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## Monetary Cross-Checking in Practice

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# Monetary cross-checking in practice<sup>†</sup>

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## Abstract

Ever since the European Central Bank presented its monetary policy strategy on the basis of two pillars – "economic" and "monetary" analysis with the latter being used as a cross-check of the first – it has been criticized for giving too much importance to monetary aggregates. Opponents argue these aggregates are largely unrelated to monetary policy and provide little or no relevant information. Supporters have instead referred to the success of the Bundesbank in controlling inflation by using monetary targets during the 1970s and early 1980s. Furthermore, loose monetary conditions in the 2000s are viewed by many as a driver of excessive growth of credit and asset prices that set the stage for the global financial crisis. We use a formal characterization of monetary cross-checking and go on to study its role in policy practice empirically. Firstly, we derive historical measures of monetary conditions using this definition of cross-checking for Germany from the 1970s to 1998 and for the euro area since then. We investigate when monetary cross-checking would have called for significant adjustments in interest rate policy. Secondly, we test empirically whether interest rate policy responded to significant deviations of money. Such cross-checks induce a nonlinear shift in rates based on a threshold in terms of filtered money growth. Our estimates of threshold autoregressive models indicate that the behavior of the Bundesbank can well be described by a standard Taylor interest-rate rule augmented by a nonlinear component which induces an interest-rate adjustment when a filtered money growth measure exceeds an empirically specified threshold. Concerning the policy making of the ECB, we find supportive evidence for Trichet's (2008) claim of an interest-rate adjustment induced by a signal from monetary cross-checking at the end of 2004. However, our empirical results would have suggested an even larger (and earlier) response.

**JEL Classification:** C10, C22, E32, E41, E43, E52, E58

**Keywords:** *cross-checking, monetary policy, money, quantity theory, Bundesbank, European Central Bank, Taylor rule, threshold autoregressive models, policy under uncertainty.*

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<sup>†</sup>The usual disclaimer applies.

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# 1 Introduction

In recent years, the usefulness of monetary aggregates for monetary policy has been questioned considerably by many monetary economists. Woodford (2006), e.g., writes:

*“I believe that a serious examination of the reasons given thus far for assigning a prominent role to monetary aggregates in (policy) deliberations provides little support for a continued emphasis on those aggregates.”*

Theoretically, the case against the use of monetary information for policy decisions is based on the New-Keynesian model which suggests that central banks should set interest rates, i.e. their major policy instrument, with reference to inflation forecasts and output gaps but without direct concern for monetary aggregates.

The importance of monetary aggregates has also declined in central bank practice. For example, the U.S. Fed de-emphasized the role of monetary aggregates in its strategy already in the early 1990s and it even ceased publication of the M3 aggregate in 2003. Moreover, while monetary targeting was relatively popular in the 1970s, nowadays no central bank pursues such a strategy any more. Currently, a very popular strategy amongst central banks is inflation targeting which uses monetary information only as one out of many variables for decision making.

Nevertheless, some central banks and some monetary theorists still hold out for a special role for money in the formulation of monetary policy. Money may, for example, contain important information about future inflation (Gerlach and Svensson (2003) and Assenmacher-Wesche and Gerlach (2007)), financial stability (Adrian and Shin (2009)), and the output gap (Beck and Wieland (2008)). The European Central Bank, e.g., maintains that its monetary analysis is important enough to deserve a particular consideration separately from its other economic analysis. The reason why the European Central Bank (ECB) assigned a special role for monetary aggregates in its strategy and has stuck to this decision despite considerable criticism might have to do with the successful policy of the Bundesbank which is often seen as the role model for the ECB. The Bundesbank officially engaged in monetary targeting for over twenty years starting at the end of 1971. The monetary aggregate it originally targeted was central bank money. In 1988, it switched targets from central bank money to M3.

Interestingly, even though the Bundesbank was more successful than most other central banks in keeping inflation low particularly in the late 1970s it very often missed its monetary target. These repeated failures can very likely be seen as a major reason why the ECB has not fully adopted the Bundesbank’s strategy of monetary targeting but has only attributed money a special, but nevertheless important role in its two pillar strategy. The ECB distinguishes an ‘economic’ and a ‘monetary’ pillar. The economic-analysis pillar is based on a wide set of domestic and international economic indicators from the real and financial

sectors (wages, import prices, interest and exchange rates etc.). It provides a basis for the assessment of short- to medium-term price developments. The monetary-analysis pillar comprises all information coming from various monetary and credit aggregates and serves to detect risks to price stability which might arise over a medium- to long-run time horizon.

Intellectual support for the inclusion of a separate monetary pillar in the ECB's strategy is provided, e.g., by Lucas (2007) who emphasizes in light of the inability of the standard New-Keynesian model to satisfactorily explain long-run trends in money and inflation that *“monetary information should continue be used as a kind of add-on or cross-check, just as it is in the ECB policy formulation today.”*

However, as mentioned above, there also exist considerable objections against the separate monetary pillar of the ECB. In addition to the fact that monetary information is considered to be useless for monetary policy decisions critics argue that monetary information has actually not been used by the ECB in its decision making in the past.<sup>1</sup> This is strongly contradicted by ECB officials. The former president of the ECB, Jean-Claude Trichet, e.g., stated in a newspaper interview<sup>2</sup> that the interest increase in December 2005 was induced by the monetary analysis. And the current president of the ECB, Mario Draghi, recently justified the extended asset purchase program in a press conference<sup>3</sup> with reference to the ECB's monetary analysis. Since the strategy of the ECB is formulated verbally only and a formalization of it has not been undertaken in the past, it has so far not been possible to formally test the practical implications of the monetary pillar at the ECB.

The objective of the current paper is to examine to which extent the use of monetary information would have suggested adjustments in the interest rate setting by the ECB in the past when *“used as a kind of add-on or cross-check”* (Lucas (2007)). We are in particular interested in the question whether the above mentioned claim of Mr. Trichet can be justified empirically. To this end, we employ results by Beck and Wieland (2007) and Beck and Wieland (2010) who proposed an interest rate rule that captures the idea of an add-on or cross-check with monetary information in a formal manner. This interest rate rule consists of two components. The first component aims to control inflationary risks based on a standard Phillips curve and aggregate demand relationship. Essentially, it is the optimal interest rate rule of an inflation-targeting central bank.

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<sup>1</sup>See, e.g., Gali et al. (2004).

<sup>2</sup>Interview with Jean-Claude Trichet, President of the ECB conducted on July 11, 2008 by Jean Pierre Robin (Le Figaro), Benedikt Fehr (Frankfurter Allgemeine Zeitung), Paul Tansey (Irish Times) and Rui Jorge (Jornal de Negócios), published 18 July 2008. Question: Central Banks, including the ECB, have been responsible for a lot of monetary growth in the recent past. To what extent are central banks to blame for the present inflation, in the euro area and elsewhere?

<sup>3</sup>Draghi, M. (2015). Introductory statement to the press conference (with Q&A), Internet: [www.ecb.europa.eu/pressconf2015htmlis150122.en.html](http://www.ecb.europa.eu/pressconf2015htmlis150122.en.html)

The second component captures the idea of cross-checking using the long-run relationship between money and inflation. It is assumed that the central bank checks regularly whether a filtered money growth series adjusted for output and velocity trends averages around the inflation target. If the central bank obtains successive signals of a sustained deviation of inflation from target it adjusts interest rates accordingly.

In the current study we make use of this idea of a non-linear interest-rate adjustment induced by monetary cross-checking and will follow two complementary approaches to examine empirically how and to which extent actual policy making by both the Bundesbank and the ECB can be described by such a behavior. Our first approach is induced by Beck and Wieland (2007, 2009) who note the similarity between monetary cross-checking as modelled in these papers and the ECB's two-pillar strategy according to which monetary information is used to cross-check results from the economic analysis. Following this rationale we will associate the ECB's "economic analysis" with the optimal interest rate policy derived from the policymaker's preferred model of the economy, i.e. the first component of our proposed interest rate rule. Our justification for this association is that this setting of the interest rate will ensure that short- to medium-run inflationary risks based on a forward-looking Phillips curve and excess aggregate demand are perfectly controlled. Similarly, we associate the ECB's "monetary analysis" with the cross-checking adjustment, i.e. the second component of the interest rate rule proposed by Beck and Wieland (2007, 2009). This adjustment exploits the long-run link between money and prices.

One potential drawback of this approach is that it relies on a specific model of the world. While our employed New-Keynesian model framework represents the workhorse model in monetary economics it nevertheless is very well conceivable that the true model of the world is not perfectly captured by it. We therefore complement our above described procedure by following the idea outlined by Taylor (1993) who uses a simple interest-rate rule and shows that this rule can fairly well describe the past behavior of the Fed. Subsequent authors have shown that this so-called Taylor rule has fairly good robustness properties in the sense that it leads to satisfactory economic outcomes across various models. In the spirit of Taylor (1993) we will make use of a standard Taylor-rule and augment it with a nonlinear cross-checking component.

Since the strong emphasis of monetary information in the ECB's strategy can be seen as a heritage of the Bundesbank and since the Bundesbank was the leading central bank in Europe before the installment of the ECB we not only look at euro area data but also extend our analysis to German data for the period from 1971 until 1998, i.e., the period after the end of the Bretton-Woods system until the introduction of the euro. Moreover, we employ evidence obtained from the Bundesbank sample to calibrate our model and to specify the empirical interest-rate rule to be used for the analysis of the ECB's monetary

policy.

Our results for Germany show that there have occurred only few phases of strong positive deviations of filtered adjusted money growth from the inflation target. As a consequence, our model-based approach only very rarely suggests an adjustment induced by monetary cross-checking. One such case took place at the beginning of the 1980s. For this period our estimated interest-rate rule similarly prescribes a nonlinear adjustment. Contrary to our model-based result, the empirical interest-rate rule does not call for any adjustment in the policy rate at the time of the re-unification when adjustment money growth significantly undershooting the inflation norm.

In line with Mr. Trichet's claim our results for the euro area suggest a non-linear interest-rate adjustment induced by monetary cross-checking at the end of the year 2005. However, our analysis also shows that the interest rate adjustment should have been probably undertaken earlier and that it should have been more sizeable.

