Monetary policy in Germany: a cointegration analysis on the relevance of interest rate rules.

Maria Eleftheriou[*†‡]

December 2005

(Revised version) October 2008

Abstract

The paper attempts to identify an empirical relationship that characterizes the way the Bundesbank adjusted its short-term rate with respect to various objectives. By building on a careful exploration of the properties of the variables involved, it is established that interest rate rules -often remarkably similar to the Taylor rule- remain valid and relevant in a Vector Error Correction framework, and thereby proposing a distinctive interpretation of German monetary policy during the period 1975-1998.

JEL classification: C32, E52, E58

Keywords: cointegration, impulse response analysis, monetary policy, Taylor rule, vector error correction model

[*]Author correspondence: Maria Eleftheriou, Department of Business Economics, Universidad Europea de Madrid, Calle Tajo s/n, 28670 Villaviciosa de Odón (Madrid), Spain. Tel.:(0034)912115200. Email: maria.eleftheriou@uem.es.

[†]This paper is part of the author's doctoral thesis completed at the European University Institute under the supervision of Helmut Lütkepohl. Financial support from the European University Institute and the Greek State Scholarships Foundation is acknowledged.

[‡]An extended version of this paper has been accepted for publication in Economic Modelling.

1 Introduction

The German Central Bank, the Deutsche Bundesbank (DBB henceforth), is commonly associated with the concept of monetary targeting. However, operationally, its policy involves the setting of the short-term interest rate, or, in other words, the translation of its main goals into interest rate objectives. The present paper is based on a careful exploration of the properties of the related variables and attempts to identify an empirical relationship that characterizes the way that the Bundesbank adjusted its short-term rate over time. The estimation of this relationship reveals the implicit way the bank's decisions translated into a reaction function and is of interest since very often EMU monetary policy is compared to what it is believed the Bundesbank would have done.[1]

Although the DBB is no longer responsible for policy setting, an analysis of the German experience is indeed most relevant for at least the following reasons. First, Germany is a major economy of the EMU and as such matters for decision making by the European Central Bank (ECB henceforth): the subscription of the DBB to the capital of the ECB is the highest among all the banks of the European System of Central Banks. Second, the ECB operates within a framework very similar to the one of the DBB, in an attempt to inherit good reputation and to cope with the uncertainties of the starting period. Third, the DBB used to be a leading monetary authority (both internationally and within the European Monetary System) that followed an independent monetary policy. Its performance is judged, by international standards, as strikingly good given that the level and the fluctuations of the domestic inflation rate over time were among the lowest. Such a stable inflation environment is

[1] Numerous studies (among others Domenech et al. (2002), Gerdesmeier and Roffia (2003), Hayo and Hofman (2003), Faust et al. (2001) and Gerlach and Schnabel (1999)) investigate monetary policy in the euro-area during the pre-1999 period; it is crucial to have reliable evidence on how policy behaviour is represented empirically in each country and primarily in Germany.

likely to be representative for the euro area, as well as for other economies worldwide. Therefore, all in all, analysing policy setting by the Bundesbank provides significant insights for the conduct of monetary policy.

There are numerous empirical studies on monetary policy in Germany. One strand of the literature focuses on the modelling of a money demand relation in various frameworks -for a brief review see Lütkepohl and Wolters (1998). Another strand of the literature acknowledges in the German monetary targeting regime key elements of inflation targeting. In this context, some often cited studies are Mishkin and Posen (1997), Bernanke and Mihov (1997) and also Clarida and Gertler (1997) and Clarida et al. (1998) who have shown that the DBB was adjusting the short-term interest rates according to an interest rate rule. However, crucial properties of the data, like for instance the integration properties, are often ignored in this empirical literature.[2]

Within the context of interest rate rules, there is a growing literature concerned with these shortcomings. The root of the matter is the finding of Granger and Newbold (1974) and Phillips (1986, 1989) that if variables integrated of order one are found not to be cointegrated, a static regression in levels is spurious. As regards up-to-date research, Christensen and Nielsen (2003), Bunzel and Enders (2005) and Siklos and Wohar (2005) have reported evidence of non-stationarity of the involved variables (with US data) and have experimented with long-run cointegrating relationships. Furthermore, Gerlach-Kristen (2003) and Österholm (2005) have explored the econometric properties of the Taylor rule and have found signs of instability, misspecification and inconsistencies due to the mistreatment of the non-stationarity of the data.

[2] Clarida and Gertler (1997) build a VECM on the grounds that ‹‹it is better suited for making long horizon run forecasts›› and make no reference to the stochastic properties of the variables. Similarly, Clarida et al. (1998) assume stationarity of the involved variables and pay no special attention to the unification of Germany, an indisputably important event included in their sample period.

The present paper begins with an analysis of the data generating process (DGP) and elaborates on an interest rate relationship, namely the Taylor (1993) rule. This is a so-called 'simple' rule originally designed to track policy setting in the United States that has become a rather popular benchmark: it calculates an economy's best interest rate value as a function of its state, which is described by the deviation of actual inflation rate from a target and of actual output from its long-run potential.[3] The analysis is performed by means of a trivariate vector error correction model (VEC model henceforth), which comprises an output variable and inflation apart from the short-term interest rate. A model that includes a measure of the money stock is without any doubt required, given the privileged role attributed to money growth in the DBB's announcements. By adding the US overnight rate, I investigate whether the DBB responded to it.

