Discretion versus Policy Rules in Practice

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Abstract

The paper seeks empirical evidence on the question if the interest rate variations of the European Central Bank (ECB) can be described by a Taylor-type reaction function. Applying least squares estimation approaches several empirical specifications will be discussed. The baseline sample focusses on monthly data that are supposed to reflect the aggregated economic performance of the euro area including the time period since the beginning of the European Monetary Union (EMU) in 1999 until February 2007. Due to the break of macroeconomic fundamentals in 2003 we will split the investigation period.

Our results propose that the ECB did not follow a Taylor-type reaction pattern over the whole investigation period. Corresponding interest rate variations can only be observed from 1999 to 2003. As we identify remarkable shifts in the estimated inflation coeffcents when splitting the observation sample we assume that empirical results may depend rather on the investigation period than on the estimated specification.

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1 Motivation

1.1 Interest rate rules in the conduct of Monetary Policy

In regard to the conduct of monetary policy modern macroeconomic theory agrees on two major aspects: First, the central bank controls certain instruments and seeks to minimize social losses from unemployment and inflation. Behavioural preferences are usually derived from loss-function concepts. The environmental conditions are guided by concepts of monetary transmission channels which are embedded in economic and social circumstances reflecting structural aspects operationally captured by supply side and demand side factors of an economy. The monetary trade-off is theoretically captured by the debate about the non-neutrality of monetary policy and empirically reflected by the concept of the sacrifice ratio (see Spahn, 2000). As a result in the short and medium run the monetary authority is supposed to balance cyclical movements of output and inflation.

Secondly, the instrument in use is the interest rate. Declining relevance of the short and medium-run relationship between money growth and inflation provides a basic theoretical framework of monetary policy (Blinder, 1997): The central bank applies interest rate policy rather than money-supply policy while facing a variety of uncertainties regarding the reactions of transmission variables (long-term interest rate, stock prices, exchange rates, credit), the reaction of aggregate demand (is-curve), the reaction of unemployment (okun's law), the reaction of inflation given chnages in unemployment (phillips-curve). The uncertain effects on private expectation formation further increase the complexity the monetary authority is confronted with.

Central banks may use interest rate rules as guidelines for their day-to-day operations and base their decision on projections of the policy rule or at least attribute a certain amount of relevance to them. Policy rules represent behavioural patterns and might be able to reduce the complexity in regard to interest rate variations and communication purposes. In 1993 Taylor intruduced his famous Taylor rule concept that has been widely disussed and extended (Taylor, 1993). His basic framework suggests a systematic policy guideline that recommends adjustments of the short-term interest rate in response to changes in real income and the inflation rate. This reaction to changes in macroeconomic fundamentals is supposed to project the interest rate decision of a central bank.

Advantages and caveats of rule based interest rate policy have been widely discussed highlighting predominantly the following aspects: Kydland, Prescott (1977) as well as Barro, Gordon (1993) promote the phenomenon of time inconsistency leading to biased discretionary monetary policy. Hence rules might be useful not only in order to prepare interest rate decisions but also for communication purposes. Taylor (1993) however emphasized the importance of flexibilty and discretionary elements in contrast to mechanical rules. Fendel (2004) adresses a

trade-off between flexibility and credibility of stabilization policy and mentions the potential loss in flexibility when acting on a too narrow policy rule.

Besides the theoretical discussion of monetary policy rules there has been work on estimating empirical reaction functions exhibiting rather practical relevance. Fendel (2004) emphasizes that reaction functions are used by private market participants in order to generate their expectations. Moreover empirical reaction functions illustrate how, given economic conditions, interest rates were set in the past and therefore provide background information for future policy decisions (ECB, 2003).

1.2 Structure

Section 2 illustrates the basic idea and theoretical modifications of the key features of Taylor-type rules. Section 3 introduces common emprirical specifications when measuring interest rate reaction functions. Section 4 applies the estimation of the derived emprirical framework to the interest rate variations of the European Central Bank (ECB). The baseline sample focusses on the aggregated economic performance of the euro area and includes the time period since the beginning of the European Monetary Union (EMU) in 1999 until the end of February 2007. Section 5 concludes.

2 Basic theoretical concept of Taylor-type rules

2.1 Idea and classification

Derived from empirical investigation of US monetary policy within the years of 1987 to 1993 Taylor (1993) interpreted the pattern of the short-term interest rate movements - given the expost observable changes of inflation and the output gap - as a kind of central bank reaction. In a more general approach such a functional form of interest rate adjustment to changes in fundamental macroeconomic aggregates has been widely discussed. Extended theoretical ideas as well as their empirical conduct are often called *Taylor-type rules.*

Kozicki (1999) characterizes Taylor-type rules in general as a class of policy rules that model the interest rate target as a function of the deviation of inflation from a target rate and the deviation of output from potential output in real terms. The rules assume that policy makers seek to stabilize output and prices about paths that are thought to be optimal and that by changing the interest rate they can influence output and prices (monetary transmission mechanism).

Moreover Taylor-type rules ought to be *responsive* to macroeconomic shocks and suggest active interventions to disturbances on the macroeconomic level. The policy reaction is guided by the policy rule that determines both, the instrument

of monetary policy (the short-term nominal interest rate) and the level of intervention (expressed by the sign and size of the specifying parameters).

Fendel (2004) describes the Taylor rule itself as an explicitely formulated policy strategy on an operational basis. He identifies some key features of Taylor-type rules and characterizes the reaction pattern as a policy rule that is rather *heuristical* than optimal, *conditional* in the sense of reactive to changes in macroeconomic aggreagtes and *active* which means that the central bank actively controls the macroeconomic changes by a variation of the real interest rate.

2.2   Formulas and economic implications

The basic *funcional form* of the original Taylor rule is given by (1).The variable i denotes the short-term nominal interest rate and is assumed to be controlled by the monetary authority.

$$i = r^* + p + \gamma \ (p - p^*) + \varphi \ (y - y^*) \tag{1}$$

Following Kozicki (1999) according to this concept the level of the interest rate depends on *four factors*: First there is the current inflation rate p. The second factor is the equilibrium real interest rate r^*, which is assumed to be determined by non-monetary factors in the long run. The sum of these two factors can be interpreted as a kind of benchmark recommendation for the nominal interest rate. The third component represents an inflation gap adjustment factor, raising the short term nominal interset rate if inflation is above its target p^* and lowering the nominal interest rate below the benchmark if inflation is below the target. Fourth, there is an output gap adjustment factor based on the difference between real output y and potential real output y^* rising the interest rate if the output gap is positive.

Factors one and two recommend alterations of the short-term *nominal* interest rate to keep inflation at its current rate provided the economy is operating at its potential. This keeps the short-term *real* interest rate constant. As the monetary authority is supposed to target a low and stable inflation while promoting maximum sustainable output, in the short run components three and four reflect two opposing policy objectives.

Moreover the concept reveals a *time dimension*. In the short run the output gap adjustment factor targets the stabilization of cyclical movements of real output while the inflation gap adjustment factor adresses a long-run inflation goal. The weights of these two objectives expressed by the parameters γ and φ indicate *preferences* in respect to the short-run trade-off between inflation and output. This is refered to the concept of the *Taylor-curve* and is in current research often called a second order phillips-curve (see Taylor, 1979). As the real output gap signals possible increases in inflation it can be interpreted as a preemptive element in regard to long-run inflation goals.

The weighting parameters represent the responsiveness of monetary policy to deviations of inflation from the inflation target and output from potential output. Taylor (1993) originally reported estimates for γ and φ both equalling 0.5. Further empirical results deviate depending on the sample period, the region and the given macroeconomic regimes.[1]

There is theoretical consensus about the role played by the real interest rate that is identified as the *stabilizing moment*. Although the nominal interest rate is the instrument that policy makers adjust it is the real interest rate the affects real economic activity (Woodford, 2001). This reflects the idea that the control of *cumulative processes* recommends an interest rate policy in real terms. According to this so called *Taylor-principle* - which represents an interest policy pattern of active intervention - the real interest rate will be increased above equilibrium when inflation is above target or output is above its potential.