The remainder of this paper is structured as follows. Section 2 presents evidence on the comovement of money growth and inflation in Germany and the euro area. Section 3 describes the relationship between trend money growth, trend inflation and trend output growth which the quantity theory implies and presents evidence on this relationship. Section 4 is dedicated to a characterization of the Bundesbank's and the ECB's policy strategies. Section 5 introduces the general definition of cross-checking and outlines the two approaches we employ for our analysis. In Section 6 we provide our calibration and describe the estimation procedure. Sections 7 and 8 applies cross-checking to German and euro area data and Section 9 concludes.

## 2 Money and inflation in Germany and the euro area: Empirical evidence

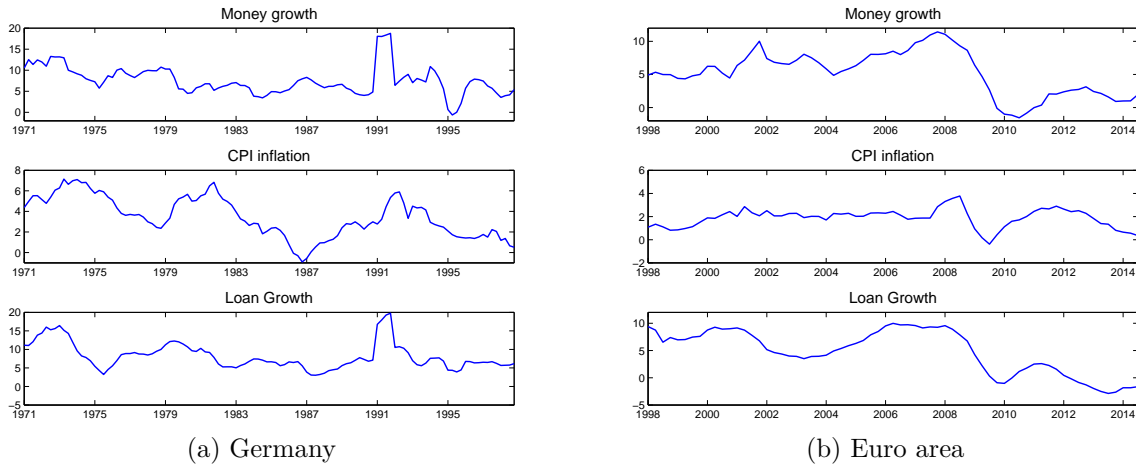
The use of monetary information for achieving the aim of price stability requires that there exists a strong and reliable relationship between money growth and inflation. Given that the velocity of money is stable the quantity theory of money predicts that inflation rates should move directly proportional to money growth rates. Recent empirical work has confirmed the existence of such a strong positive correlation between money growth and inflation.<sup>4</sup> Figure 1 provides empirical evidence on money growth (M3) and inflation for Germany and the euro area. For Germany, the data cover the period from 1971 to 1997, for the euro area the data span the period from 1998 to 2010.

Several features of Figure 1 are noteworthy. First, money growth and inflation have tended to move together in Germany and the euro area most of the time. In Germany,

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<sup>4</sup>See for example Gerlach (2004), Pill and Rautananen (2006), Assenmacher-Wesche and Gerlach (2007) or Benati (2009).

Figure 1: Money growth and inflation: Germany and euro area



Note: Figure 1 plots German (left panels) and euro area (right panels) money growth and CPI inflation rates. German data are plotted for the period 1971 to 1997, euro area data are plotted for the period 1998 and 2010. Growth rates are computed as year-on-year percentage changes.

e.g., money growth and inflation rates both increased at the beginning of the seventies and declined afterwards. Similarly, the two rates both moved upwards at the end of the eighties and declined towards the mid nineties. For the euro area we can observe that money growth and inflation shared an upward trend in the period from 1998 until 2007/08 and have both experienced a sharp decline afterwards. Secondly, we can see, however, that there also existed periods in which the degree of co-movement was relatively weak. This is, e.g., the case for the eighties in Germany. The third observation we can make is that money growth seems to lead inflation.<sup>5</sup> This feature of the data is particularly pronounced in Germany but also existent in the euro area.

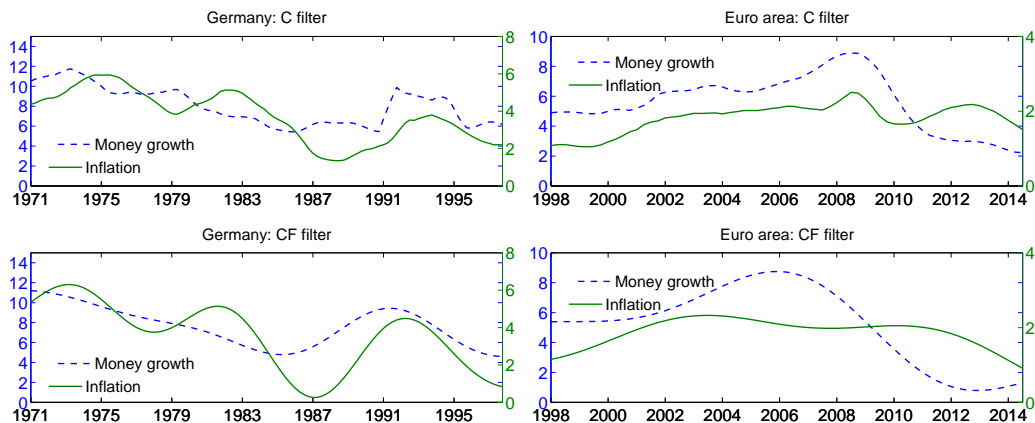
In Figure 1, **actual** growth rates of money and the CPI price level are plotted. Since the quantity theory of money is commonly understood as applying to the long- rather than the short-run we proceed by filtering out the short- to medium-term components of the time series reported in the above figures. To uncover the underlying trends in money growth and inflation two different techniques were used. Following studies such as Assenmacher-Wesche and Gerlach (2007) or Beck and Wieland (2008) the two upper panels of Figure 3 use the adaptive filter developed by Cogley (2002) (denoted by *C filter*) to detect the long-run trends in money growth and inflation. In this case, the trend measure of the growth rates in money and the CPI price level is computed by simply attributing a constant share of any innovation in the respective growth rate to the past trend. The two lower panels of Figure 3 plot the resulting trends from applying the Christiano-Fitzgerald band-pass filter (denoted by *CF filter*). The Christiano-Fitzgerald band-pass filter is a

<sup>5</sup>See also Benati (2009) for further recent evidence on this issue.

linear filter, like the Hodrick-Prescott filter, but it recovers the trend as the component of the series with periodicity between a lower and an upper bound which we set equal to two quarters and 32 quarters.<sup>6</sup>

Both methods for uncovering underlying trends in money growth and inflation confirm the conclusions drawn above. It can be clearly seen that money growth and inflation rates tend to move together closely both in Germany and the euro area. Moreover, money growth leads inflation by several quarters in Germany whereas the evidence in this respect for the euro area is much weaker.

Figure 3: Long-run money-inflation link



Note: Figure 3 plots filtered money growth and CPI inflation rates for Germany (left panels) and the euro area (right panels). The “C Filter” corresponds to the filter as proposed in Cogley (2002), the “CF Filter” corresponds to the filter as proposed in Christiano and Fitzgerald (2003).

### 3 Money/Inflation long-run theory and adjustments

The second, i.e., the cross-checking component of our proposed formalization of the ECB’s two-pillar strategy exploits the long-run link between money and prices which is illustrated in this section. Starting point of our derivation of the long-run theory between money growth and inflation is the equation of exchange which defines velocity of money,  $v$ , as:

$$v_t = -m_t + p_t + y_t, \tag{1}$$

<sup>6</sup>The Christiano-Fitzgerald band-pass filter is by far the more commonly used filter. However, while estimates of past trend money growth obtained with the Christiano-Fitzgerald band-pass filter may change as the sample is extended into the future, an advantage of the simpler adaptive filter is that the past trend values remain fixed. We therefore decided to report results from both filter techniques. For further reference on the Christiano-Fitzgerald band-pass filter, see Christiano and Fitzgerald (2003).



where  $(m, p, y)$  denote the logarithms of money, the aggregate price level and real output. Taking first differences we approximate the equation in growth terms:

$$\Delta v_t = -\Delta m_t + \Delta p_t + \Delta y_t. \quad (2)$$

$\Delta$  is the first-difference operator. In the long-run, output growth and the change in velocity will settle down to trend and reveal a proportional relationship between money growth and inflation. In the short-run, however, fluctuations in velocity and output growth are likely to obscure this relationship.