The analysis examines a complete historical period of German monetary policy, as it covers the period from roughly 1975 to 1998. In 1975, shortly after the breakdown of the Bretton Woods system of fixed exchange rates, the first annual monetary target was announced by the DBB. According to its statute, the bank was bound to 'safeguard the currency', which, in Issing (1997), was interpreted to mean price stability. By means of a procedure that remained in principle unchanged, the bank was setting targets for monetary growth that implicitly incorporated goals for inflation.[4] On 1 January, 1999 the responsibility for the conduct of monetary policy was handed to the ECB.

The paper is organized as follows: in the next section, I provide explanatory information on the dataseries and the econometric framework utilized; in the third

[3] The reader is referred to Eleftheriou (2003) for some issues associated with its specification and other developments.

[4] For a comprehensive presentation of the German monetary policy see Neumann and von Hagen (1993) and Schmid (1999).

section, I present the results of the empirical analysis for each model and, in the last section, I offer some concluding remarks. In a nutshell, I demonstrate that a stable interest rate rule, very similar to the popular Taylor (1993) rule, emerges repeatedly as the long-term relationship connecting the policy rate with output and inflation. Thereby, an untraditional standpoint on the DBB's monetary policy is put forward and an alternative methodological approach is established.

2 Preliminary Analysis

The data. The time series used are monthly seasonally unadjusted from 1974:01 to 1998:12. A description of the data is found in Appendix A, and in Figures 1 and 2. The series are labelled as follows: p stands for the log of consumer price index, $\Delta p(= p_t - p_{t-1})$ for monthly inflation rate, y for the log of real GDP, $m3 - p$ for the log of real M3, RS for the call money rate, RL long-run rate and $USRS$ for the US Federal Funds rate.

Regarding the short-term rate used as the policy instrument of the DBB, the call money rate (also known as the day-to-day rate, or the overnight interbank lending rate) is thought to be more appropriate given the practice of monetary policy in Germany. This choice is not uncommon in the relevant literature- Clarida and Gertler (1997), Clarida et al. (1998), Lütkepohl and Wolters (2003), Brüggemann (2003) have used the same rate as the relevant policy variable.

A caveat to the analysis is its reliance on ex-post revised data, i.e., not on the data that was available to the policymakers at the time their decisions were taken. Concerning data on German real output, Clausen and Meier (2003) have found that real-time and ex-post revised data are generally quite close, inferring that the magnitude of the revisions is not large.

Unit root and cointegration tests. As argued, the stochastic properties of the data series need to be well understood in order to obtain a consistent and robust model- the details of the unit root and cointegration analysis may be provided by the author upon request. It is worth pointing out that apart from the common tests, other tests that allow for different kinds of shifts in the series have been performed (see Lanne et al. (2002), (2003) and Saikkonen and Lütkepohl (2000a, b)). Along these lines, there is evidence that RS_t, $\Delta p_t y_t$, $(m3-p)_t$, $USRS_t$ and RL_t are integrated of order one (I(1)) and that there is cointegration among three or more variables- in section 3, in the context of each model, further discussion is offered.

The model. Given these findings, the interaction between the short-term interest rate and the other variables is analyzed by means of VEC models:

$$\Delta Y_t = \Pi \begin{bmatrix} Y_{t-1} \\ Trend_{t-1} \end{bmatrix} + \sum_{j=1}^{k-1} \Gamma_j \Delta Y_{t-j} + \Xi D_t + u_t, \tag{1}$$

in which $\Pi = a\beta'$, Y_t contains the endogenous variables, D_t the deterministics, and u_t is an unobservable zero mean independent white noise process with a constant and nonsingular covariance matrix Σ_u. The lag order k is determined by the Akaike criterion and the cointegration rank is set according to the outcome of the cointegration tests in each case. Furthermore, α contains the loading coefficients, i.e. the weights of the cointegration relations in each equation of the system, and β the coefficients of the cointegration relationships. To identify β', its first part is assumed to be an identity matrix, i.e. $\beta' = [I_r : \beta'_{(M-r)}]$, where r is the cointegrating rank, M is the number of the variables and $\beta'_{(M-r)}$ is a $((M-r) \times r)$ matrix. Thus, the reader is invited to note of the ordering of the variables in Y_t.

As for the deterministics, apart from a linear trend restricted to the cointegration relation, the models contain one constant and eleven seasonal dummies. They may also contain shift dummies and/or impulse dummies.[5] The trend enters restricted to the cointegrating relation, and, in this way, the relation is expected to capture the adjustment of the short-term rate to deviations of the real output from its potential. The major advantage of such a structure, which is not uncommon in the literature (see Juselius (1996), Juselius (1998), Johansen and Juselius (2001) and Brüggemann (2003)), is the avoidance of an arbitrary choice for measuring the output gap. Besides, as described in Deutsche Bundesbank (1995) and pointed out in Döpke (2004), linear detrending is an important input to the production function approach, a method used by the Bundesbank for the calculation of the production potential. However, as a robustness check, models with explicit output gap measures are also built.

Concerning the sample period, the 1974 values are used as pre-sample observations and the period used for the actual estimation of the model depends on the lag order k of each model: thus, when $k = 12$, the estimation period starts in February 1975 and there are 287 observations. Once the full model is estimated, a system method of the sequential elimination of regressors is implemented in order to detect possible zero restrictions.

In the first place, a three-variate model is estimated. Following this, I proceed by building a "5-variate model" where both the long-term rate and the money stock variable are included so as to obtain a broader and more comprehensive picture of

[5] $S9006$ ($S9101$) takes the value 1 from June 1990 (January 1991) onwards. $I9006$, $I9101$, $I8103$ and $I9301$ equal unity in June 1990, January 1991, March 1981 and January 1993 respectively, and zero elsewhere.