Clarida, Gali, Gertler (2000) summarize the parameter setup of $\gamma > 1$ and $\varphi > 0$ as stabilizing whereas $\gamma < 1$ and $\varphi < 0$ might result in cumulative processes. Consequently the values of $\gamma = 1$ and $\varphi = 0$ may provide useful *evaluation benchmarks* for our estimation approaches.

2.3 Theoretical modifications

From a theoretical point of view one can think of several modifications extending the baseline concept given by (1). Economically motivated dimensions are given by varying the set of explanatory variables incorporated in the reaction pattern in regard to timing and qualitative innovation. Plausible specifications can be derived from the concept of monetary transmission and its underlying assumptions.

In regard to the use of additional *explanatory variables* one can find many extensions in recent theoretical as well as empirical research. Fendel (2004) highlights lagged values of the short-term interest rate to capture smoothing behaviour of the central bank as well as the real exchange rate to account for aspects of international competitiveness. Ullrich (2003) also incorporates interest rate smoothing and extends the basic estimation equation by foreign interest rates and the growth rates of monetary aggregates. Siklos, Werner, Bohl (2004) investigate a systematic interest rate reaction to variations in asset prices using stock and housing prices as instruments for future inflation. Asset prices are assumed to serve as indicators for upcoming inflation and the performance of the real economy in general.

Based on the fundamental reaction principle additional arguments x within the central bank's reaction function seem to be plausible. The coefficient ω is supposed to indicate the relevance of the additional variables (2).

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[1]Empirical results will be disussed in section 4.

$$i = r * + p + \gamma \ (p - p*) + \varphi \ (y - y*) + \omega \ x \qquad (2)$$

Extending the basic concept in regard to the *time dimension* can be motivated by transmission lags, markets' rigidities and informational aspects. While in the original version of the Taylor rule interest rate recommendations at time t (quarter period) are based on the output gap in the same quarter and on inflation change over the previous four quarters ending in the same quarter, one can also think of reaction patterns that build upon variations of macroeconomic fundamentals of prior periods. In an empirical context this motivates the implementation of lags within the estimation equations.

Fendel (2004) distinguishes between implicitely and explicitely formulated interest rate reaction concepts. The former incorporate expected values on the right hand side that will be influenced by today's interest rate decisions and will therefore be endogenous. The latter model the short-term interest rate as a function of lagged explanatory variables. In the context of empirical analysis these two types are often refered to as forward-looking and backward-looking specifications.

Kozicki (1999) emphasizes the aspect of interest rate smoothing in the context of the timing dimension and proposes an extension of the basic taylor rule by following aspects: The central bank is assumed to be concerned about the stability of financial markets and therefore smoothes interest rates. Smoothing may also indicate a certain responsiveness of monetary policy actions to inflation and the output gap observed over several periods rather than just one single period. Alternatively smoothing may be justified when the economic impact of changes in the short-term interest rate is uncertain.

3 Measurement aspects of Taylor-type reaction functions

3.1 Deriving econometric specifications

3.1.1 Modelling aspects

Econometric modelling builds upon economic theory which provides empirical investigations of monetary policy with basic thoughts about markets' interactions and transmission adjustment mechanisms adressing time aspects as well as nominal rigidities. Moreover we are given a certain idea of or even explicit information about the central bank's goals and preferences. The theoretical modifications of Taylor-type rules (section 2) prepare some basic economic hypothesis for the plausible construction of empirical specifications and their estimation (section 4).

Modelling aspects are the determination of a set of explanatory variables and instruments which have to be constructed from observable data or estimates of the macroeconomic concepts in use. Adressing time we have to identify plausible lag structures, depending on the sample frequency chosen for the econmtric framework and reflecting our theoretical assumptions about macroeconomic processes.

In order to generate reliable estimates we should be aware of the potential characteristics of the time series in use and therefore have to examine the statistical properties of our macroeconomic aggregates. Controlling for potential data misbehaviour within our sample will influence our choice of estimation technique.

3.1.2 Explanatory variables

Econometric specification has to transfer the theoretical arguments within the interest rate rule to macroeconomic time series aggregates. Central aspects refer to the observability, availability and accuracy of the data. Usually there are several aggregates and measurement concepts available. To investigate the central bank's interest rate decisions the suitability of the information providing aggregates has to be examined.

Examples in the estimation context of Taylor-type reaction functions are the existence of a variety of inflation measures and different methods regarding the determination of potential output. Since there are several *inflation measures* like, for example, the Consumer Price Index (CPI), core inflation concepts, or the GDP deflator one has to decide which time series to use.

Approximation of the *output gap* requires the estimation of potential output. Theoretical approaches include productivity growth, labour-force participation, changes in the natural rate of unemployment as well as the growth of the capital stock. In general there are difficulties in assessing the output gap empirically. An often used concept is the application of the percentage difference between real output and an estimate of potential real output. But one can also think of different approaches to estimate potential output. Detrending some measure of real GDP by a filtering technique seems common practice.[2]

The measurement and availability of asset prices and money stock aggregates is usually less problematic.

3.1.3 Time

To adress the time dimension we have to focus on two major aspects: data availability and monetary transmission. As only few of the aggragates are known with much accuracy until several quarters or perhaps years later, when the central bank is supposed to decide about alterations of the policy instrument the true

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[2]To capture the impact of using several detrending and estimating techniques Kozicki (1999) compares 6 different measures of potential output.

values of most of the macroeconomic indicators are not available. Therefore the central bank has to rely on current estimates or forecasts of aggregates that will usually be revised several times after their first announcement.

Orphanides (2001) stresses the potential discrepancy comparing estimation results based on *real-time data* to investigations using expost revised aggregates. He concludes that the latter might not adequately capture a central bank's decision which is rather based on real-time observations. Real-time policy recommendations can therefore differ considerably from those measured by expost revised data. As the monetary authority sets its operating instrument at time t as a function of observable variables reflecting inflationary and real activity conditions in the economy at time t estimated policy reaction functions based on expost revised data might therefore yield misleading descriptions of historical policy decisions.

The *lag structure* of the single specifications depends on our theoretical considerations about structural aspects of the economy reflecting observable frictions and markets' interactions as well as our assumptions about the ratio of the monetary authority. Taylor (1993) evaluates a quarterly time period as too short to model the impact of demand and supply shocks on the price level whereas he judges a one quarter period as too long to capture adjustments of the short-term interest rate. Moreover Taylor suggests the use of monthly rather then quarterly data to adress the frequency of interest rate variations allowing a model to be more responsive in the short run. On the other hand - to smooth temporary price fluctuations - he proposes the assessment of a moving average of the price level over several quarters. In regard to the outout gap similar considerations seem plausible.

Further modification aspects refer to the role of *price expectations* which might be approximated by futures markets, the term structure of interest rates or forecasts of the variables in use.

3.1.4 Estimation techniques

Literature on the empirical assessment of Taylor-type reaction functions offers a variety of estimation approaches reflecting several aspects of economic theory through its econometric specifications. Carstensen (2006) estimates a probit model to adequately treat the nature of the alteration steps of the ECB's refinancing conditions. Ullrich (2003) - approximating interest rate variations by the overnight market interest rate (EONIA) - proposes an OLS technique for single equation estimation and applies an IV-regression approach for her two-equation model to control for endogenity aspects. Gerlach, Schnabel (1999) modify an OLS single equation model by a set of dummy variables to correct for intra-European exchange market reactions within the years 1992 until 1993. Siklos, Werner, Bohl (2004) discuss IV and GMM estimation procedures to incorporate the information and the time aspects of adding asset prices to the standard Taylor rule specification, concluding that asset prices can be highly relevant as instruments rather

than as separate arguments in policy rules. Belke, Polleit (2006) apply GMM highlighting the fact that the central bank cannot observe the expost realized contemporaneous right-hand side variables therefore instrumenting inflation and the output gap by a lagged set of explanatory variables.

To estimate an empirical reaction function we will focus on a single-equation OLS estimation approach that captures the responsiveness of the short-term nominal interest rate to variations of the macroeconomic fundementals over the sample period on average. In order to apply a forward-looking specification we will extend the basic OLS procedure by the use of instruments for future inflation and expected output growth.