The behavior of velocity may be characterized as a function of the nominal interest rate,  $i$ , real output,  $y$ , and money demand shocks,  $\epsilon_t^{md}$ , using a standard money demand equation:

$$m_t - p_t = \gamma_y y_t - \gamma_i i_t + \epsilon_t^{md}. \quad (3)$$

Here,  $\gamma_y$  denotes the income elasticity and  $\gamma_i$  the semi-interest rate elasticity of money demand. Taking first differences, re-arranging (3) and combining it with (2) we obtain the following expression for the changes in velocity:

$$\Delta v_t = (1 - \gamma_y)\Delta y_t + \gamma_i \Delta i_t + \Delta \epsilon_t^{md}. \quad (4)$$

Long-run equilibrium values (denoted by the superscript  $*$ ) can then be determined as follows. In the long-run, money demand shocks would average to zero, and the nominal interest rate would settle down to its steady state level. Thus, the long-run trend in velocity corresponds to  $\Delta v_t^* = (1 - \gamma_y)\Delta y_t^*$ , and long-run inflation is proportional to long-run money growth adjusted for output and velocity trends:<sup>7</sup>

$$\Delta p_t^* = \Delta m_t^* - \gamma_y \Delta y_t^*. \quad (5)$$

Table 1: Estimates of income elasticities of money demand and potential output

| Parameter       | Value | Economic interpretation and source  |
|-----------------|-------|---|
| $\gamma_y^{DE}$ | 1.75  | Income elasticity of money demand in Germany. Value based on Akhtar and Putnam (1980).  |
| $\gamma_y^{EU}$ | 1.34  | Income elasticity of money demand in the euro area. Value based on Calza et al. (2001). |

In our empirical analysis we will follow equation (5) and adjust money growth for output growth using the estimate of the income-elasticity of money demand. To compute

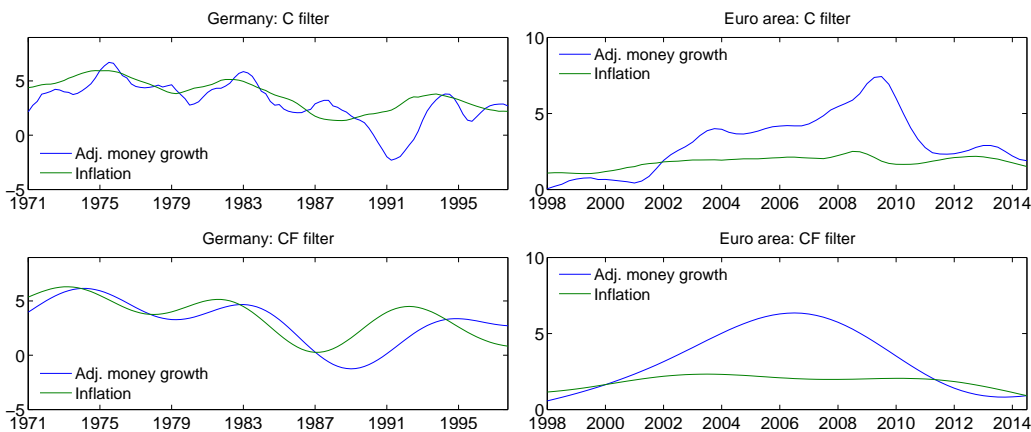
<sup>7</sup>A trend in velocity may not only arise from potential output growth  $\Delta y_t^*$  with an income elasticity  $\gamma_y$  different from unity, but also from other sources such as financial innovations (see Orphanides and Porter (2001) and Masuch et al. (2001)).

long-run values of the variables we will use the two alternative filters discussed in the previous section. Thus, if one denotes adjusted money growth by  $\mu$  and uses the superscript  $f$  to denote the filtered value of a series, we employ

$$\mu_t^f = \Delta m_t^f - \gamma_y \Delta y_t^f \quad (6)$$

in our empirical analysis. The parameter values used for the income-elasticity of money demand,  $\gamma_y$ , are taken from Akhtar and Putnam (1980) for Germany and Calza et al. (2001) for the euro area and are reported in Table 1. The resulting time series for adjusted money growth in Germany and the euro area are plotted in Figure 5. In the case of Germany, the graphs provide strong support for the implications of the quantity theory: There is clear evidence of a strong co-movement between adjusted money growth and inflation. For the euro area we still find a positive correlation, the degree of the comovement is much weaker though.

Figure 5: Long-Run Adjusted Money Growth-Inflation Link



Note: Figure 5 plots filtered adjusted money growth and CPI inflation rates for Germany (left panels) and the euro area (right panels). The “C Filter” corresponds to the filter as proposed in Cogley (2002), the “CF Filter” corresponds to the filter as proposed in Christiano and Fitzgerald (2003). Adjustments are done according to equation 6.

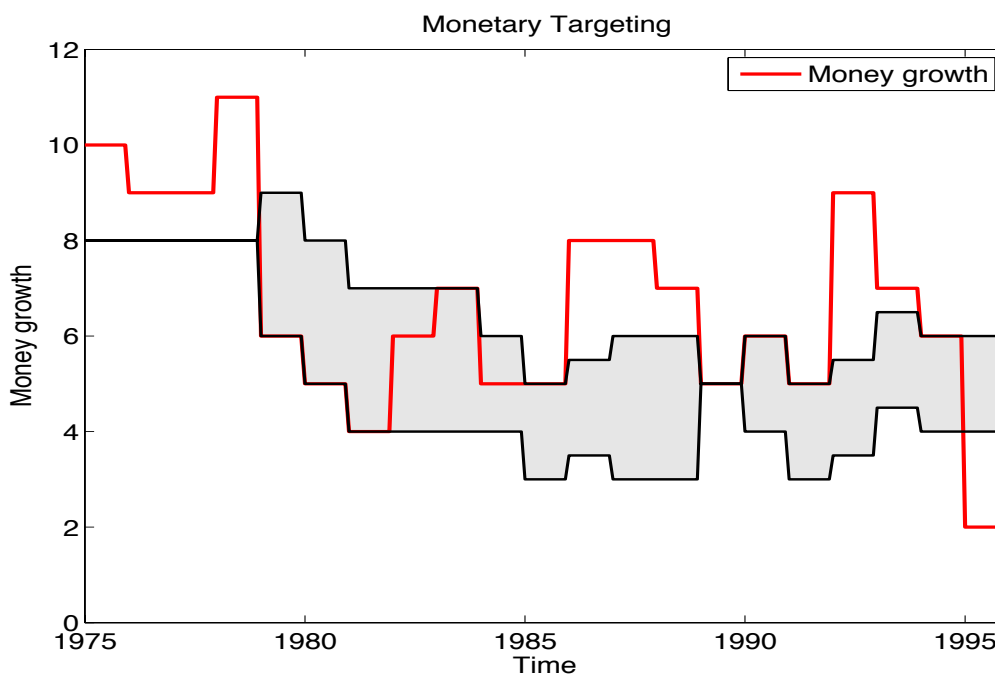
## 4 Bundesbank strategy heritage at the ECB

The Bundesbank had a long tradition of pursuing its objective of long-run price stability by means of a medium-term monetary targeting strategy. Since December 1971 it has set annual monetary targets, first for the growth rate of the central bank money stock, a measure close to the monetary base, and since 1988 for the growth rate of M3. Initially, the Bundesbank announced a single target growth rate but starting in 1979 an annual target growth rate range, which implied a widening cone for the growth rate of M3 throughout

the year. The derivation of the monetary targets was based on the quantity theory of money as stated above. The target growth rate of the chosen monetary aggregate was derived by estimating the growth rate of potential output over the coming year, adding the rate of price change it considered to be “unavoidable”, and subtracting the estimated change in trend velocity over the coming year.

Even though the Bundesbank successfully managed to keep inflation low most of the time it very often missed its monetary target. A graphical illustration of the many target misses is given in Figure 7 which is based on Issing (1997). This chart shows that the Bundesbank missed its target almost 50% of the time. Target misses were particularly pronounced after the German unification: The period of 1991 to 1996 was characterized by four misses and two near misses of the target range, all but one on the upper side.

Figure 7: Bundesbank monetary targets and German money supply



Note: Figure 7 plots the Bundesbank’s monetary targets (target ranges) and the development of the actual money supply. Source: Table 1 of Issing (1997).

One very interesting element in the Bundesbank’s process of setting the monetary target concerns the concept of “unavoidable price increases”, also denoted as “inflation norm”.<sup>8</sup> This inflation norm was set prior to the monetary target each year, and defined the intended path for inflation over the following year. Figure 8 reports the Bundesbank’s

<sup>8</sup>After 1984 the Bundesbank abandoned the concept of “unavoidable price increases“ and replaced it by a medium-term price increase assumption of 2%. See pages 81 of Bundesbank (1995). In the following discussion we refer to both concepts as the Bundesbank’s inflation norm.

inflation norm and actual and trend (C filter) German CPI inflation over the period 1971 to 1997. This figure clearly illustrates the Bundesbank's motivation behind the concept of "unavoidable price increases" for the period before 1985:

In view of the unfavorable underlying situation, the Bundesbank felt obliged until 1984 to include an "unavoidable" rate of price rises in its calculation. By so doing, it took due account of the fact that price increases which have already entered into the decisions of economic agents cannot be eliminated immediately, but only step by step. On the other hand, this tolerated rise in prices was invariably below the current inflation rate, or the rate forecast for the year ahead. The Bundesbank thereby made it plain that, by adopting an unduly "gradualist" approach to fighting inflation, it did not wish to contribute to strengthening inflation expectations. (Deutsche Bundesbank (1995), pp 80-81).

After 1985, trend inflation kept close to the inflation norm until 1990, significantly rose above it as a consequence of the unification and returned to it only in 1996. On the other hand, actual inflation (which was not a concern for the Bundesbank) considerably deviated from the norm both before and after the unification.

Contradicting statements by Bundesbank officials several authors have claimed that monetary aggregates have not played a major role in actual policy making of the German central bank. Examples of the numerous studies that found that its policy can be described well by a standard Taylor rule which does not attribute a specific role to monetary aggregates are listed in Table 2.<sup>9</sup> Clarida et al. (1998) and Faust et al. (2001) both estimate a standard Taylor Rule for the Bundesbank and find similar coefficients: a equilibrium rate around three, a coefficient on inflation somewhat above one and a low coefficient on the output gap. The former explicitly test for the significance of money, which is rejected.

Bec et al. (2002) allow for different reactions in recessions and expansions and argue that the Bundesbank followed a Taylor Rule only during expansions and then reacted stronger to the output gap than argued before. In recessions, on the other hand, the interest rate seems to have followed a random walk. Surico (2003) tests for asymmetric preferences but finds little evidence for non-linearity. All studies supporting the view that the Bundesbank followed a linear Taylor rule are estimated with ex post revised data, which may be inadequate for the analysis of monetary policy given possibly large revisions. Orphanides (2001) shows that the estimation of the Federal Reserve's policy function with revised data results in misleading conclusions and other examples are numerous.<sup>10</sup>

Clausen and Meier (2003) construct real time estimates of the output gap and estimate a non-forward looking Bundesbank reaction function using an error correction model. In

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<sup>9</sup>See in addition Weymark (2001), Neumann and Von Hagen (2002), Sauer and Sturm (2007).

<sup>10</sup>Other paper finding that real-time data changes conclusions about monetary policy rules include Orphanides (2001), Orphanides and Van Norden (2002) and Lansing (2002).

