exclude that serially correlated policy shocks may play a role in describing the US federal funds rate path, his results support the importance of the lagged interest rate in Taylor-type models for the Federal Reserve.

3 Data

We use quarterly data series for the period 1990.1-2003.2, using a weighted average of the national three-month money market interest rates as the relevant dependent variable. This variable has been obtained from Thomson Financial Datastream. To take the forward-looking nature of monetary policy and the real-time critique of Orphanides (2001) into account, we have obtained expected real-time inflation and output growth time series from

\(^8\) Therefore, Equation (5) enables identifying the effects of both partial adjustment and serially correlated errors without resorting to other evidence, such as the forecastability of the term structure, as suggested by Rudebusch (2002). The test proposed by English et al. (2003) is preferable, since a lack of forecastability of the term structure might reflect violations of the expectations hypothesis assumptions instead of a misspecification of the monetary policy rule (Söderlind et al., 2003).
Consenus. These time series are unique and not revised. This implies that an analysis based on these series is not subject to the real-time critique. Furthermore, the time series are forecasts of inflation and output growth. Every month, major banks in the EMU-countries give their forecasts for the near future, i.e. the current and the next year. We derived quarterly forecast time series from these Consensus series as follows. The first quarter forecast value in year $t$ is defined as the three-month average of the forecasted values for year $t$ in the first three months of year $t$. The forecast values in the remaining quarters of year $t$ are defined as the three-month averages of the forecasted values for year $t + 1$ in the three relevant months of year $t$. Our approach yields a ‘target’ horizon of about four to five quarters, which is quite similar to the optimal policy horizon suggested by Orphanides (2001).\(^9\) Instead of using the output gap, we employ forecasts of GDP growth. As pointed out by Gerlach (2004b), in contrast to expected growth rates, estimates of the output gap do not seem to play any role in the ECB’s Governing Council’s motivation for policy decisions.

As a first step of the analysis, let us briefly examine the data. The Consensus inflation series, shown in Figure 1, closely follows the short-term interest rate. The Consensus forecasts of output growth shows a decline at the time of the ERM crisis and the 2001 terrorist attack.

\(^9\) A drawback of this procedure is that there is a jump in the time series between March and April. However, dummy tests find no evidence for the systematic impact due to this dataset construction.
The ADF tests shown in Table 1 indicate that especially for inflation and the interest rate unit roots are present. To cope with the non-stationarity of most series, we test every Taylor rule for the possible existence of a cointegrating relationship. All Taylor rules, except for Taylor’s original rule, comprise a cointegrating relationship. This implies that the Ordinary Least Squares (OLS) estimates for the original Taylor rule are ex ante known to be spurious.

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10 Results of these cointegration tests are available upon request.
Table 1: (Augmented) Dickey-Fuller level tests

<table>
<thead>
<tr>
<th></th>
<th>Interest Rate</th>
<th>Consensus Inflation</th>
<th>Consensus Output Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without trend</td>
<td>-0.946</td>
<td>-1.070</td>
<td>-3.136**</td>
</tr>
<tr>
<td>With Trend</td>
<td>-2.245</td>
<td>-1.779</td>
<td>-3.185*</td>
</tr>
</tbody>
</table>

Note: (Augmented) Dickey-Fuller tests, including a constant, lagged dependent and first differenced lagged dependent, for the sample period 1990:1-2003:3. */**/*** denote respectively significance at 10%, 5% or 1%