3.2 Empirical specifications

3.2.1 Basic Taylor rule

The original Taylor rule specification regresses the short-term nominal interest rate on current values of the output gap and the rate of inflation. Following Ullrich (2003) we will therefore start with the estimation of the reduced form version of the Taylor rule concept. Derived from its basic functional form (1) the estimation specification in (3) incorporates the variables r^* and p^* in the intercept.[3] Within our empirical setup the output gap will be labeled by $\widetilde{y}$.[4]

$$i_t = \alpha + \beta \, p_t + \varphi \, \widetilde{y}_t \tag{3}$$

3.2.2 Interest rate smoothing

Interest rate smoothing can be incorporated by putting some weight on the previous level of the short-term interest rate in addition to inflation and the output gap when deciding on the current interest rate level (Kocicki, 1999). Siklos, Werner, Bohl (2004) start their investigation by incorprating the lagged values of the policy instrument as additional explanatory variables. Therefore we generally extend specification (3) by some lagged value of the short-term nominal interest rate (4).

$$i_t = \alpha + \rho \, i_{t-n} + \beta \, p_t + \varphi \, \widetilde{y}_t \tag{4}$$

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[3]The inflation target has been explicitely announced by the ECB as a constant target while the equlilibrium real interest rate is a theoretically motivated long-run concept and due to the variety of underlying economic theories hard to determine. Following Gerlach (1999), Siklos, Werner, Bohl (2004) and Taylor (1993) we will assume r^* and p^* to be constant within the sample period.

[4]Throughout the investigation the subscript t will denote the point in time. Depending on its sign, n will express a lead or a lag that shifts the observed value of the variables.

The parameter ρ is supposed to indicate the smoothing behaviour of the central bank. As the ECB changes its refinancing conditions in quarterly sequences it might be appropriate to incorporate smoothing lags of at least 3 months.

3.2.3 Monetary pillar

Moreover we will investigate the empirical relevance of the ECB's second pillar commitment. Therefore we add the annual growth rate of money balances M3, m to the set of regressors (Ullrich, 2003), (Belke, Polleit, 2006). Formulas are given by (5).

$$i_t = \alpha + \beta \, p_t + \varphi \, \widetilde{y}_t + \omega \, m_t \tag{5}$$

3.2.4 Backward-looking specification

There are two major aspects adressing interest rate reaction functions by the implementation of backward-looking estimation specifications. First, the use of lagged explanatory variables captures the problem of *data availability* at the period the central bank decides on interest rate alterations. Secondly, from a theoretical point of view, one could also regard this model approach as a kind of *learning-by-doing behaviour* of the monetary authority (Siklos, Werner, Bohl, 2004). A corresponding estimation equation is given by (6), while an interest rate smoothing component may be added optionally.

$$i_t = \alpha + \beta \, p_{t-n} + \varphi \, \widetilde{y}_{t-n} + \omega \, m_{t-n} \tag{6}$$

3.2.5 Forward-looking approach

As central banks and financial markets typically rely on forecasts, Clarida, Gali, Gertler (2000) emphasize the sensitivity of interest rate policy to changes in *expected* inflation. In general, forward-looking specifications incorporate proxies for expectations of key variables. Siklos, Werner, Bohl (2004) introduce the real exchange rate, stock prices and housing prices in order to determine whether the ECB may have been reacting to developments in the financial sector. Furthermore it is considered that asset prices may serve as forward-looking variables that can be used as instruments within estimations of forward-looking reaction functions.

Siklos, Werner, Bohl (2004) as well as Belke, Polleit (2006) estimate several extensions of the basic Taylor rule for the euro area by a single equation GMM technique. Their estimation approach aims at exploiting the information given at the contemporaneous period to approximately simulate the generation of forecasts. From this point of view assessing an IV approach adresses the time dimension of information processes. Chosen instruments are supposed to be predetermined at the time of an interest rate decision. Therefore, they have to be

dated on period *t-1* or earlier and should help to predict the contemporaneous variables which are still unobserved at time t.

We will structure the estimation procedure according to a two stages least squares method (2SLS) and regress on simulated expectations. As the information given in prior time periods is supposed to predict current values of inflation and the output gap, equations (7) and (8) approximate forecasting mechanisms over the investigation period on average. The set of instruments *ivar* contains quarterly lags of inflation, the output gap and money growth. Moreover we will add the growth rate of a stock price index as an asset price proxy. Fitted results p^e and $\widetilde{y}^e$ will be used as explanatory variables within equation (9).

$$p_t^e = \theta + \lambda \ ivar_{t-n} \tag{7}$$

$$\widetilde{y}_t^e = \pi + \nu \ ivar_{t-n} \tag{8}$$

$$i_t = \alpha + \beta \ p_t^e + \varphi \ \widetilde{y}_t^e \tag{9}$$

4 Estimation - procedure and results

4.1 Data

To investigate the interest rate behaviour of the ECB we use aggregated EMU-12 data on a monthly basis. The sample period starts in January 1999 and ends in February 2007. This provides us with 98 observation periods for the basic specification based on current values of the explanatory variables.[5]

According to Belke, Polleit (2006) and Ullrich (2003) we will use the following aggregates for estimating the introduced specifications: The central bank's *policy instrument*, the refinancing conditions will be captured by a short-term nominal interest rate. Belke, Polleit (2006) use a three-months money market interest rate to approximate the policy rate whereas Ullrich (2003) assesses the overnight market interest rate (EONIA). As the latter gives us a useful approximation of the ECB's interest rate decisions we will incorporate monthly averaged values of this concept (see also ECB, 1999). Figure 1 provides an overview of the originary policy intrument and its proxy.

[Figure 1]

Euro area *inflation* p_t is measured by the year-on-year percentage change in the Harmonised Index of Consumer Prices (HCPI) calculated by (10).

$$p_t = ln(HCPI_t) - ln(HCPI_{t-12}). \tag{10}$$

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[5]Data sources are listed in Table 21.

To approximate the *real output gap* we use the Industrial Production Volume Index I for the euro area and apply a Hodrick-Prescott filter in its original form (see Hodrick, Prescott, 1997). The filter removes a smooth trend I^* from our time series I by minimizing (11).

$$\sum_{t=1}^{T}(I - I^*)_t^2 + \lambda \sum_{t=1}^{T}[(I^*_t - I^*_{t-1}) - (I^*_{t-1} - I^*_{t-2})]^2 \qquad (11)$$

The residual $(I - I^*)$ is commonly referred to as some kind of business cycle component. As proposed by Ravn, Uhlig (2002) the smoothing parameter applied to monthly time series data is set at $\lambda = 129.600$. To provide the procedure with more information in order to improve our detrending estimates we apply the filtering method over the time period starting in January 1991. Figure 2 shows the outcome of the detrending method.

[Figure 2]

The output gap $\widetilde{y}_t$ is measured as the deviation of the logarithm of actual industrial production I_t from its trend I^*_t as given by (12).

$$\widetilde{y}_t = ln(I_t) - ln(I^*_t) \qquad (12)$$

As the second pillar of the ECB refers to the development of the money stock aggregate M3, *money growth* m_t is measured by its year-on-year percentage change for the euro area (13).

$$m_t = ln(M3_t) - ln(M3_{t-12}) \qquad (13)$$

As an additional instrument for the output gap and inflation in our forward-looking estimation approach the growth rate of the Dow Jones STOXX 50 (Europe) Index ps_t will be incorporated as well (14).

$$ps_t = ln(STOXX_t) - ln(STOXX_{t-12}) \qquad (14)$$

4.2   Time series' characteristics

Granger, Newbold (1974) adressed the danger of unreliable estimation results due to a *spurios regression*. This phenomenon is still valid when regressing time series data as, for example, macroeconomic aggregates. The reliability of our least squares estimators and the corresponding test statistics depends on the statistical characteristics of the aggregates in use. In our context applying least squares estimation methods requires stationary datasets. A stochastic process is stationary if its mean and variance are constant over time and the covariance between two values depends only on the time separating them and not on the point of observation.

From an economic point of view considering our specifications one might not be scared. As the monthly averages of our interest rate proxy stick very closely to the refinancing conditions given by the central bank, the variance of interest rate will not vary very much. The same is supposed to hold for the time series of our output gap approximation. In the case of inflation, money growth and stock prices this might be different. Phases of hyperinflation or asset price bubbles may bring about a rather extreme development of these aggregates. However within our investigation period these phenomenons do not seem to be of much relevance.