$S9006$ and $I9006$ account for the unification of Germany and are related to the money stock series, which according to the Bundesbank's explanatory notes, cover unified Germany from June 1990 onwards. Similarly, $S9101$ and $I9101$ are related to the data on output which, according to the German Federal Statistical Office, covers both the former German Democratic Republic and the former Federal Republic of Germany from January 1991 onwards. $I8103$ captures the rise in the German day-to-day rate in the first quarter of 1981, which came as a response to the oil shock and the sharp rise in the U.S. interest rates. Finally, the $I9301$ dummy is necessary because of the European Monetary System crisis.

the interacting monetary policy variables. In the so-called "$USRS$-model", the US overnight rate is added as the fourth endogenous variable.[6] The models are estimated by a two stage procedure.[7] When the instantaneous residual correlations are small the dynamics of the system are explored by means of forecast error impulse responses- allowing me to avoid imposing any identifying restrictions, thereby also avoiding a major source of uncertainty. In the opposite case, I compute the orthogonalized impulse responses .[8]

To close the section, it is useful to remark that the modeling framework employed is particularly suitable for testing restrictions on long-run and short-run dynamics. Furthermore, it pays attention to the integration properties of the series and, thus, avoids any potential misspecifications arising from neglecting them. Moreover, in the context of monetary policy rules, the built-in partial adjustment mechanism captures the observed interest rate smoothing. Last but not least, regarding an interest rate rule as a long-run relationship refers to the concept of a target rate that is reached via gradual changes in the policy rate so as to restore equilibrium to the implied target rate path.

3 Empirical evidence

3.1 The three-variate model

Let us start with the simplest model: the vector of endogenous variables is $Y_t' = [RS_t, y_t, \Delta p_t]$, the lag order k is set equal to 12 and the deterministics, apart from

[6] The computations are performed with the software JMulTi (version 2.70 beta, www.jmulti.de) and the restrictions on coefficients are checked with PcGive (version 10, GiveWin2).

[7] In the first step, β is estimated by Johansen's reduced rank procedure (Johansen (1995)) and in the second, the estimator of β is treated as fixed while the rest of the regressors are estimated.

[8] See Breitung et al. (2004) for information on the impulse response analysis.

the constant, the trend, and the seasonal dummies, include $S9101, I9101$ and $I9301$. There seems to be one cointegrating relation among the three variables, which comes mainly from the relationship between inflation and the short-term rate.

The estimated cointegrating relationship, with the coefficient of the short-term rate normalised to 1, turns out to be (the standard errors are reported in curly brackets and the t-statistics in parentheses):

$$\begin{aligned} RS_t &= \underset{\substack{\{0.185\} \\ (1.937)}}{0.359} y_t - \underset{\substack{\{0.000\} \\ (-1.011)}}{0.0003} Trend_t + \underset{\substack{\{2.790\} \\ (5.438)}}{15.169} \Delta p_t \qquad (2) \\ \text{or } RS_t &= 0.359(y_t - 0.0008 Trend_t) + 15.169 \Delta p_t. \end{aligned}$$

This long-run relationship between the policy rate and the two indicators that describe the state of the German economy bears a marked resemblance to a Taylor-like rule for the interest rate.[9] The inflation rate enters with the expected sign and its coefficient is larger than 12 (or unity in annual terms), a value that ensures a rise in the real rate when inflation rises. The coefficient of the trend adjusted real output has the expected sign, and is very close to the output gap coefficient suggested by Taylor (1993). However, here the output gap is not calculated exogenously, but is captured through the specification of the model- see below or models with explicit gap measures, which deliver comparable parameter estimates. Note that the average real output growth per month is estimated to be 0.08% (i.e., almost 1% per year). Setting both the output and the inflation coefficients equal to the values of the original Taylor rule, i.e., to 0.5 and 18 (or 1.5 in annual terms) is not rejected by the data; the produced

[9] Equation (2) may not be interpreted as an IS curve because the trend-adjusted real output is positively related to the real interest rate. Regarding the Fisher effect, i.e. the relationship connecting the inflation rate with the long-run rate, but which here involves the short-term rate as in Mishkin & Simon (1995): restricting β_y=0 yields a p-value of 0.031 in a $\chi^2(1)$ distribution; restricting β_y=β_{trend} =0 yields a p-value of 0.000 in a $\chi^2(2)$; and restricting β_y=0 and $\beta_\pi = 12$ yields a p-value of 0.013 in a $\chi^2(2)$. Therefore, the output variable plays a significant role and shall not be dropped from the error correction term.

p-value is 0.72 in a $\chi^2(2)$ distribution.[10]

Equation (2) does not feature interest rate smoothing, as usually happens with empirical Taylor-type rules, but in the given framework, partial adjustment is captured perfectly by the dynamics of the model as a whole. Thus, it is interesting to briefly discuss the estimated short-term interest rate equation. The adjustment coefficient in interest rate equation is negative and highly significant, which implies a stable model where deviations of the rate from its equilibrium value are corrected by monetary policy actions. As a result, equation (2) can be interpreted as a monetary reaction function. The magnitude of the loading coefficient suggests that a negative 1 percentage point deviation (of the interest rate from the implied target path) triggers an increase by 5 base points in the policy rate in the next period.[11] Moreover, there is dynamic feedback among the short-term rate, inflation, and output with the lags of the three variables entering the equation. Concerning the deterministics, apart from the constant and some seasonal dummies, the shift dummy for German unification is also needed. As for interest rate smoothing, one cannot deny its presence, given the importance of the lagged values of the variable in the equation.