4 Empirical results

Table 2 shows our estimation results for the full sample period. Starting with Taylor’s original specification, we observe in column 1 of Table 2 that the inflation gap estimate, $\hat{k}_\pi = 2.91$, is very significant and the output gap estimate, $\hat{k}_y = 0.20$, is not. A joint Wald-test on these estimates results in a convincing rejection of $k_\pi = 1.5$ and $k_y = 0.5 (P = 0.00)$. These level specification results are spurious since they do not take into account the presence of unit roots in the time series. The reported low Durbin-Watson value, $DW = 0.64$, underpins this.
<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Eq. (1) ***</th>
<th>Eq. (2a) and (2b) ***</th>
<th>Eq. (3a), (3b) and (3c) ***</th>
<th>Eq. (5) ***</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k_o$</td>
<td>3.80 ***</td>
<td>-1.16</td>
<td>1.90</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>(0.48)</td>
<td>(3.32)</td>
<td>(5.01)</td>
<td>(2.01)</td>
</tr>
<tr>
<td>$k_\pi$</td>
<td>2.91 ***</td>
<td>3.10 ***</td>
<td>1.09 ***</td>
<td>3.12 ***</td>
</tr>
<tr>
<td></td>
<td>(0.16)</td>
<td>(0.48)</td>
<td>(0.34)</td>
<td>(0.44)</td>
</tr>
<tr>
<td>$k_y$</td>
<td>0.20</td>
<td>1.99</td>
<td>0.06</td>
<td>1.31</td>
</tr>
<tr>
<td></td>
<td>(0.18)</td>
<td>(1.25)</td>
<td>(0.11)</td>
<td>(0.85)</td>
</tr>
<tr>
<td>$\rho$</td>
<td></td>
<td></td>
<td>0.97 ***</td>
<td>0.32 ***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.05)</td>
<td>(0.08)</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0.82 ***</td>
<td></td>
<td></td>
<td>0.76 ***</td>
</tr>
<tr>
<td></td>
<td>(0.09)</td>
<td></td>
<td></td>
<td>(0.11)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.95</td>
<td>0.98</td>
<td>0.98</td>
<td>0.99</td>
</tr>
<tr>
<td>$DW$</td>
<td>0.64</td>
<td></td>
<td></td>
<td>1.33</td>
</tr>
</tbody>
</table>

Notes: Newey-West standard errors are in parentheses. */**/*** denote respectively significance at 10%, 5% or 1%. # $k_o = r^* + \pi^* - k_y^*$. ** All equations are defined as in the text.
The NLS estimates of the partial adjustment model are given in the second column of Table 2. Once more we find a very significant inflation gap estimate, $\hat{k}_x = 3.10$, and an significant output gap estimate. The smoothing parameter estimate, $\hat{\lambda} = 0.81$, is also significant.

The NLS regression results for the serially correlated error model are largely in line with earlier results. The inflation gap estimate, $\hat{k}_x = 1.09$, is very significant and the output gap estimate, $\hat{k}_y = 0.06$, is not. The parameter point estimate, $\hat{\rho} = 0.97$, is close to 1. And finally, we observe the presence of at least second-order serial correlation in the residuals.

The final model we estimate, is the combined model due to English et al.. We find a very significant inflation gap estimate, $\hat{k}_x = 3.12$, and an insignificant output gap estimate, $\hat{k}_y = 1.31$. Moreover, both the partial adjustment parameter estimate, $\hat{\lambda} = 0.76$, and the serial correlation parameter, $\hat{\rho} = 0.32$, are significant at respectively the 1% and 5% significance levels.

As explained in the Introduction, focusing on the pre-ECB period may yield unreliable estimates. In this section we therefore focus on the period after the creation of the ECB. Even though the ECB became only formally in charge of monetary policy making in 1999, we include some months in 1998 as the interest rate cut at the end of 1998 was clearly coordinated by the ECB. In order to increase the degrees of freedom, we employ monthly observations for these regressions.
Comparing the results of Table 3 with those of Table 2, various conclusions stand out. First, the model of English et al. (2003) again outperforms the other models. Furthermore, the partial adjustment parameter estimate and the serial correlation parameter are significantly different from zero,
suggesting both policy inertia and serially correlated errors in ECB Taylor rules. The main difference between both tables is that for the ECB period both the coefficients for inflation and output gap variables are significantly different from zero. So this evidence suggests that the ECB is not an ‘inflation nutter’, as is sometimes suggested by critics of the ECB. It also suggests that the results of previous studies including pre-ECB observations may be biased.