For a formal investigation we apply an *Augmented Dickley-Fuller test* (see Dickey, Fuller, 1979). Results are given in Table 1. For any of our time series we are able to reject the null hypothesis of non-stationarity. As these results are in line with our theoretical considerations non-stationarity will not bias the outcomes of our estimations.

[Table 1]

4.3 Macroeconomic heterogenity of the sample period

4.3.1 Estimation results of the basic sample period

Before interpreting the estimation results we will have a brief look at the development of the basic aggregates over time. Figure 3 provides an overview of the eonia money market interest rate, inflation and the output gap within our sample period.

[Figure 3]

Starting with robust output growth accompanied by upcoming inflationary pressure until the beginning of the year 2001 the ECB raised interest rates steadily resulting in an overnight rate close to 5 percent at peak.[6] As indicated by a negative output gap, ranging between 0 and -2.0 from autumn of the year 2001 until the beginning of 2005, the aggregated EMU economy did not recover. Aggregated inflation resting around its target value of about 2.0 percent annual change. Between 2001 and spring of the year 2003 refinancing conditions eased steadily, afterwards remaining unchanged until the end of the year 2005 when the ECB started a phase of increasing interest rates when output gap recovered to positive values.

Estimation results of the baseline regression specification, the interest-rate smoothing approach, a quarterly lagged specification and a forward-looking approach for the whole sample period are given in Tables 4 to 9.

[Tables 4 to 9]

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[6]Rising inflation may also be attributed to a further phase of converging national price levels within the non-homogenous currency area.

For the basic Taylor rule specification (Table 4), inflation is not significant whereas the output gap is reported significant on the 1 percent level yielding a estimated coefficient of (0.49**). Moreover the R-squared is reported with a value of 0.66. Within the smoothing approach (Table 5) - including a quarterly lag of the interest rate - the output gap and the smoothing term provide us with reasonable point estimates of (0.25**) and (0.68**) that are significant at a level of 1 percent. Again, inflation is not significant. In the backward-looking specification (Table 6) we regress the current interest rate on quarterly lags of the inflation rate, the output gap and money growth. In this case we recieve a significant coefficient estimate for the inflation rate (5 percent level) but a negative coefficient value of (-0.20*). The forward-looking IV specification (Table 9) yields a positive inflation coefficient of (0.37†) that is significant at a 10 percent level. Instrumented output gap is significant at the 1 percent level with a coefficient value of (0.41**).[7]

4.3.2 Sample split and clarification of investigation aspects

Assuming an interest rate reaction based on a Taylor rule mechanism sign and size of the coefficients as well as the inference section do not provide reasonable results. A statisticaly significant, positive coefficient estimate for inflation is only given by our forecast-simulating IV approach. For most of the specifications our results are not in line with related research and therefore do not seem to be very plausible. Prior investigations - predominantly focussing on earlier time periods - report statistically significant and economically more plausible results for the estimated inflation and output gap coefficients (Ullrich, 2003), (Carstensen, 2006), (Belke, Polleit, 2006). To explain the discrepancy regarding the reported results one can think of at least two reasons:

First, the explicit *reanouncement* of the setup of the ECB's two pillar approach in May 2003 might have lead to a change in the reaction pattern evolving its effects some time after the official change (ECB, 2003), (Arestis, 2006). The communicated strategy change comprises (a) an interest rate behaviour of attributing a higher weight on the growth rate of the money stock concept M3 emphasizing the view that inflation is rather a monetary phenomenon (Issing, 2003), and (b) a clarification in regard to the inflation target from a range between zero and 2.0 annual percentage growth of the HCPI to about 2 percent. Therefore one could expect that the shift in the relevance of the ECB's two pillars may confront us with a non-homogenous observation period in regard to the behavioural pattern.

Secondly, at the beginning of the year 2001 the ECB faced a *discrepancy* in regard to its fundamental inflation indicators. M3 money growth was still

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[7]Auxiliary first stage regressions are given by Tables 7 and 8. All in all we recieve reasonable results. However the inclusion of a stock price proxy does not exhibit much relevance. Figures 9 and 10 compare the fitted values of our simulation estimations to the actual time series.

trending upwards while the real economic factors were indicating a recession (Figure 4).

[Figure 4]

Interest rate reactions from 2001 onwards brought about a slow decline in refinancing conditions followed by a long period of unchanged interest rates remaining at 2.0 percent. The comparably weak economic performance of the euro area after the New Economy stock market correction in spring 2001 resulted in only little variation of aggregated inflation and aggregated real output growth. Therefore available data on this period may not provide powerful estimation results.

As comparable investigations refer to shorter and historically earlier time periods ending in the years 2002 to 2005 it might be reasonable to estimate the performance of our specifications within different observation periods seperately. Tables 2 and 3 compare the first and second sample moments as well as the range of the fundamental aggregates for two observation sequences, dated before and after the announcement of the strategic change in the conduct of interest rate policy behaviour in May 2003.

[Tables 2, 3]

One can observe substantial differences in regard to the datasets. A comparison of the two periods indicates a decrease in the range and the volatility of all aggregates. Inflation declined in range by about 55 percent from the corridor of 2.29 percentage points to a range of 1.00 percentage point reducing its standard deviation from 0.0055 to 0.0025. The output gap measure and monetary growth arriving at a decline in range of about 26 percent and 24 percent have also been stabilizing in regard to volatility. Furthermore the long period of unchanged refinancing conditions of 18 months starting in June 2003 ending in November 2005 resulted in a smaller variation of our policy instrument.

Therefore we will procede our investigation by splitting the sample into two periods. The first starting in January 1999 ending in April 2003 containing 52 monthly observations. The second time period starting in May 2003 counting 46 monthly observations lasting until February 2007.

The resulting investigation setup focusses on the following aspects: (a) *Can we identify a robust pattern of the ECB's interest rate variations reflecting the basic idea of a Taylor-type rule?* (b) *Does the observed behaviour meet the theoretically motivated Taylor-principle?* (c) *Can the announced change in the monetary strategy be confirmed by the data?*

4.4 Estimation results of the splitted sample

4.4.1 Preliminary examination

To motivate the quantitative assessment we compare the two time periods by scatter plots that adress the quality and the dimension of an interest rate reaction to changes in inflation and the growth rate of the chosen monatery aggregate. Figures 5 and 6 show the observed interest rate values vertically. Inflation is plotted on the horizontal axes. The scatter plot for the first period indicates a positive interest rate adjustment to changes of the inflation rate. In contrast to that for the second period we observe a negative slope of the fitted line, therefore not reflecting a Taylor-type reaction pattern.

[Figures 5, 6]

Figures 7 and 8 plot the interest rate towards M3 growth. For both figures we recieve the indication of a positive sign which is in line with our expectations.

[Figures 7, 8]

4.4.2 Statistical evaluation

Before refering to the economic implications we will summarize our results in regard to statistical significance discussing the level of empirical significance of the estimated coefficients and the overall fit of our model specifications. Results for the first observation period (*sample 1*, 1999m1 - 2003m4) are given by Tables 10 to 14.

[Tables 10 to 14]

For the *basic specification* (Table 10) all estimated coefficients are significant at the level of 1 percent. The regression yields an R-squared of 0.79 which is much higher than for the whole estimation period. The *smoothing approach* (Table 11) provides equally significant point estimates and a very high R-squared value of 0.97. For the *backward-looking* estimation (Table 12) we recieve inflation of the previous quarter only significant at a 10 percent level, lagged output gap and lagged money growth being significant at a 1 percent level. Our *monetary pillar assessment* (Table 13) provides signifincance on an at least 5 percent level, output gap even at a 1 percent level. The R-squared is reported with a value of 0.81. For the *forward-looking* specification (Table 14) instrumented inflation and output gap coefficients are significant at the 1 percent level. Compared to the basic sample (Tables 4 to 9) we find significant estimates for the inflation term at an equally high overall model fit.

Tables 15 to 19 summarize the second sample period (*sample 2*, 2003m5 - 2007m2). Throughout all specifications the estimated inflation coefficients and

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the output gap are significant. Monetary growth is even significant at the 1 percent level (Table 18). Backward- and forward-looking specifications (Tables 17 and 19) do not deviate remarkably from the estimations of the prior time period.