In Table 1, some diagnostic statistics for the model and the individual residuals are collected: the residuals seem to be free of autocorrelation and of autoregressive conditional heteroskedasticity. To check the stability of the model the Chow Forecast test has been implemented on selected dates: January 1984, January 1985, June 1990 and January 1991.[12] As shown in Table 2, the bootstrapped p-values of the Chow Forecast test do not reject parameter constancy.

[10] Note also that the estimates in equation (2) are exceptionally close to the findings of Hayo & Hofmann (2003) who work in a one-equation framework.

[11] This adjustment coefficient is identical to the one reported by Brüggemann (2003) for the period 1984- 1998.

[12] The first two dates are relevant because, in 1985, the Bundesbank modified some elements of its strategy, an amendment that had already become important in the earlier years. Obviously, the other two dates account for the unification of Germany.

The dynamic structure of the model is explored by means of an impulse response analysis. To start with, the off-diagonals of the residual correlation matrix are small (only one is marginally different from zero) and the matrix can be treated as diagonal and consequently isolated shocks to individual equations make sense. Thus, the forecast error impulse responses have been calculated for the full model and are depicted in Figure 3 together with 95% confidence intervals.[13] These intervals are based on Hall's bootstrap procedure (see Benkwitz et al. (2001)) for 2000 bootstrap replications.

Given the interest in the relevance of the Taylor rule, attention is drawn to the adjustment of the short-term rate to shocks hitting the non-policy variables of the system, namely, real output and inflation. These responses are illustrated in the first row of Figure 3. Very clearly, and in line with the predictions of the Taylor rule, a positive shock to output or inflation leads to a longlasting and significant increase in the short-term interest rate.[14]

In the first column of Figure 3, the responses to an interest rate shock are depicted: a rise in the interest rate, apart from a positive impact on the same that lasts for half a year, marginally lowers the output, but the response is insignificant. As for the response of inflation, contrary to what one would expect, it is positive albeit quantitatively small and insignificant.[15] In the second column, the responses of an impulse to output are displayed. Clearly, a one-time impulse has a long-term positive

[13] The orthogonal impulse responses have also been computed and are perceptibly identical.

[14] These findings are invariant to the inclusion of different dummy variables, of a second cointegrating relation and even to the inclusion of an explicit output gap measure, as reported below.

[15] This observation refers to the so-called "price puzzle", the nature and resolution of which remains unclear despite the large body of research dedicated to it. On the one hand, Sims (1992), Leeper et al. (1996) and Christiano et al. (1996), among others, have shown that in the United States economy the puzzle disappears when the model features a commodity price index. On the other hand, recently, Giordani (2004) has proposed a distinct approach and argued that the price puzzle is related with the omission an of output gap measure from the model. See below for models featuring an exogenous gap measure, where the price response improves.

effect on output itself and also on the inflation rate. In the third column, where the responses of an impulse on inflation are displayed, we observe a long-term effect on inflation itself and an insignificant negative response of the output. On the whole, the generated dynamics are not unreasonable and different from what the literature reports.

In the one-equation framework, the fit of the rule is usually explored by plotting the estimated target rate series together with the historical values. Accordingly, in the present framework, the top panel of Figure 4 depicts the historical interest rate series together with the fitted values of the variables restricted in the cointegrating space, both as deviation from their mean. Given that the fitted values are not adjusted for the German unification, a persistent deviation of the two series is observed after 1991. Likewise, given that the fitted values are not adjusted for seasonal and other short-run dynamics, the corresponding series are extraordinarily volatile. The bottom panel of Figure 4 takes care of these as it depicts the residuals from regressing the interest rate series (solid line) and the variables restricted in the cointegrating space (dashed line) on the short-run dynamics and the unrestricted variables (i.e. the constant and the dummies); again both series enter as deviations from the mean. Despite the downward deviation from mid-1984 to 1988 and the upward deviation until 1991, the fitted series replicate the original ones quite closely in most instances.[16]

As a robustness check, I estimate models with explicit output gap measures constructed in various ways. Due to space limitations the results are not reported here; however, it is worth pointing out that the derived cointegrating coefficients are reasonable and in line with the previous interpretation, and the same happens with the loading coefficients. The impulse responses are largely plausible and consistent with

[16]The first period was characterized by numerous currency realignments within the EMS and the second was a transition period with significant changes in Germany and in Europe (Delors report on the transition to EMU, capital controls removal etc).

the predictions of the Taylor rule; besides, the price puzzle disappears in the long run.

The analysis of this section has shown that the short-term rate reacts to inflation and to output in a trivariate model. And it is motivating to see how the addition of the money stock or of other variables affect these findings.