Table 2: Estimations of Taylor Rules

| Studies                                     | Estimation Period | Data              | Taylor Rule | TR+Money |
|---|-------------------|-------------------|-------------|----------|
| Clarida, Gali and Gertler (1998)            | 1979:03-1993:12   | revised           | yes         | no       |
| Faust, Rogers and Wright (2001)             | 1985:01-1998:12   | revised           | yes         |          |
| Bec, Salem, and Collard (2002) <sup>a</sup> | 1982:01-1997:11   | revised           | yes         |          |
| Clausen and Meier (2003) <sup>b</sup>       | 1973Q1-1998Q4     | constr. real time | yes         | no       |
| Surico (2003) <sup>c</sup>                  | 1992:02-1998:12   | revised           | yes         |          |
| Gerberding, Seitz, and Worms (2005)         | 1979Q1-1998Q4     | revised           | yes         |          |
| Gerberding, Seitz, and Worms (2005)         | 1979Q1-1998Q4     | real time         | no          | yes      |

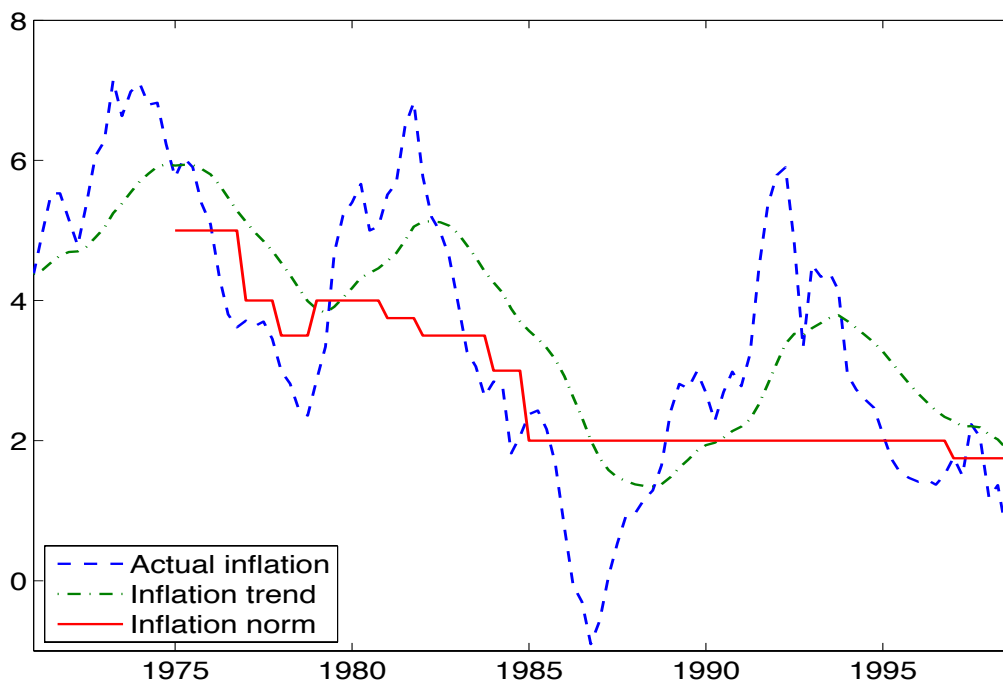
<sup>a</sup> differences between expansions and recessions

<sup>b</sup> error correction framework & non-forward looking TR

<sup>c</sup> asymmetric preferences

their set-up money does not matter. Gerberding et al. (2005), however, construct a full real time dataset for the Bundesbank and show that a standard Taylor rule estimated with real time data is in fact unable to explain the Bundesbank's interest rate decisions. They show that only a rule augmented with the growth of the output gap and the money gap works well. From a positive and highly significant coefficient for the money gap they conclude that the Bundesbank did indeed follow an explicit money target. We later reconsider how money really influenced Bundesbank interest rates and allow for a (non-linear) role of filtered adjusted money growth.

Figure 8: Bundesbank inflation norm, actual and trend inflation



Note: Figure 8 plots the Bundesbank's inflation norm and actual and trend (C filter) German CPI inflation.

Given the dominant role which the Bundesbank played in the European Monetary

System and its undisputed success in keeping inflation rates low it is not surprising that the Bundesbank is often considered to have acted as the role model for the ECB. It should therefore not astonish that monetary information plays an important role also in the monetary policy strategy of the ECB. However, given the repeated and partly pronounced target misses of the Bundesbank the ECB did not adopt a monetary targeting strategy (as the Bundesbank had done) but chose an alternative framework which allows for a prominent role of money.

Contrary to the monetary policy strategies of the U.S. Federal Reserve and many inflation-targeting central banks, which assign no special role to monetary aggregates, the ECB has maintained a separate and important role for money in its two pillar strategy.

The ECB distinguishes an “*economic*” and a “*monetary*” pillar:

The **economic analysis** assesses the short to medium-term determinants of price developments. The focus is on real activity and financial conditions in the economy. The economic analysis takes account of the fact that price developments over those horizons are influenced largely by the interplay of supply and demand in the goods, services and factor markets. ...

The **monetary analysis** focuses on a longer-term horizon than the economic analysis. It exploits the long-run link between money and prices. The monetary analysis mainly serves as a means of *cross-checking*, from a medium to long-term perspective, the short to medium-term indications for monetary policy coming from the economic analysis."<sup>11</sup>

In the following section, we provide a formal interpretation of this two-pillar strategy based on former work by Beck and Wieland (2007, 2009) and suggest two practical cross-checking implementations.

## 5 Modelling monetary cross-checking

Based on the empirical evidence on money growth and inflation trends, Lucas (2007) suggested to continue using information on monetary aggregates as an add-on or cross-check in interest rate policy. In this spirit, Beck and Wieland (2007) have formulated an interest rate rule with monetary cross-checking. It consists of two components:

$$i_t = i_t^{EA} + i_t^{CC}. \quad (7)$$

The first component, denoted by the superscript *EA*, refers to the interest rate policy which the policy maker would choose based on its regular analysis of the economy which does not include a specific role for monetary or credit aggregates. The second component,

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<sup>11</sup>The quotes are taken from <http://www.ecb.int/pub/pdf/other/monetarypolicy2004en.pdf>.

denoted by the superscript  $CC$ , refers to an additive adjustment in interest rate setting due to monetary cross-checking.

In our analysis below we will consider two approaches to implement this rule. In the first approach we derive results on the basis of a specific model of the world whereas the second one is empirical in nature and follows Taylor (1993). Each of these two approaches has pros and cons which will be described in the following two subsections.

### 5.1 Model-based setting of the interest rate

To understand the intuition underlying the two components of the proposed interest rate rule let us assume that the central bank believes that a certain model, denoted as the central bank's preferred model, represents a good characterization of the economy. Furthermore, assume that the central bank's major policy instrument is given by the short-term interest rate  $i$ . Given the parameter estimates of the preferred model and given the available data, the central bank would then make an interest rate decision  $i_t^{PM}$  which is assumed to be optimal based on the available information. Since this interest rate decision is made in a situation characterized by uncertainty both about model parameters and data and about shocks hitting the economy the policymaker would not be able to clearly identify potential sources of any emerging deviations of the inflation rate from its target. For example, if the central bank's preferred model was the (New) Keynesian model, in the case of persistent output gap misperceptions, the model-based forecast would indicate that a sequence of inflationary shocks was the source of the observed upward shift in inflation rather than a deviation of output from potential.

It is important to understand that this assessment would also incorporate information on monetary aggregates because the theoretical analysis based on the (New) Keynesian model would attribute the upward shift in money growth to the same source. Money is therefore not a neglected information variable. Conditional on the model and the model-consistent output gap estimate money growth does not provide further information affecting the model forecast. The reason is that the level of output and inflation are observed directly.<sup>12</sup>

Instead, the idea of cross-checking is motivated from the perspective of model uncertainty and the search for robustness in policy design. The proposal is to base policy on the preferred model in normal times, but to check policy outcomes regularly against another simpler model. As argued above, the preferred model needs to provide a satisfactorily good characterization of the economy in normal times and could, e.g., be given by the (New) Keynesian model. The simpler model used for cross-checking is the long-run relationship between money and inflation implied by the quantity theory. Ideally, the regular cross-check

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<sup>12</sup>If output, inflation and money growth were afflicted with measurement error, money would provide further information that would help improve estimates of current output and inflation. This information role is investigated by Coenen et al. (2005), but plays no role in the present paper.

should not lead to deviations from the model-dependent optimal interest rate policy,  $i_t^{PM}$ , in normal times. In the example given above, this would be the case when persistent central bank misperceptions regarding unobservable measures such as the output gap are absent. However, the cross-check should trigger a policy adjustment,  $i_t^{CC}$ , if trend money growth deviates from a rate consistent with stable inflation in a statistically unusually persistent manner. This statistical test may be based on the null hypothesis that the preferred model is correct.