[Tables 15 to 19]

4.4.3   Economic interpretation and context relevance

In this section we will refer to the economic implications of the sign and the size of the point estimates. The *basic specification* for the *first sample* (Table 10) yields positive values for both, inflation (0.52**) and the output gap (0.35**). In contrast to this the estimation results of the *second sample* (Table 15) reveal a strong negative inflation coefficient (-0.54**) the output gap still at (0.37**). This supports our assumption of a structural break in regard to the interest rate reaction pattern.

In both samples the *smoothing parameters* (Tables 11 and 16) yield relatively strong positive estimates of (0.51**) and (0.70**). This plausibly reflects the ECB's step by step interest rate adjustments. Due to the little interest rate variations we recieve a very high coefficient value for the second period. Technically this is also reflected by a comparably high R-squared.

For the *backward-looking* specification we receive higher coefficients of the output gap but lower parameter estimates of inflation in both samples (Tables 12 and 17). An additional lag of pre-quarter M3 growth for the first sample period yields a significant but only small coefficient (0.06**) whereas for the second time period we recieve a higher value of (0.13**).

Compared to the basic specification the introduction of current *monetary growth* as an additional explanatory variable does not exhibit much impact on the other variable's parameter estimates (Tables 13 and 18). Money growth itself yields small - but as mentioned above statistically significant - values of (0.10*) and (0.12**).

The IV-forecasting approach (Tables 14 and 19) yields a comparably high inflation coefficient of (0.92**) for the first sample whereas for the second period we recieve a negative coefficient value of (-0.42†). For both samples instrumented output gaps report almost equal results with estimated values of (0.31**) and (0.30**).

The differences of the two observation periods in the context of a Taylor-type reaction pattern can be demonstrated by simulating an interest rate setting based on the first sample's estimated reaction coefficients. Figure 11 shows the fitted Talyor interest rate derived from the baseline specification in comparison to the actual development of the refinancing proxy. The discrepancy from May 2003 onwards can be impressively observed.

[Figure 11]

Finally we will compare our results to similar estimations of empirical reaction functions for the euro area. Table 20 provides an overview of the basic results according to the specifications and investigation periods.

[Table 20]

For her basic specification and a sample period from January 1999 to August 2002 Ullrich (2003) identifies small reactions to inflation (0.25) but strong responses to output deviations (0.63*). Incorporating money growth yields a stronger reaction to inflation (0.65*) but a negative sign for the monetary aggregate (-0.20*). Belke, Polleit (2006) - covering a sample period from 1999 to the first quarter 2005 - report an inflation coefficient of (0.49**) and a comparably high output gap reaction of (1.94**). This might be due to the set of instruments used within their GMM appraoch and the use of quarterly data. Carstensen (2006) investigates monthly aggregates from January 1999 to June 2005 reporting a small output gap reaction of (0.15*) for his basic as well as a monetary specification. Estimated inflation coefficients yielding values of (0.19†) and (0.10†) are comparably small.

5 Conclusion

Our results propose that the ECB did not follow a Taylor-type reaction pattern over the whole investigation period but only from 1999 to 2003. In addition to that the theoretically derived benchmarks that are supposed to provide macroeconomic stability are empirically only partially confirmed by the data. We receive significant estimates for the output gap coefficient that are above the benchmark value of zero and therefore indicate a stabilizing interest rate behaviour for all of our specifications and within the whole observation period. In contrast to that we cannot observe a reaction to changes of the inflation rate that exceeds the proposed benchmark value of unity. Therefore the theoretically motivated Taylor-principle is not met. This result is in line with the outcomes of related estimation approaches.

Moreover we observe a remarkable shift in the estimated coefficients for inflation when comparing the two observation periods. In the second observation period we even find a significant negative coefficient sign for inflation. A significant change in the reaction to monetary growth can not be identified. Our estimation results report small but robust coefficient values.

As we observe remarkable shifts in the estimated inflation coefficents when splitting the observation sample, we assume that estimation results may depend rather on the investigation period than on the specification. Therefore we confirm Hamalainen (2004) who stated that estimated Taylor-type rules are not robust in the sence that estimated relative weights tend to shift over time. This can also lead to changes in sign, reflecting changes in the conduct of interest rate policy

as we supposed in the case of the ECB. This means that using observations that span over long periods where switches in policy regimes are assumed to have taken place might not be appropriate when estimating Taylor-type rules.