3.2 The money stock model

This section presents a model where both the long-term rate and a measure of the money stock have been added to the basic trivariate model. The vector of the endogenous variables is $Y_t' = [\Delta p_t,\ RL_t,\ RS_t,\ y_t,\ (m3-p)_t]$, the lag order is set equal to 12 and in addition to the usual deterministics the following dummies are included: $S9006$, $S9101$, $I9006$, $I9101$, $I8103$ and $I9301$. As for the cointegrating rank, I proceed with two cointegrating relations. These are estimated to be (the standard errors are reported in curly brackets and the t-statistics in parentheses):

$$\begin{aligned} \Delta p_t &= \underset{\substack{\{0.005\} \\ (9.266)}}{0.050} RS_t - \underset{\substack{\{0.010\} \\ (-2.115)}}{0.021} y_t + \underset{\substack{\{0.006\} \\ (4.276)}}{0.024} (m3-p)_t - \underset{\substack{\{0.000\} \\ (-3.455)}}{0.00005} Trend_t \\ \text{or } RS_t &= 0.420(y_t + 0.0004Trend) + 20.000\Delta p_t - 0.048(m3-p)_t, \qquad (3) \end{aligned}$$

$$\begin{aligned} RL_t &= \underset{\substack{\{0.042\} \\ (9.787)}}{0.415} RS_t + \underset{\substack{\{0.079\} \\ (3.383)}}{0.266} y_t - \underset{\substack{\{0.043\} \\ (-4.549)}}{0.195} (m3-p)_t - \underset{\substack{\{0.000\} \\ (-0.698)}}{0.0001} Trend_t \\ \text{or } (m3-p)_t &= 1.364y_t + 2.128RS_t - 5.128RL_t + 0.001Trend. \qquad (4) \end{aligned}$$

Equation (3) resembles a Taylor-type augmented interest rate rule. Setting the inflation and output coefficients as equal to the values reported in equation (2), or to the Taylor (1993) values, and the coefficient of money stock to zero, yields p-values of 0.25 and 0.07 respectively. As far as the second cointegrating vector is concerned, this qualifies as a money demand relation: the output variable captures the effect of the volume of transactions on the demand of money; the short-term rate captures the own M3 rate of return; and, finally, the long-term rate captures the opportunity cost of holding money instead of other assets.[17] The income elasticity is comparable to the findings of other studies that cover the same period and use similar specifications, albeit with different variables- see Brüggemann (2003) and Lütkepohl and Wolters (2003). Its being greater than one is justified by declining income velocity during the discussed period. The coefficients for the long-term and the short-term rates show the expected signs and are comparable to the findings of other authors- see Brüggemann (2003) and Lütkepohl (2004). Since interest rates are not expressed in logs, their coefficients do not reflect elasticities directly; thus, for an interest rate of 6% [7%], which is the average short-term [long-term] rate value over the 1974 -1998 period, the elasticity would be 0.13 [-0.36].

The loading coefficients, as they emerge after the subset restrictions, suggest that inflation equilibrium corrects to deviations from equation (3). Interestingly, the short-term rate rises to bring down inflation, implying that the first cointegrating vector operates as a reaction function. Similarly, the long-run rate rises and the real output falls to adjust to any deviations. Moving to the second cointegrating vector, money stock drops when the long-run rate exceeds its equilibrium long-run value, confirming in this way the interpretation of a money demand relation.

In table 1 the diagnostic statistics for the model and individual equations are presented. As for stability, Table 2 reports that the Chow Forecast test does not reject parameter constancy for the tested dates. The residual correlation matrix has two significant off-diagonal elements and thus, in Figure 5, the orthogonal impulse

[17] Hubrich (2001) offers a discussion on the variables entering the money demand relation.

responses with the usual confidence intervals are presented.[18]

The last row depicts the effects of the various shocks on the short-term rate. A permanent positive shock to output leads to a positive response and the same holds for a shock to the inflation rate, although the former does not seem to be significant. Interestingly, the policy rate rises when the long-run rate or the money stock is hit by positive shocks: the former is in accordance with the evidence of a stationary interest rate spread, and the latter is not implausible given that increasing money stock leads to increasing inflation and calls for policy tightening.

In the first column, a one-time impulse in the real output has a persistent effect on the same and leads to a long-run positive effect on the long-run rate. It also causes a positive, albeit not significant, response in the money stock, a reaction which is not implausible taking into account that it involves the real money stock and not the nominal series. Moving to the second column, an impulse on inflation seems to lead to a long-run effect on the same and to a negative response on the output. It also leads to an initially significant positive response in the long-run rate, this being evidence in favor of the Fisher effect. Note that this also results in an initial decline in the real money stock, which may be due to policy actions, and later on, after an increase, the real money stock adjusts to its pre-shock value. In the third column, a shock in the long-term interest rate has a persistent effect on the same and tends to reduce real money balances. In the fourth column, a one-time impulse to real money has a lasting positive effect on the same, as well as on real output and inflation; this last observation confirms the efficiency of using money targets in the German economy. What is puzzling is the positive reaction of the long-term interest rate; Lütkepohl and Wolters (2003) have observed a similar impact after a shock in nominal money

[18] Note that the ordering of the variables is: y_t, Δp_t, RL_t, $(m3-p)_t$, RS_t. and that the forecast error impulse responses do not differ substantially.

and offer a discussion on its possible sources.