To formally derive the cross-checking rule we follow Beck and Wieland (2008). These authors show that the policy with cross-checking can be derived from a first-order condition that includes trend inflation and that a central bank that relies on the New-Keynesian model expects that trend inflation will turn out to match the target as long as policy is set to stabilize expected inflation in every period, i.e. that  $E[\bar{\pi}] = \pi^* = 0$  holds. However, as argued above, such confidence in model-based forecasts and estimates of unobservable variables may be misplaced. The simulations of historical output gap misperceptions conducted in Beck and Wieland (2008) illustrate that sustained trend deviations from target may occur even under policies that aim to stabilize inflation as close to target as seems feasible on the basis of model forecasts. Following Lucas' recommendation, a sceptical policy maker may therefore instead consider the simpler model of trend inflation given by the long-run relationship between money and inflation according to which

$$E[\bar{\pi}] = E[\mu^f] \tag{8}$$

holds. Such a "monetarist" central bank that exclusively uses this model of trend inflation to inform policy would conduct open-market operations in period  $t$  such that trend inflation as estimated by the most recent observation on filtered adjusted money growth is expected to equal the inflation target:

$$E[\bar{\pi} | \mu_t^f] = \pi^* = 0. \tag{9}$$

$\mu_t^f$  can be monitored without relying on model-based estimates of potential output. As a result, the central bank can stabilize trend inflation in spite of output gap misperceptions.<sup>13</sup>

Beck and Wieland (2008) argue that even though the monetarist model is very appealing from a long-run perspective it would probably be a mistake to abandon any attempt at short-run inflation stabilization suggested by alternative model frameworks such as the New-Keynesian model. Instead, they consider the monetary model of trend inflation for cross-checking purposes. Specifically, the central bank is instructed to check every period whether filtered money growth is still consistent with attaining the inflation target or

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<sup>13</sup>Of course, a natural question concerns the implications of sustained velocity shifts for this strategy of stabilizing trend inflation. This possibility is investigated in Beck and Wieland (2008). There it is shown that simple recursive estimation of money demand parameters would be effective in avoiding incorrect cross-checks.



whether trend money growth has shifted. This check is accomplished by monitoring the test statistic,

$$\kappa_t = \frac{\mu_t^f - \pi^*}{\sigma_{\mu^f}}, \quad (10)$$

and comparing it to a critical value  $\kappa^{crit}$ . Here,  $\sigma_{\mu^f}$  denotes the standard deviation of the filtered money growth measure. It can be determined under the null hypothesis that the central bank's preferred model, that is the New-Keynesian model is correct.

As long as the test statistic does not signal a sustained shift in filtered money growth, the central bank implements the optimal policy under the preferred Keynesian-style model. As a result it will stabilize short-run inflation variations very effectively in the absence of persistent output gap misperceptions. Once the central bank receives successive signals of a shift in trend inflation as estimated by filtered money growth, i.e. ( $\kappa_t > \kappa^{crit}$  for  $N$  periods) or ( $\kappa_t < -\kappa^{crit}$  for  $N$  periods), policy is adjusted so as to control trend inflation.

The two policy parameters  $\kappa^{crit}$  and  $N$  play different roles.  $\kappa^{crit}$  reflects the probability that an observed deviation of  $\mu^f$  from  $\pi^*$  is purely accidental (for example a 5% or 1% significance level).  $N$  defines the number of successive deviations in excess of this critical value. Thus, the greater  $N$  the longer the central bank waits to accumulate evidence of a sustained policy bias. The chosen values are shown in **Table 3** of the next section.<sup>14</sup>

## 5.2 Taylor-rule based setting of the interest rate

Our alternative approach to determine  $i_t^{EA}$  makes use of a standard Taylor rule. While an interest-rate choice based on such a rule is certainly suboptimal given a specific model it has the advantage of showing a high degree of robustness in the presence of model uncertainty.

We base our linear specification (11) on Gerberding et al. (2005), which extend the forward-looking Taylor Rule specification of Clarida et al. (1998) by introducing money growth deviation from the money growth target.

$$i_t = \rho i_{t-1} + (1 - \rho) i_t^{m*} + \epsilon_t, \quad (11)$$

where  $i_t^{m*}$  is the central bank's target rate defined as

$$i_t^{m*} = \alpha + \pi_{t+n}^* + \beta (\pi_{t+n|t} - \pi_{t+n}^*) + \gamma_1 y_{t|t+1} + \gamma_2 \Delta y_{t|t+1} + \lambda (m_{t|t+1} - m_t^*), \quad (12)$$

where  $i_t$  is the interest rate,  $i_t^{m*}$  is the target rate,  $\pi_{t+n}$  is the expected inflation in  $n$  periods at  $t$ ,  $\pi_{t+n}^*$  is the inflation target in  $n$  periods,  $y_{t|t+1}$  is the output gap in  $t$ , which is

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<sup>14</sup>The optimal size of the cross-checking adjustment can be derived from a first-order condition that includes the expectation of trend inflation based on the simple monetary model. For more details, see Beck and Wieland (2008).

known only in  $t + 1$ , and  $\Delta y_{t|t+1}$  is the respective output gap growth,  $m_{t|t+1}$  is the money growth both in  $t$ , which is also known only in  $t + 1$ , and  $m_t^*$  is the money growth target in  $t$ . The coefficients, which we estimate are  $\rho, \alpha, \beta, \gamma$  and  $\lambda$ .

The central bank hence potentially reacts to deviations of inflation from the inflation target, to the output gap and its growth, as well as the money gap. Note that the inflation target of the Bundesbank in the estimation period was not constant but decreased from 5% in 1979 to 1.75% in 1998. The interest rate rule is forward looking and interest rates are smoothed.

We then employ a threshold autoregressive (TAR) model originally introduced by Tong (1978) to estimate a non-linear Taylor Rule which allows for regime-dependent reactions of interest rates to a filtered adjusted money growth series. The choice of this variables as a source of non-linearity in Taylor Rule estimations is a novel approach. Previous work on non-linear Taylor Rules only focused on non-linear behavior with respect to inflation, the output gap or the persistence.<sup>15</sup>

Including a filtered adjusted money growth series to which interest rates can respond differently depending on the state of the measure yields a non-linear specification that resembles closely the model derived cross-checking mechanism. In the most general specification we allow for three regimes and for a reaction to filtered adjusted money growth in all of them:

$$i_t = \rho i_{t-1} + (1 - \rho) i_t^{cc1} + \epsilon_t \quad (13)$$

with

$$i_t^{cc1} = i_t^{m*} + \begin{cases} \delta_u (\mu_t^f - \pi_t^*) & \text{if } \mu_{t-1}^f - \pi_{t-1}^* > \gamma_u \\ \delta_m (\mu_t^f - \pi_t^*) & \text{if else} \\ \delta_d (\mu_t^f - \pi_t^*) & \text{if } \mu_{t-1}^f - \pi_{t-1}^* < \gamma_d \end{cases} \quad (14)$$

Note that here, in addition to the linear rule, we allow for reactions to filtered adjusted money growth  $\delta_d, \delta_u, \delta_m$ , depending on the state of the variable, i.e. whether it is below, above or in between the thresholds  $\gamma_d$  and  $\gamma_u$ . If we would set  $\delta_m = 0$ ,  $\delta_d = \delta_u$  and  $\gamma_d = -\gamma_u$  the specification implies the same form of cross-checking as the model derived mechanism from before. The central bank would then adjust its interest rate whenever the filtered adjusted money growth is above or below a certain threshold were the thresholds and the magnitude of the adjustment is symmetric. We allow for a much more flexible model in order not to influence the empirical estimations in any direction.

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<sup>15</sup>Such models have been estimated, for example, by Taylor and Davradakis (2006) and Koustas and Lamarche (2012) for the Bank of England and by Castro (2011) for the European Central Bank, the Bank of England and the Federal Reserve. While Castro (2011) introduces a regime-dependent coefficient on a financial conditions index, regime-switching is still driven by inflation.

## 6 Calibration and estimation

### 6.1 Model-based approach: Parameter calibration

To perform monetary cross-checking the central bank needs to compute the test statistic given by equation (10) and then compare the result with the critical value  $\kappa^{crit}$ . To this end, not only the long-run component of adjusted money growth needs to be computed as described in Section 2 but also the parameters  $\pi^*$ ,  $\sigma_{\mu^f}$ ,  $\kappa^{crit}$  and  $N$  need to be specified. In our analysis for Germany we assume that the inflation target  $\pi^*$  is time-varying and is given by the Bundesbank's inflation norm which was discussed in Section 4.  $\sigma_{\mu^f}$  denotes the standard deviation of the filtered money growth measure under the null hypothesis. Theoretically, it is straightforward to compute this standard deviation for the following case: Interest rates are set according to the model-dependent optimal interest rate rules and the model is correct. Then the mean of  $\mu^f$  corresponds to  $\pi^*$  and  $\sigma_{\mu^f}$  is given by the empirical standard deviation of the filtered money growth measure. Empirically, the computation of  $\sigma_{\mu^f}$  is not so straightforward. To obtain a value for  $\sigma_{\mu^f}$  we proceed as follows: First, we determine a period for which we can be relatively confident that no significant deviation of the long-run adjusted money growth and inflation from its targeted value occurred. Figure 8 shows that this seems to be best true for the period from 1975 to 1982. We then subtract the time-varying inflation target and compute  $\sigma_{\mu^f}$ . The value in this period is equal to 0.7851 and is - as the other parameter values - reported in Table 3.

Table 3: Parameters of the cross-checking component of monetary policy

| Parameter                    | Value  | Economic interpretation  |
|------------------------------|--------|--|
| $\sigma_{\mu^f}$ (C filter)  | 0.7851 | Empirical standard deviation of filtered adjusted money growth $\mu^f$ (C filter) minus inflation target in the period from 1975 to 1982.  |
| $\sigma_{\pi^f}$ (C filter)  | 0.5400 | Empirical standard deviation of filtered inflation $\pi^f$ (C filter) minus inflation target in the period from 1975 to 1982.              |
| $\sigma_{\mu^f}$ (CF filter) | 0.4926 | Empirical standard deviation of filtered adjusted money growth $\mu^f$ (CF filter) minus inflation target in the period from 1975 to 1982. |
| $\sigma_{\pi^f}$ (CF filter) | 0.6710 | Empirical standard deviation of filtered inflation $\pi^f$ (CF filter) minus inflation target in the period from 1975 to 1982.             |
| $\kappa^{crit}$              | 1.96   | 5% critical value for the cross-checking rule.   |
| $N$                          | 4      | Number of periods required for a sustained deviation in the cross-checking rule.   |

As discussed in the previous section, the two parameters  $\kappa^{crit}$  and  $N$  play different roles.  $\kappa^{crit}$  reflects the probability that an observed deviation of  $\mu^f$  from  $\pi^*$  is purely accidental. In our analysis we have set  $\kappa^{crit}$  equal to 5%.  $N$  defines the number of successive periods for

which adjusted money growth exceeds the critical value until an interest rate adjustment is triggered. As can be seen in Table 3 we chose  $N$  to be equal to 4. The two chosen values for  $\kappa^{crit}$  and  $N$  imply that the probability that an observed deviation of  $\mu^f$  from  $\pi^*$  is purely accidental in the absence of policy misperceptions is at most  $6.25^{-6}$ .