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A   Figures

Figure 1: Approximating refinancing conditions

Figure 2: Detrending real industrial production
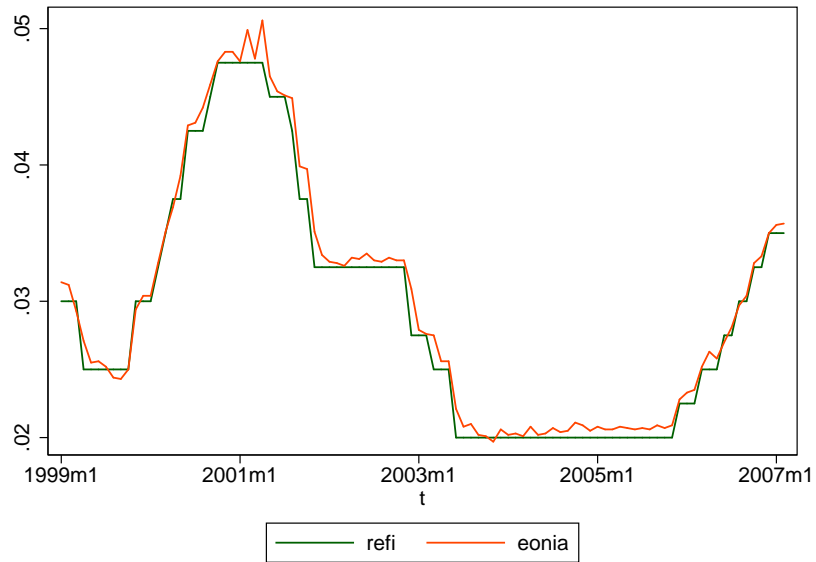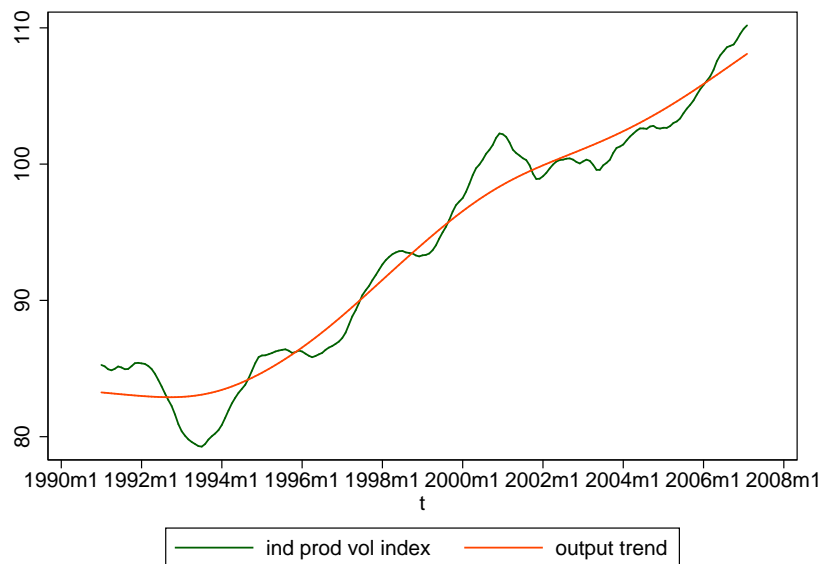
Figure 3: Eonia, inflation, output gap proxy, 1999m1 - 2007m2
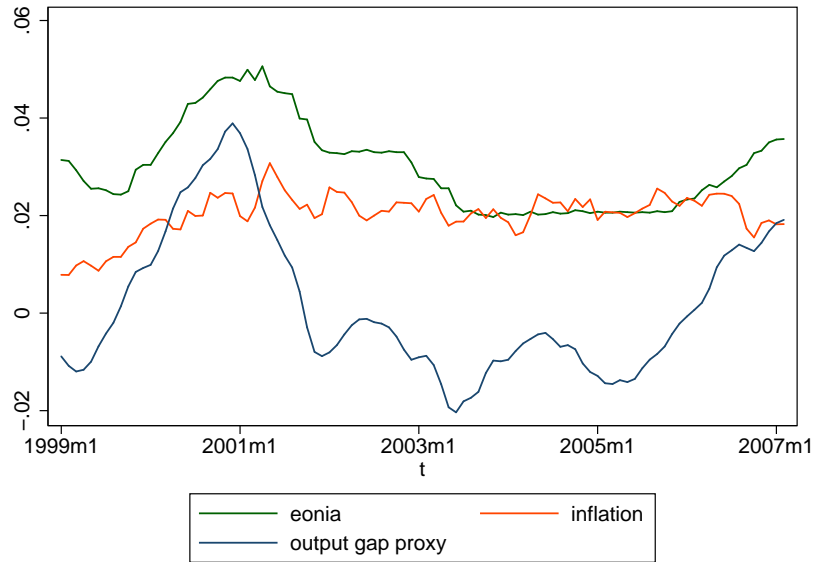
Figure 4: Output gap proxy, m3, 1999m1 - 2007m2
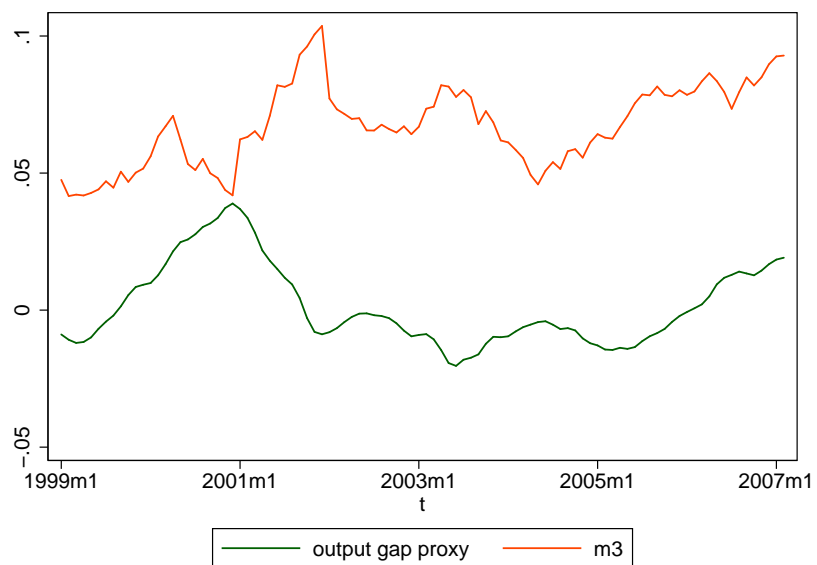
Figure 5: Inflation and interest rate variations, 1999m1 - 2003m4
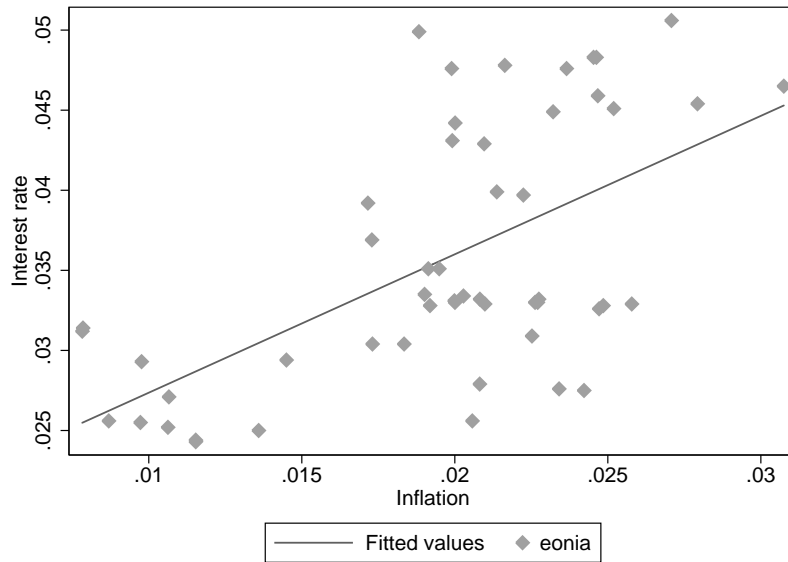
Figure 6: Inflation and interest rate variations, 2003m5 - 2007m2

Figure 7: M3 growth and interest rate variations, 1999m1 - 2003m4

Figure 8: M3 growth and interest rate variations, 2003m5 - 2007m2

Figure 9: Simulated inflation forecasts, 1999m1 - 2007m2

inflation ——— simulated inflation forecast, F3

Figure 10: Simulated output gap forecasts, 1999m1 - 2007m2

output gap proxy ——— simulated output gap forecast, F3

v
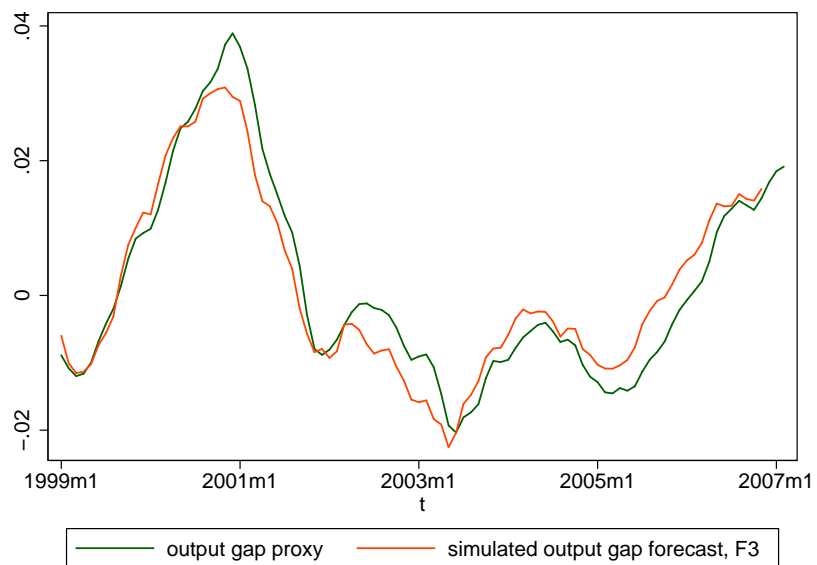
Figure 11: Fitted sample1 taylor interest rate, 1999m1 - 2007m2
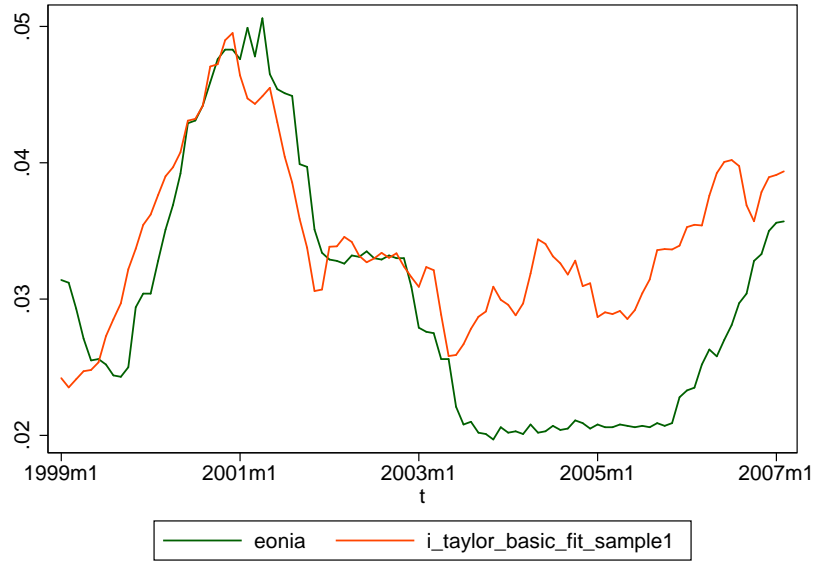
B Stationarity