Finally, in the last column the responses to a shock on the policy rate are depicted. The response of the real output eventually turns significantly negative; the immediate response is insignificant, albeit below zero at the very beginning. Also Hubrich and Vlaar (2004), in a study built on a structural VEC model that focuses on monetary transmission in Germany for the period 1979- 1998, find a small but insignificant decrease in output after a shock in the interest rate. As for the response of inflation, it seems to be negative only in the very beginning. Brüggemann (2003) derives a similar inflation response for the period 1975- 1983 from a structural VEC model with data on Germany. And also Hubrich and Vlaar (2004) report a negative response of inflation that only lasts for one quarter. Finally, an impulse in the overnight rate leads to an initial increase in the real money stock, which in the end becomes an insignificant decline.[19]

3.3 Models with four endogenous variables

The US overnight rate model. Clarida et al. (1998) report that the US Federal Funds rate enters significantly in the DBB reaction function: given the size of the economy of the United States, it is likely that the DBB showed interest for the evolution of this foreign policy rate, since it affected the bilateral exchange rate and finally the prices in Germany. To investigate the relevance of the $USRS_t$, a four-variate model is formed and is specified in a similar way as previously- more information may be provided upon request. One of the two cointegration relations turns out to be not significantly different from equation (2) and can be interpreted as a reaction

[19] The initial increase of the money stock seems rather confusing at first glance, as a policy contraction cannot imply an increase in money. However, given that the plotted variable is expressed in real terms and that the impact response of the inflation rate is negative, the impact reaction of the nominal money could be negative as well.

function relationship, since the short-term rate adjusts to restore equilibrium.[20] As for the US overnight rate, the restrictions of the subset model suggest that it can be treated as a weakly exogenous variable.

The forecast error impulse responses of the policy rate indicate that a permanent positive shock to output leads to an increase in the short-term interest rate and, similarly, a positive shock to the inflation rate causes an increase in the short-term interest rate, a response that becomes clearly significant after two years. Interestingly, the response of the German short-term interest rate to a shock in the US overnight rate is also positive and significant for two years.

4 Concluding remarks

The paper establishes a framework for analysing monetary policy setting in a key economy of the EMU and, since this economy experienced an admirable performance as regards price stability, the findings of the paper are of use to policymakers seeking a similar objective. To be more specific, the study explores the way the short-term rate of the Bundesbank adjusted to various objectives during the period 1975 to 1998. As demonstrated, the common stochastic trend that emerges among the policy rate, the domestic inflation rate and the measure of economic activity qualifies as an interest rate rule, which is comparable to the Taylor (1993) rule as far as the derived parameter estimates are concerned. Interestingly, this long-run interest rate rule, expressed via robust parameter estimates and dynamics emerges repeatedly from models featuring various pertinent variables. What is more, in general these models generate reasonable dynamic behavior.

The higher dimension models explain how the policy rate of the Bundesbank

[20] As before, restricting the output and inflation coefficients to the Taylor (1993) values is not rejected by this model either.

reacted to movements in other indicators. More specifically, the inclusion of the Federal Funds rate as a means of capturing the importance of foreign constraints in the adjustment of the German policy instrument leaves the reactions to the inflation rate and output virtually unaffected, and generates a positive impact on the policy rate. Fascinatingly, the inclusion of the real money stock does not disturb the size of the Taylor-rule parameter estimates. Most importantly, in all cases, and independently of the composition of the model, the impulse response analysis illustrates that the response of the day-to-day rate to shocks in output and inflation is perceptibly robust and consistent with the predictions of a Taylor-type interest rate rule.

Furthermore, it is demonstrated that the Taylor-type interest rate rule remains relevant in a representation where the stochastic properties of the variables are adequately modelled, outwitting a thorny criticism often encountered in the literature. In this way, the paper contributes to the current empirical literature by leading the way in employing an alternative framework with interesting qualities for analyzing monetary policy. Given that the rule is incorporated into an error correction model, some of its usual features are not present in the standard way, but instead are captured indirectly through the short-term dynamic structure of the model. In particular, despite the absence of the interest rate smoothing parameter, the partial adjustment is captured by the dynamics of the model. Likewise, although there is no constant term as such in the cointegrating relationship- the reason for this being the inclusion of the trend that encapsulates it in some way-, it is included in the deterministics of the model. Moreover, the output gap is not exogenously measured, but is captured within the model as the deviation of the real output from its trend.

To conclude, the study can be extended to countries which have officially adopted some form of inflation targeting as a framework for monetary policy-making. Such an experiment will allow us to explore how the functioning and the dynamics of the model are affected.

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A APPENDIX [Data description]

The sources of the used data are as follows:

-The nominal M3 stock is provided by the Bundesbank, the Central Bank of Germany.

-The price index is the CPI for all items with base year 1995 and is extracted from the OECD database. Inflation is measured as the month-on-month difference.

-The short-term rates for both Germany and the United States are extracted from the OECD database.

-The GDP at constant 1995 prices is provided by the Federal Statistical Office of Germany. The time series of the monthly observations are interpolated from quarterly figures by means of the programme ECOTRIM by Eurostat.

-The long-term rate for Germany, as measured by the yield on federal securities of more than 10 years maturity is taken from the International Financial Statistics of the IMF.

B APPENDIX [Tables & Figures]

Table 1: Diagnostic tests

3-variate model	ΔRS_t	Δy_t	$\Delta^2 p_t$		
PORT (48)	352.66(0.11)	[VARCHLM(20): 781.34(0.06)]			
PORT (12)	19.93(0.07)	8.15(0.77)	1.94(0.99)		
ARCH(20)	50.58 (0.00)	27.26(0.13)	28.40(0.10)		
JB	244.48(0.00)	195.31 (0.00)	67.46(0.00)		
5-variate model	$\Delta^2 p_t$	ΔRL_t	ΔRS_t	Δy_t	$\Delta(m3-p)$
PORT (76)	1649.03(0.15)	[VARCHLM(2-16): 475.28(0.19)-3559.42(0.69)]			
PORT (3)	0.71 (0.86)	0.59(0.89)	5.13(0.16)	2.19(0.53)	2.95(0.39)
PORT (6)	2.15 (0.90)	0.87(0.98)	14.57(0.02)	4.01(0.67)	4.12(0.66)
ARCH(4)	4.96 (0.29)	6.67(0.15)	10.60(0.03)	21.79(0.00)	2.01(0.73)
ARCH(16)	9.41 (0.89)	21.19(0.17)	51.20(0.00)	25.21(0.06)	10.1(0.86)
JB	69.57(0.00)	11.99(0.00)	32.72(0.00)	295.18(0.0)	73.1(0.00)

Notes: LM(k) is a Langrange multiplier test for k-th order autocorrelation of the model residuals. JB is the Jarque-Bera test for nonnormality, PORT (k) is the Portmanteau test for k-th order residual autocorrelation, ARCH (k) is an Lagrange multiplier test for k-th order autoregressive conditional heteroscedasticity. Values in parentheses besides the test statistics are p-values.