## 6.2 Taylor-based approach: Estimation procedure

We will shortly comment on the estimation of the linear rule that is fully standard and estimated as in Gerberding et al. (2005) and then discuss the estimation of the non-linear model in more detail.

For our Taylor Rule estimations we use quarterly real time data from 1979Q1 to 1998Q4 made available by Gerberding et al. (2005).<sup>16</sup>

As is typical for Taylor Rules with a forward looking inflation target, we substitute expected values by the realized values and estimate the model with the generalized method of moments (GMM), which solves the problem that regressors are correlated with forecast errors in the error term. As instruments for the linear model we use information available to Bundesbank decision makers at time  $t$ , which could have been used to forecast inflation, the output gap, output gap growth and the money gap. We include as instruments: interest rates from lag 1 to 4, inflation of vintage  $t$  for lag 1 to 4, output gap of vintage  $t$  for lag 1 to 4, output gap growth of vintage  $t$  for lag 1 to 4, money growth gap of vintage  $t$  for lag 1 to 4. For the non-linear specification we add regime-dependent instruments of the threshold variable.

As Koustas and Lamarche (2012) we base our estimation on Caner and Hansen (2004), who set up a TAR estimation procedure which allows for instrumental variables. As discussed the forward-looking nature of our Taylor Rule necessitates the use of instrumental variables. We are able to consistently estimate thresholds, policy coefficients of the standard Taylor Rule and coefficients of the newly introduced non-linearity with respect to the proposed threshold variable. For any given bound  $\gamma$ , the model is estimated by GMM, using a Newey-West weight matrix with Bartlett kernel so that standard errors are HAC-robust.<sup>17</sup> Among all estimated models, we choose the model, which minimizes the respective GMM minimization criterion. This procedure yields consistent estimates  $\hat{\gamma}$  of  $\gamma$ . Conditional on the consistent estimate of  $\gamma$ , estimates of slope coefficients have standard asymptotic distributions. Therefore inference on these can be conducted in the traditional way.

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<sup>16</sup>For more information regarding, the organization of the dataset, the included variables, the differences between the revised and real time data, and the exact source of each vintage we refer the interested reader directly to Gerberding et al. (2005).

<sup>17</sup>A weight matrix convergence procedure is applied, which iterates until coefficient estimates do not change significantly any more.

The estimation procedure hence follows four steps:

1. Let  $\Gamma$  be the set of all values of the Threshold variable.
2. For each  $\gamma \in \Gamma$  estimate the model via GMM
3. Choose  $\gamma$  so that

$$\hat{\gamma} = \arg \min J(\gamma) \tag{15}$$

where  $J$  represents the objective function of GMM estimation

4. Estimate the model with the optimal Threshold via GMM.

We restrict the set of all thresholds  $\Gamma$  that can be estimated in the minimization procedure. First, we assure a minimum of 1% deviation of the thresholds on both sides of 0; second, we assure that outer regimes contain at least 10% of all available observations; third, GMM weight iteration has to converge within 1000 iterations steps; fourth, estimates of the equilibrium real interest rate have to be larger than zero; and fifth the coefficient on the inflation gap needs to be larger than one. The optimal threshold estimate is then chosen among the remaining values and the respective GMM model computed, which concludes our estimation procedure. We set the forecast horizon to one and a half years, employ the C-Filter, and use the same parameters for the filter and the income elasticity of the money demand as before.

## 7 Monetary cross-checking in Germany

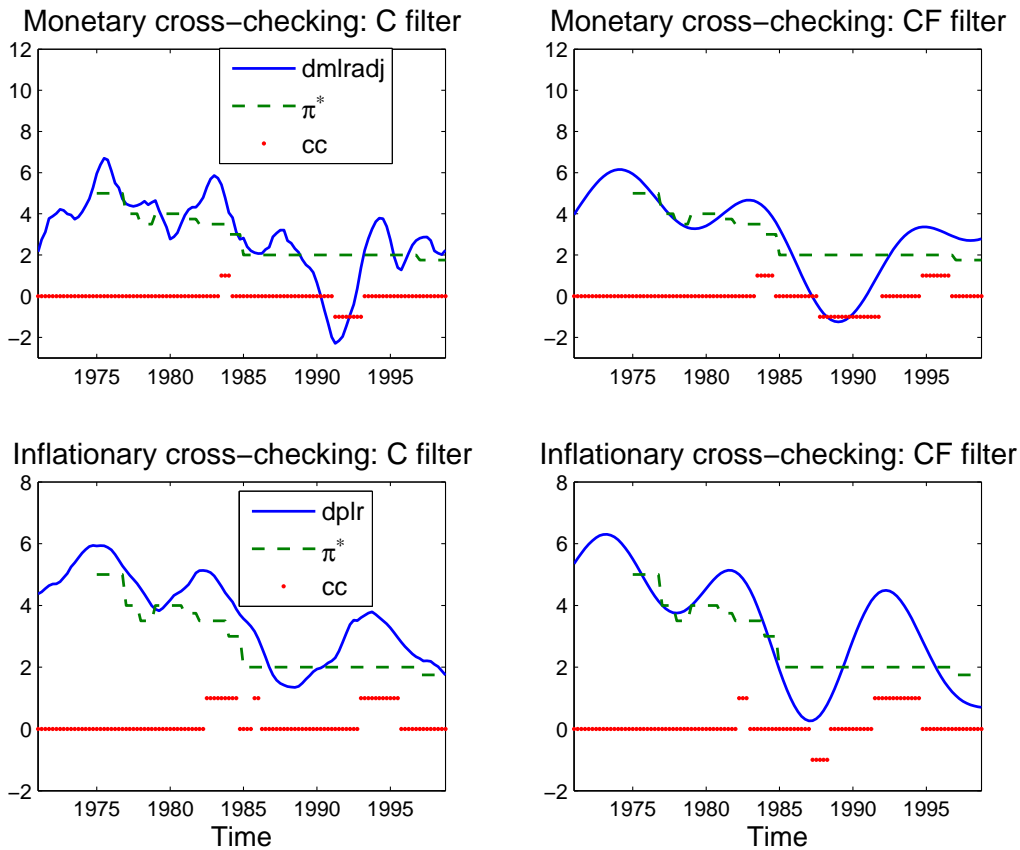
Having outlined our formal approach to monetary cross-checking in the previous section we now want to examine to which extent monetary cross-checking would have suggested adjustments in German and to what extent the Bundesbank did actually engage in cross-checking, i.e. in how far the Bundesbank reacted to strong deviations of filtered adjusted money growth from the inflation target.

### 7.1 Model-based results

Figure 9 presents the results of our analysis for Germany. The panels of this figure illustrate to which extent monetary cross-checking would have suggested adjustments in German short-term interest rates in the period from 1971 to 1998. In addition to the adjustments implied by monetary cross-checking (upper two panels) results are also reported for the case when long-run inflation rates are used for cross-checking purposes as suggested, e.g., Woodford (2006) (lower two panels). The solid lines plot long-run adjusted money growth (upper two panels) or long-run inflation rates and the dotted lines plot the Bundesbank's inflation norm. To compute long-run values of a variable either the Cogley-Filter (left two

panels) or the Christiano-Fitzgerald filter (right two panels) were used. The line denoted by *cc* takes the value zero when cross-checking suggests no interest rate adjustment and it takes the value one (minus one) when cross-checking suggests a positive (negative) interest rate adjustment.

Figure 9: Cross-checking in Germany



Note: Figure 9 reports cross-checking results for German data when monetary (upper two panels) or inflationary information (lower two panels) is used. The solid line plots long-run adjusted money growth (upper two panels) or long-run inflation rates (lower two panels) and the dotted lines plot the Bundesbank's inflation norm. The line denoted by *cc* takes the value zero when cross-checking suggests no interest rate adjustment and it takes the value one (minus one) when cross-checking suggests a positive (negative) interest rate adjustment.

Three major features of Figure 9 stand out. First, the choice of the filter has no major impact on the cross-checking results. Second, cross-checking would have suggested interest rate adjustments only very rarely over the sample period of more than 25 years. Third, we can identify suggested adjustments in both directions. Across both measures and both filters cross-checking suggested a positive adjustment of interest rates during the early 1980s. Around 1990 the monetary measures calls for a negative adjustment of interest rates, even though inflation was partly above the target. A downward adjustment of interest

rates would have accelerated inflationary dynamics. We suspect that the Bundesbank therefore did not react as strictly to downward tendencies, as it did to upward movements. We will further discuss this issue in section 7.3.

Summarizing our results for the German data we conclude that monetary cross-checking can help to avoid big positive deviations of inflation rates from target.

## 7.2 Taylor-rule based results

Table 4 contains the estimation output of the models (11), (13), and (16), where the latter model is defined below.

Table 4: Estimation Output

|                   | Linear            | Three Regimes     | Two Regimes       |
|-------------------|-------------------|-------------------|-------------------|
| Persistence       | 0.84***<br>(0.02) | 0.83***<br>(0.01) | 0.83***<br>(0.01) |
| Real Rate         | 3.15***<br>(0.41) | 3.41***<br>(0.17) | 3.42***<br>(0.18) |
| Inflation Gap     | 1.75***<br>(0.21) | 1.91***<br>(0.17) | 1.83***<br>(0.18) |
| Output Gap        | -0.04<br>(0.11)   |                   |                   |
| Output Gap Growth | 1.02***<br>(0.20) | 0.43***<br>(0.11) | 0.41***<br>(0.12) |
| Money Gap         | 0.48***<br>(0.07) | 0.46***<br>(0.08) | 0.46***<br>(0.08) |
| $\delta_u$        |                   | 0.61***<br>(0.17) | 0.59***<br>(0.16) |
| $\delta_m$        |                   | 0.09<br>(0.24)    | -0.08<br>(0.14)   |
| $\delta_d$        |                   | -0.05<br>(0.11)   |                   |
| Upper Bound       |                   | 1.40              | 1.40              |
| Lower Bound       |                   | -2.00             |                   |
| J-Stat            | 13.95             | 13.72             | 14.25             |
| P-Value           | 0.93              | 0.99              | 0.99              |

**Linear Model** The benchmark model delivers a persistence parameter of 0.84, an equilibrium rate of 3.15%, a strong and significant reaction to the inflation gap, as well as significant and notable reactions to the output gap growth and the money gap. The interest rates are not reacting to the output gap. These results are nearly identical to Gerberding et al. (2005), who estimate the same model.