Table 1: Augmented Dickey-Fuller test for unit root

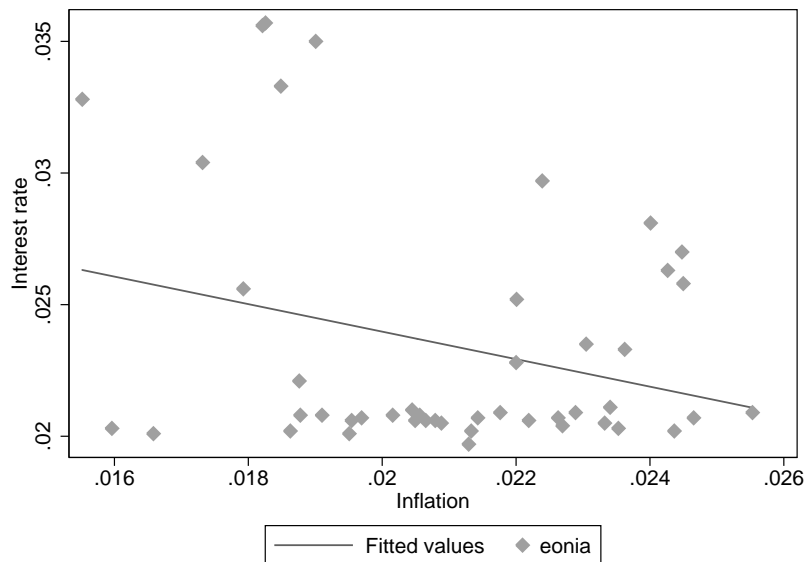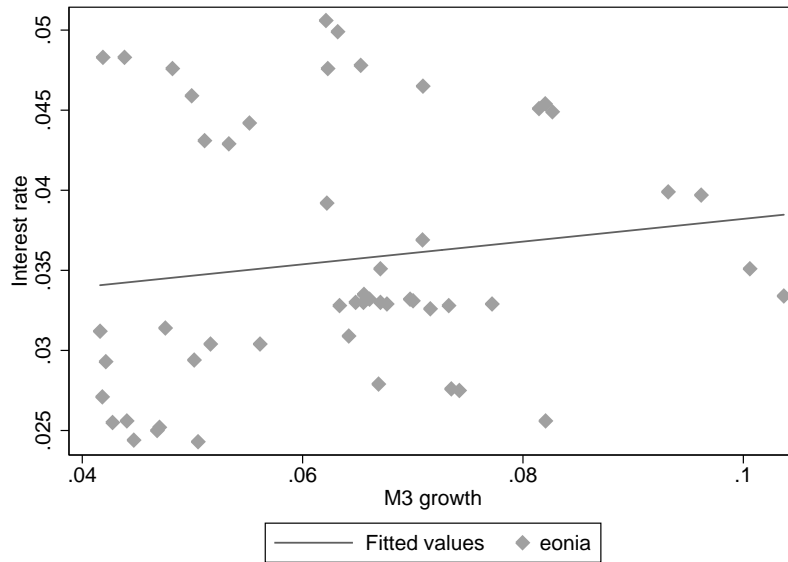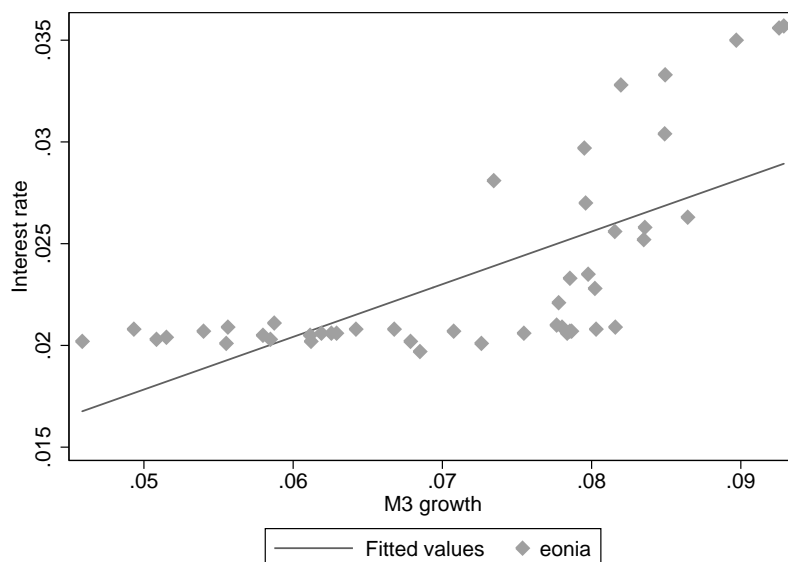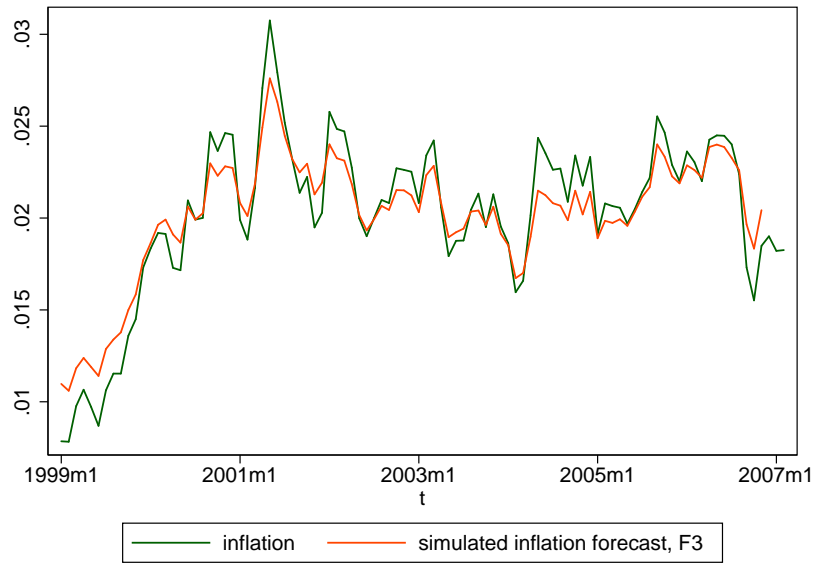| Variable	Option(Lag)	TestStat	1% C.Val	5% C.Val	P-Value
eonia	drift(6)**	-2.517	-2.372	-1.663	0.0069
eonia	drift(4)**	-2.384	-2.370	-1.663	0.0097
eonia	trend(6)*	-3.412	-4.060	-3.459	0.0499
eonia	trend(4)†	-3.192	-4.055	-3.457	0.0860
inflation	drift(1)**	-3.392	-2.366	-1.661	0.0005
inflation	trend(1)†	-3.224	-4.044	-3.452	0.0797
output gap	drift(3)**	-2.748	-2.367	-1.661	0.0036
output gap	drift(1)**	-2.584	-2.366	-1.661	0.0056
m3	drift(5)**	-2.376	-2.368	-1.662	0.0098
m3	drift(3)*	-2.092	-2.367	-1.661	0.0196
stock prices	drift(5)*	-2.045	-2.368	-1.662	0.0219
stock prices	drift(2)*	-1.969	-2.367	-1.661	0.0260

Significance levels : † : 10%   ∗ : 5%   ∗∗ : 1%

C Summary statistics

Table 2: Summary statistics, 1999m1 - 2003m4

Variable	Mean	Std. Dev.	Min.	Max.	N
eonia	0.0356	0.008	0.0243	0.0506	52
inflation	0.0196	0.0055	0.0078	0.0308	52
output gap	0.0064	0.0161	-0.0146	0.0389	52
m3	0.0634	0.0158	0.0416	0.1037	52

Table 3: Summary statistics, 2003m4 - 2007m3

Variable	Mean	Std. Dev.	Min.	Max.	N
eonia	0.0234	0.0047	0.0197	0.0357	46
inflation	0.021	0.0025	0.0155	0.0255	46
output gap	-0.004	0.0112	-0.0203	0.0191	46
m3	0.0717	0.0124	0.0459	0.0929	46

D Regression outputs

D.1 Basic sample

Table 4: Basic specification, 1999m1 - 2007m2

Variable	Coefficient	(Std. Err.)
inflation	0.0994	(0.1245)
output gap	0.4853**	(0.0367)
Intercept	0.0272**	(0.0026)