Table 2: Stability tests

	3-variate model		5-variate model	
	S-S	F	S-S	F
1984.01	241 (0.19)	0.64(0.98)	840.56 (0.01)	0.64(0.62)
1985.01	244.81(0.18)	0.58(1.00)	856.59(0.00)	0.72(0.64)
1990.06	281.86(0.00)	0.85(0.73)	744.50(0.25)	0.81(0.77)
1991.01	232.62(0.24)	0.78(0.88)	n.a.	0.82(0.82)

Notes: "S-S" denotes the Sample Split Chow test and "F" the Chow Forecast test. Values in parentheses besides the test statistics are corresponding bootstrapped (after 1000 replications) p-values. See Candelon and Lütkepohl (2001) for a discussion.

Figure 1: Time series in levels (p, Dp, RS, y, er, USRS, m3-p, RL)

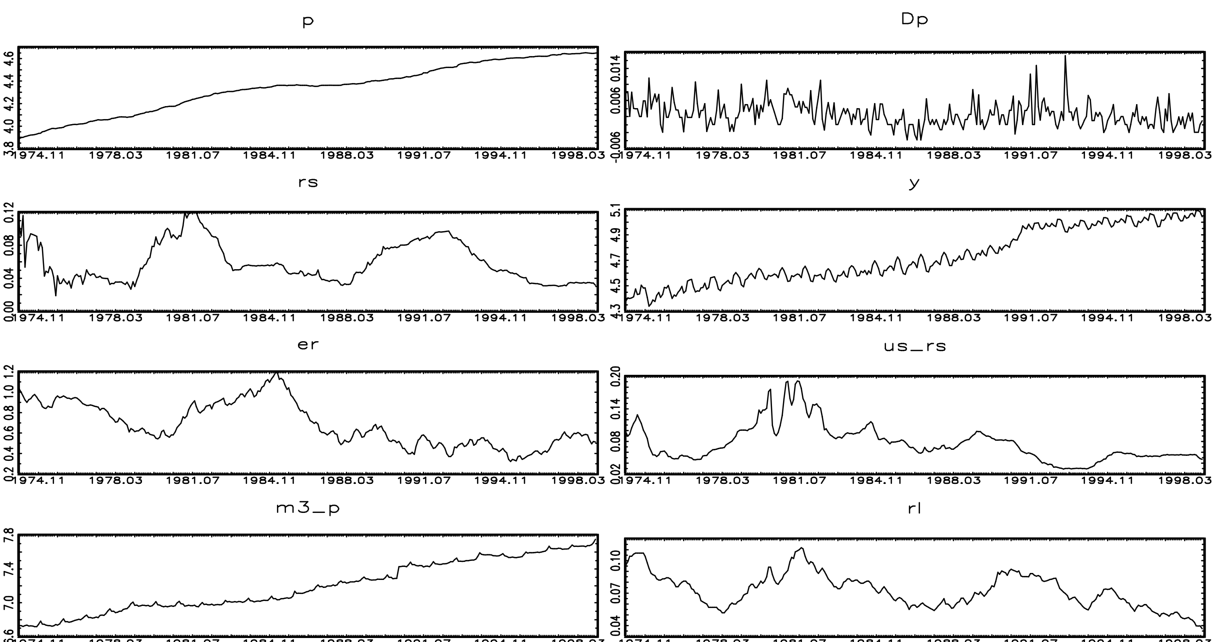

Figure 2: Time series in first differences (Dp, RS, y, er, USRS, m3-p, RL)