5 Conclusions
During the last decade, Taylor rules have been proven to be effective frameworks within which monetary policy can be accurately described. However, the lion’s share of this literature disregards the dynamic aspects of the short term interest rate. Rudebusch (2002) rightly criticized conventional Taylor-rule analyses, arguing that the high significance of the partial adjustment models could well be due to persistent shocks that central banks face. The innovative modelling approach by English et al. (2003) enables to unravel the true dynamics of the short term interest rate in Taylor rules. Using recent euro area data we find evidence for the coexistence of partial adjustment and serial correlation within ECB Taylor rules. Gerlach-Kristen (2004) reports similar findings for Taylor rules for the Federal Reserve. In contrast to her analysis, we use real-time data take Orphanides’ (2001) arguments into account. Finally, our results suggest that the ECB is not an ‘inflation nutter’, as the coefficients for inflation and the output gap in our preferred Taylor-rule model estimated for the period after the creation of the ECB are significantly different from zero.
Data Appendix

Sources and definitions of quarterly time series

- **Euro area three-month nominal interest rate** is used as dependent variable in the analysis and it is obtained from Thomson Financial Datastream (Ticker EMESTBIL) for the period 1990.I – 2003.II. Before 1999.I it corresponds to the real GDP-weighted average of national three-month nominal interest rates, from 1999.I it corresponds to EURIBOR.

- **Euro area expected inflation series** is constructed from averages of consumer inflation forecasts published by Consensus Economics for all euro area countries except Luxembourg. National expected inflation series are constructed as follows. For the first quarter of a given year $t$, expected inflation is defined as the average - over the first three months of year $t$ - of the for year $t$ forecasted consumer inflation. For the remaining quarters of year $t$, expected inflation is defined as the average - over the relevant three months of year $t$ - of the for year $t+1$ forecasted consumer inflation. These national series are aggregated with annually-updated real GDP weights.

- **Euro area expected inflation gap** is defined as the euro area expected inflation series (see previous bullet) minus two percent.

- **Euro area expected growth series** is constructed from averages of real GDP growth forecasts published by Consensus Economics for all euro area countries except Luxembourg. National expected real GDP growth series are constructed as follows. For the first quarter of a given year $t$, expected growth in real GDP is defined as the average - over the first three months of year $t$ - of the for year $t$ forecasted growth in real GDP. For the remaining quarters of year $t$, expected real GDP growth is defined as the average - over the relevant three months of year $t$ - of the for year $t+1$ forecasted growth in real GDP. These national series are aggregated with annually-updated real GDP weights.

Sources and definitions of monthly time series

- **Euro area three-month nominal interest rate** is used as dependent variable in the analysis and it is obtained from Thomson Financial Datastream (Ticker EMESTBIL) for the period 1998.6 – 2003.6. Before 1999.1 it corresponds to the real GDP-weighted average of
national three-month nominal interest rates, from 1999.1 it corresponds to EURIBOR.

- **Euro area expected inflation series** is constructed from averages of consumer inflation forecasts published by Consensus Economics for all euro area countries except Luxembourg. Note that the *monthly* national expected inflation series are constructed differently than the earlier described *quarterly* series. For month \( x \) of a given year \( t \), expected (national) inflation is defined as \([((13-x)/12] \) times the inflation forecast for year \( t \) plus \((1-[(13-x)/12]) \) times the inflation forecast for year \( t+1 \). These national series are aggregated with annually-updated real GDP weights.

- **Euro area expected inflation gap** is defined as the euro area expected inflation series (see previous bullet) minus two percent.

- **Euro area expected real GDP growth series** is constructed from averages of real GDP growth forecasts published by Consensus Economics for all euro area countries except Luxembourg. Note that the *monthly* national real GDP growth series are constructed differently than the earlier described *quarterly* series. For month \( x \) of a given year \( t \), expected (national) real GDP growth is defined as \([(13-x)/12] \) times the real GDP growth forecast for year \( t \) plus \((1-[(13-x)/12]) \) times the real GDP growth forecast for year \( t+1 \). These national series are aggregated with annually-updated real GDP weights.
References