N	98
R^2	0.6607
F $_{(2,95)}$	92.4825

Significance levels :   † : 10%   ∗ : 5%   ∗∗ : 1%

Table 5: Smoothing specification, 1999m1 - 2007m2

Variable	Coefficient	(Std. Err.)
L3.eonia	0.6840**	(0.0220)
inflation	0.0443	(0.0410)
output gap	0.2493**	(0.0131)
Intercept	0.0082**	(0.0010)

N	95
R^2	0.9734
F $_{(3,91)}$	1110.2547

Significance levels :   † : 10%   ∗ : 5%   ∗∗ : 1%

Table 6: Backward-looking specification, 1999m1 - 2007m2

Variable	Coefficient	(Std. Err.)
L3.p	-0.2019*	(0.0867)
L3.output gap	0.5906**	(0.0255)
L3.m3	0.0725*	(0.0288)
Intercept	0.0287**	(0.0018)

N	98
R^2	0.8585
F $_{(3,94)}$	190.0536

Significance levels :   † : 10%   ∗ : 5%   ∗∗ : 1%

Table 7: Instrumenting inflation, 1999m1 - 2007m2

Variable	Coefficient	(Std. Err.)
L3.p	0.6330**	(0.0785)
L3.p_stocks	-0.0002	(0.0017)
L3.y_gap	0.0305	(0.0249)
L3.m3	0.0533†	(0.0283)
Intercept	0.0038*	(0.0018)
N	107	
R^2	0.5879	
F $_{(4,102)}$	36.3758	
Significance levels :	$\dagger : 10\%$ $* : 5\%$ $** : 1\%$	

Table 8: Instrumenting output gap, 1999m1 - 2007m2

Variable	Coefficient	(Std. Err.)
L3.p	0.1277	(0.1307)
L3.p_stocks	0.0205**	(0.0028)
L3.y_gap	0.8044**	(0.0414)
L3.m3	0.1173*	(0.0471)
Intercept	-0.0105**	(0.0030)
N	107	
R^2	0.8628	
F $_{(4,102)}$	160.4088	
Significance levels :	$\dagger : 10\%$ $* : 5\%$ $** : 1\%$	

Table 9: Forecast simulation ($t+3$), 1999m1 - 2007m2

Variable	Coefficient	(Std. Err.)
F3.p_hat	0.3683†	(0.2184)
F3.y_hat	0.4097**	(0.0532)
Intercept	0.0219**	(0.0045)
N	95	
R^2	0.4402	
F $_{(2,92)}$	36.1719	
Significance levels :	$\dagger : 10\%$ $* : 5\%$ $** : 1\%$	

D.2 Sample 1

Table 10: Basic specification, 1999m1 - 2003m4

Variable	Coefficient	(Std. Err.)
inflation	0.5212**	(0.1001)
output gap	0.3480**	(0.0341)
Intercept	0.0232**	(0.0020)

N	52
R^2	0.7933
F $_{(2,49)}$	94.0218

Significance levels :   † : 10%   ∗ : 5%   ∗∗ : 1%

Table 11: Smoothing specification, 1999m1 - 2003m4

Variable	Coefficient	(Std. Err.)
L3.eonia	0.5099**	(0.0411)
inflation	0.2619**	(0.0596)
output gap	0.2724**	(0.0160)
Intercept	0.0102**	(0.0012)

N	49
R^2	0.9662
F $_{(3,45)}$	429.4442

Significance levels :   † : 10%   ∗ : 5%   ∗∗ : 1%

Table 12: Backward-looking specification, 1999m1 - 2003m4

Variable	Coefficient	(Std. Err.)
L3.p	0.1209†	(0.0667)
L3.output gap	0.4721**	(0.0214)
L3.m3	0.0641**	(0.0234)
Intercept	0.0262**	(0.0011)

N	52
R^2	0.9471
F $_{(3,48)}$	286.5511

Significance levels :   † : 10%   ∗ : 5%   ∗∗ : 1%

Table 13: Monetary pillar specification, 1999m1 - 2003m4

Variable	Coefficient	(Std. Err.)
inflation	0.3236*	(0.1301)
output gap	0.3921**	(0.0382)
m3	0.0987*	(0.0438)
Intercept	0.0205**	(0.0022)
N	52	
R^2	0.8131	
F $_{(3,48)}$	69.5928	
Significance levels :	† : 10%	* : 5%	** : 1%

Table 14: Forecast simulation ($t+3$), 1999m1 - 2003m4

Variable	Coefficient	(Std. Err.)
F3.p_hat	0.9170**	(0.1398)
F3.y_hat	0.3136**	(0.0369)
Intercept	0.0164**	(0.0028)
N	52	
R^2	0.752	
F $_{(2,49)}$	74.2859	
Significance levels :	† : 10%	* : 5%	** : 1%

D.3 Sample 2

Table 15: Basic specification, 2003m5 - 2007m2

Variable	Coefficient	(Std. Err.)
inflation	-0.5350**	(0.1176)
output gap	0.3673**	(0.0264)
Intercept	0.0362**	(0.0025)

N	46
R^2	0.8323
$F_{(2,43)}$	106.6811

Significance levels :   † : 10%   ∗ : 5%   ∗∗ : 1%

Table 16: Smoothing specification, 2003m5 - 2007m2

Variable	Coefficient	(Std. Err.)
L3.eonia	0.6996**	(0.0554)
inflation	-0.1315*	(0.0631)
output gap	0.2249**	(0.0166)
Intercept	0.0111**	(0.0023)

N	46
R^2	0.9650
$F_{(3,42)}$	385.8774

Significance levels :   † : 10%   ∗ : 5%   ∗∗ : 1%

Table 17: Backward-looking specification, 2003m5 - 2007m2

Variable	Coefficient	(Std. Err.)
L3.p	-0.2118**	(0.0769)
L3.output gap	0.4107**	(0.0208)
L3.m3	0.1299**	(0.0173)
Intercept	0.0212**	(0.0021)

N	46
R^2	0.9333
$F_{(3,42)}$	195.9823

Significance levels :   † : 10%   ∗ : 5%   ∗∗ : 1%

Table 18: Monetary pillar specification, 2003m5 - 2007m2

Variable	Coefficient	(Std. Err.)
inflation	-0.4784**	(0.0902)
output gap	0.3039**	(0.0231)
m3	0.1175**	(0.0208)
Intercept	0.0263**	(0.0026)
N		46
R^2		0.9047
F $_{(3,42)}$		132.8911
Significance levels :	† : 10%	∗ : 5% ∗∗ : 1%

Table 19: Forecast simulation ($t+3$), 2003m5 - 2007m2

Variable	Coefficient	(Std. Err.)
F3.p_hat	-0.4190†	(0.2372)
F3.y_hat	0.3047**	(0.0433)
Intercept	0.0320**	(0.0050)
N		43
R^2		0.5737
F $_{(2,40)}$		26.9118
Significance levels :	† : 10%	∗ : 5% ∗∗ : 1%

E Comparison

Table 20: Estimated Taylor-type rules for the Euro Area

Author	Specif.	p	$\widetilde{y}$	smooth	money
Ullrich	basic	0.25	0.63*	0.19*	
(1999m1:2002:m8)	m3	0.65*	0.26*	0.27*	-0.20*
Belke, Polleit	basic	0.49**	1.94**	0.75**	-
(1999q1:2005q1)	m3	-0.16**	2.41**	0.70**	0.19**
Carstensen	basic	0.19†	0.15*	0.61†	
(1999m1:2005m6)	m3	0.10†	0.15*	0.62†	0.09*
Own results:					
basic sample	basic	0.04	0.25**	0.68**	-
sample 1	basic	0.51**	0.27**	0.51**	-
-.-	m3	0.32*	0.39**	-	0.10*
sample 2	basic	-0.13*	0.22**	0.70**	-
-.-	m3	-0.48**	0.30**	-	0.12**

Significance levels : † : 10%   ∗ : 5%   ∗∗ : 1%

F Data sources

Table 21: Data sources

Variable	Aggregate	Database
eonia	Money Market Overnight Rate	Deutsche Bundesbank
refi	ECB Refinancing Conditions	Eurostat Database
p	Harmonized Consumer Price Index	Eurostat Database
$\widetilde{y}$	Industrial Production Volume Index	Eurostat Database
m	M3 Money Stock	Eurostat Database
ps	Dow Jones STOXX 50 (Europe)	Eurostat Database