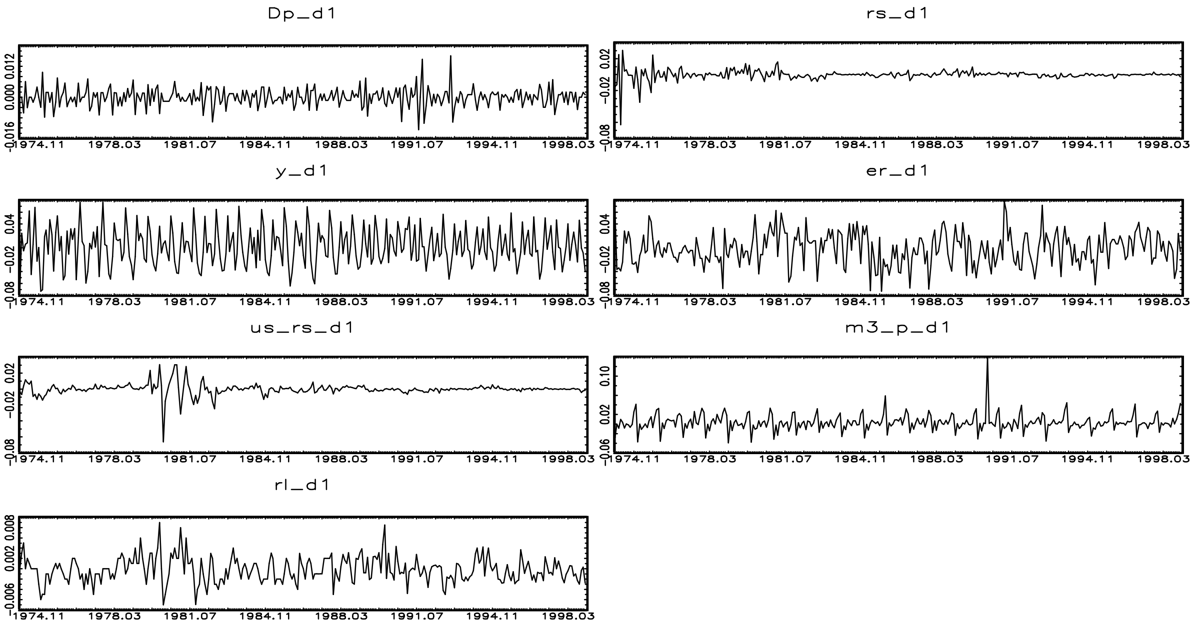

Figure 3: Impulse Responses for the 3-variate model

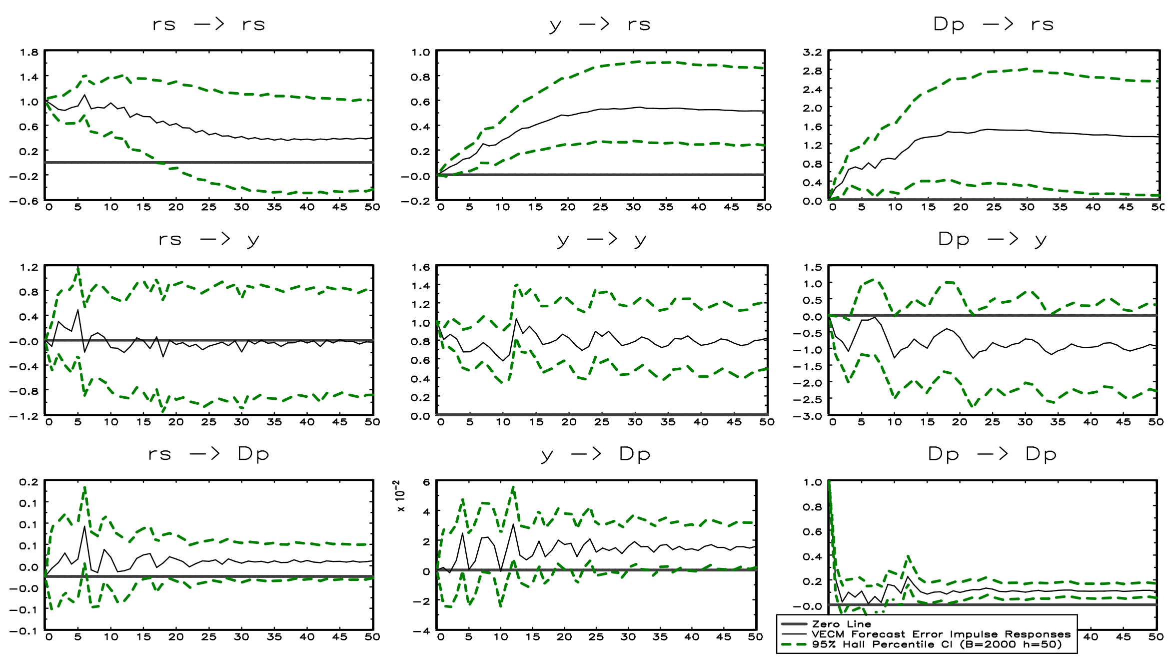

Figure 4: Cointegration graphics for the 3-variate model

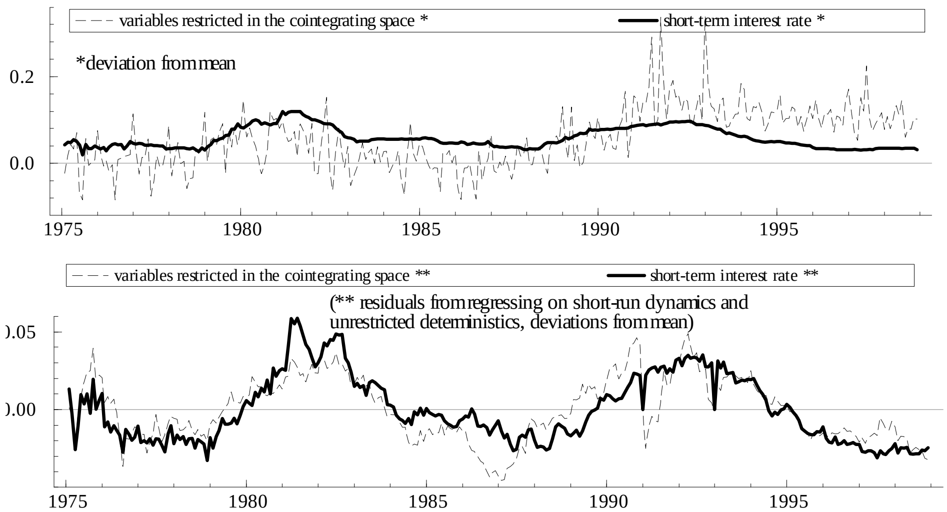

Figure 5: Impulse Responses for the 5-variate model