**Three regime model** Next we allow the central bank to respond to the filtered adjusted money measure explored before and therefore estimate model (13). As the output gap is insignificant in the linear model, we drop it here. With exception of the coefficient for the output gap growth, the coefficients are very similar in the non-linear model. Interestingly the coefficient on the money gap does not change considerably when filtered adjusted money growth is added to the explanatory variable. Instead, the coefficient on the output gap growth is halved. The upper bound is estimated to be 1.4% and the

highly significant coefficient on the filtered adjusted money growth measure is 0.61. In the middle regime the coefficient on filtered adjusted money is very close to zero and not significant. The lower bound is estimated to be -2%, and the corresponding coefficient is insignificant as well. We hence conclude that there was no adjustment when filtered money growth was below a certain threshold and no linear reaction to it in the middle regime.

**Two Regime Model** We therefore estimate a model with only two regimes. Even though the previous results showed that the filtered money coefficient for all but the upper regime were insignificant, we again allow a reaction to the threshold variable in both regimes.

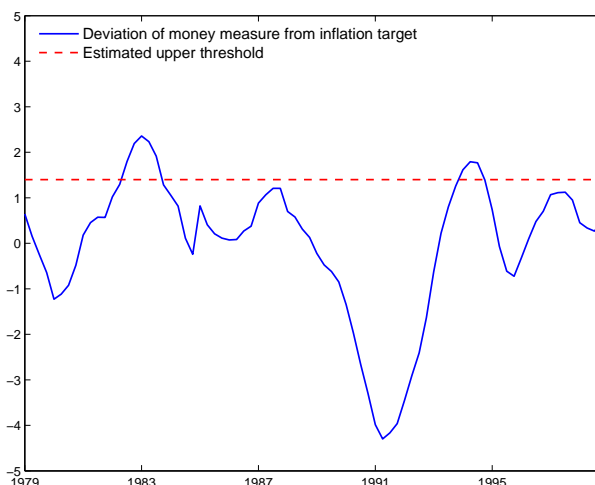
$$i_t = \rho i_{t-1} + (1 - \rho) i_t^{cc2} + \epsilon_t \quad (16)$$

with

$$i_t^{cc2} = i_t^{m*} + \begin{cases} \delta_u (\mu_t^f - \pi_t^*) & \text{if } \mu_{t-1}^f - \pi_{t-1}^* > \gamma \\ \delta_d (\mu_t^f - \pi_t^*) & \text{if } \mu_{t-1}^f - \pi_{t-1}^* < \gamma \end{cases} \quad (17)$$

The parameters for the persistence, the real rate and the inflation gap are again very similar. Most importantly, the upper bound remains at the same value and the coefficient on the measure – again significant at the 1% level – is very similar. The coefficient on the measure below the bound is very close to zero and not significant.<sup>18</sup>

Figure 10: Filtered inflation measure with bounds



Note: Figure 10 shows the threshold estimate of our non-linear Taylor-Rule specification 16. The solid blue line represents the deviation of filtered adjusted moneys growth from the Bundesbank inflation target in the period from 1797Q1 to 1998Q4. The dashed red line shows the threshold estimate. Note that during two phases the Bundesbank reacted to our proposed money growth measure.

<sup>18</sup>Dropping the coefficient for the lower regime, results are nearly identical, with a bit stronger reaction to the measure above the threshold.



Figure 10 plots the filtered inflation measure and the estimated bound of 1.4. In a little over 10% of the time the measure was above that threshold and interest rates were adjusted: from 1982Q3 to 1983Q3 and from 1994Q1 to 1994Q3 summing up to 8 quarters. In these periods the Bundesbank adjusted the interest rates around 1% with a maximum adjustment of 1.4% in 1983Q1.

Using a TAR model to estimate the non-linear dynamics of a monetary policy cross-check via an filtered adjusted money growth series, we could uncover interesting and intuitive results. Above a certain threshold, when filtered adjusted money growth should signal future higher inflation, the Bundesbank reacted strongly to this measure of filtered money growth. Interestingly, we find no evidence, that the Bundesbank would react to any strong downward deviations of filtered money growth. <sup>19</sup>

### 7.3 Comparing model based and Taylor-rule based results

The model based cross-checking mechanism (C-Filter) suggests a positive adjustments of the interest rates in 1983 and a negative one after German re-unification. When we empirically test for actual cross-checking we do find significant adjustments starting in 1982Q2. The suggested adjustment by the model based mechanism shows that the calibration would have called for a stronger adjustment. The symmetry of the model based mechanism requests an adjustment in 1991. However, we have shown that the Bundesbank actually was only concerned with adjustments when the measure warned against high future inflation. Note, however, that the measure dropped strongly below the inflation target only once at that was during the special circumstances around the German re-unification. With our estimations we detect a second phase of positive adjustments shortly thereafter, in 1993, during the following re-unification boom. Interestingly, the model based mechanism with the CF Filter hits out in 1995.

Summarizing, we only detect few phases of strong positive deviations of filtered adjusted money growth from the inflation target, which partly is due to the fact that the Bundesbank actually adjusted interest rates when this growth was higher than the inflation target by more than 1.4%. The biggest difference concerns the symmetry of the mechanism: while the model based one suggests adjustments also when the measure is below the inflation target for too long, we do not find evidence for such adjustments.

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<sup>19</sup>Thinking about the Bundesbank's reputation as being strict on positive inflation deviations from target (Surico, 2003), the fact that only positive deviations induced action is not that surprising.

## 8 Monetary cross-checking: Messages for euro-area monetary policy 1999 - 2014

### 8.1 Model-based results

To compute the cross-checking test statistics for the euro area we use the parameter values chosen for the German case. As will become obvious below, the time period in which the null hypothesis of long-run adjusted money growth being equal to the inflation target seems to be extremely short for the euro area. For this reason and given the fact the Bundesbank served to a certain degree as a role model for the ECB, we think that the choice of the German values is appropriate.

As outlined in the introduction the major motivation of our study of the euro area is the question to which extent the use of monetary information could have been useful for monetary policy decision in the euro area in the recent past. One major criticism of the two-pillar strategy of the ECB has been that the monetary pillar was unnecessary and did not have any influence on monetary policy decisions. Gali et al. (2004), e.g., write:

... M3 growth played little role for interest-rate setting ...

On the other hand, Trichet (2008) made the following statement:

In the euro area we have certainly not been loose or lax! I trust that the ECB did well and took the right decisions in the past. Let me give you an example: you know that when we decided to increase rate in December 2005 (editors note: after almost two and a half years at 2.0%), we were advised by the IMF not to increase rates; we were advised by the OECD not to increase rates; we were advised by a number of other eloquent voices not to increase rates. We did it nonetheless, because our monetary analysis in particular strongly suggested that we should. Today nobody suggests that we were wrong in our analysis and in our decision, on the contrary.<sup>20</sup>

And recently Draghi (2015) motivated the extended asset purchase program with reference to the monetary analysis:

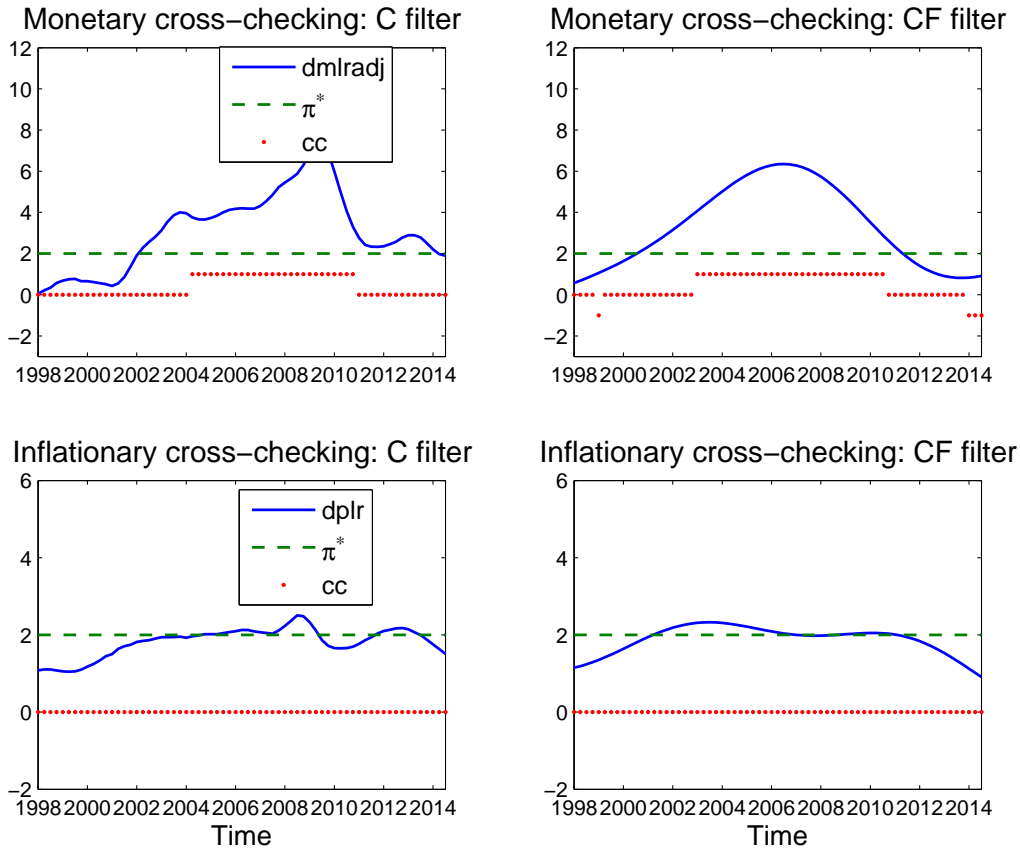
A cross-check of the outcome of the economic analysis with the signals coming from the monetary analysis confirmed the need for further monetary policy accommodation.<sup>21</sup>

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<sup>20</sup>Interview with Jean-Claude Trichet, President of the ECB conducted on 11 July 2008 by Jean Pierre Robin (Le Figaro), Benedikt Fehr (Frankfurter Allgemeine Zeitung), Paul Tansey (Irish Times) and Rui Jorge (Jornal de Negócios), published 18 July 2008. Question: Central Banks, including the ECB, have been responsible for a lot of monetary growth in the recent past. To what extent are central banks to blame for the present inflation, in the euro area and elsewhere?

<sup>21</sup>Draghi, M. (2015). Introductory statement to the press conference (with Q&A), Internet: [www.ecb.europa.eu/presspressconf2015htmlis150122.en.html](http://www.ecb.europa.eu/presspressconf2015htmlis150122.en.html)

Figure 11: Cross-checking in euro area



Note: Figure 11 reports cross-checking results for euro area data when monetary (upper two panels) or inflationary information (lower two panels) is used. The solid line plots long-run adjusted money growth (upper two panels) or long-run inflation rates (lower two panels) and the dotted lines plot the ECB's upper inflation bound of 2%. The line denoted by *cc* takes the value zero when cross-checking suggests no interest rate adjustment and it takes the value one (minus one) when cross-checking suggests a positive (negative) interest rate adjustment.

Figure 11 shows our results for monetary (upper two panels) and inflationary (lower two panels) cross-checking for the euro area. The two graphs for monetary cross-checking both show that a positive interest rate adjustment is suggested by monetary cross-checking at the latest after the second quarter of 2004. When the Christian-Fitzgerald filter is used the adjustment should have taken place even earlier. Looking at the results for inflationary cross-checking for the euro area this conclusion could not be drawn.

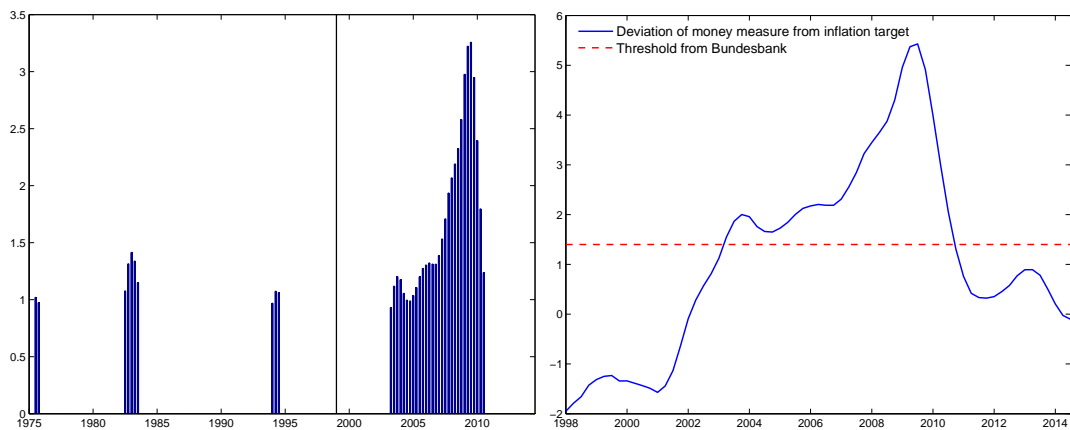
## 8.2 Taylor-rule based results

First, we aim at confirming these results based on our estimations and ask again: If the ECB had followed the same cross-checking as the Bundesbank, when would it have

increased its rates? To answer this question we check when the filtered adjusted money growth in the euro area exceeded the threshold estimated before. We can then also compute how large the suggested adjustment was. In addition, we answer the following question: If the Bundesbank had been responsible for the euro area interest rates, how would the Bundesbank have set them? To do so we employ the reaction function estimated until 1998 and compute the target rates using euro area data.

### 8.2.1 If the ECB had employed Bundesbank cross-checking

Figure 12: Cross-Checks and Euro Area threshold variable



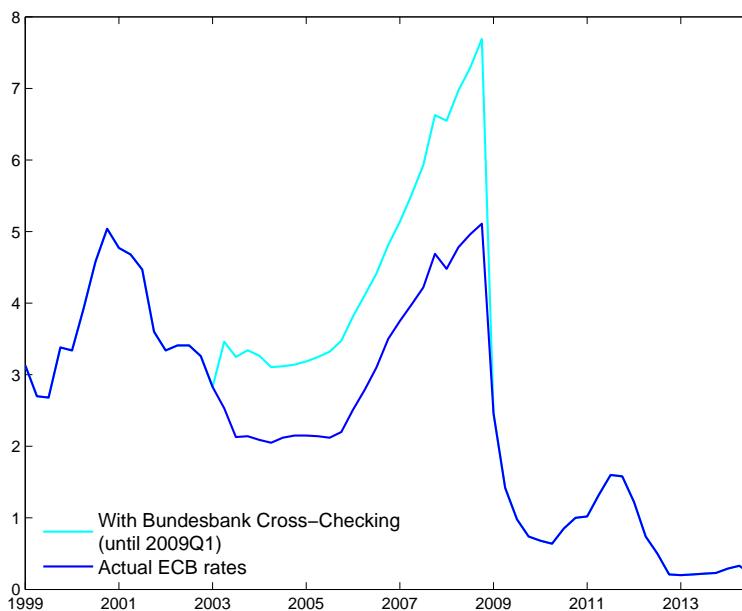
Note: *The left panel of Figure 12 shows the suggested cross-checks using the results from (13). The right panel plots the filtered inflation measure for the euro area and the bound from the Bundesbank estimations.*

Looking at the left panel of 12 the cross-checking mechanisms suggests an adjustment of the interest rates roughly every ten years. The suggested adjustments in Germany until 1999 were between 1% and 1.5%. The suggested adjustments look fundamentally different for the euro area after 1999. Already in the first quarter of 2003 the filtered inflation measure of the euro area exceeded 1.4. Note, however, that after three quarters the measure shortly decreased before it continued to increase slowly from the first quarter of 2005 onwards. The fact that the measure was initially not far above the threshold and remained flat for quite some time may give some justification for the ECB's decision not to increase interest rates earlier. In any case, using the estimated Bundesbank cross-checking mechanism we again detect unsustainable developments early on.

In 2014Q2 the measure was very close to zero and hence fully in line with an inflation target of 2%. Hence it does currently not signal too low money growth and this analysis therefore does at the moment not support a monetarist argument for an expanded asset purchase program.

Figure 13 contrasts the actual interest rates with the ones the ECB would have set if

Figure 13: Actual interest rates and counterfactual with cross-checking



Note: The dark blue line in Figure 13 shows the actual ECB interest rates. The cyan line shows also shows actual ECB interest rates, but with Bundesbank-style Cross-Checking as estimated in the two-regime case in 4. Therefore the European Central Bank would react with a coefficient of 0.6 on the money growth measure, if last periods measure was above 1.4%.

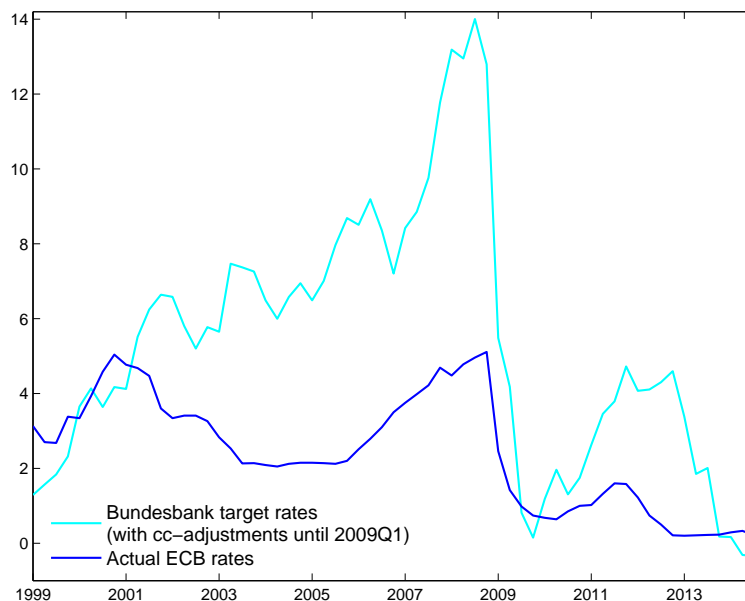
it followed the same cross-checking mechanism that the Bundesbank followed. Note the actual interest rate turnaround in late 2005 that we discussed before and that Trichet (2008) justified with reference to the ECB's monetary pillar. If the ECB had taken its Bundesbank heritage more serious and adopted the upper threshold of 1.4, it would have increased interest rates already in 2003 and we would have experienced higher interest rates in the run-up to the crisis. It seems monetary cross-checking would have helped to prevent interest rates that were too low for too long. We will return to this discussion later.

Our results are very similar to those from the model based approach. In fact, this similarity is little surprising. Remember that in the latter a test statistics is computed, see Equation (10). Using a significance level of 5%, a deviation above (or below) 1.5 signals a shift in filtered money growth. This is very similar to the estimated bound of 1.4. The difference is, of course, that based on the model the central banks waits for 4 periods before an adjustment is suggested. This explains why based on the estimated threshold an adjustment is suggested one year before.

### 8.2.2 Euro-area interest rates induced by the Bundesbank reaction function

Here we use the linear Bundesbank reaction function to compute euro area target rates in the run-up to the financial crisis.

Figure 14: Actual interest rates and rates from Bundesbank rules



Note: The dark blue line in Figure 14 shows the actual ECB interest rates and the cyan line shows target rates from the Bundesbank Taylor Rule (16) computed using euro area data. We shut down the adjustment due to cross-checking in 2009Q1. From 2001 until the eruption of the crisis, the Bundesbank would have set higher rates than the ECB did. Since 2014Q1 the target rates are negative and below the actual rates.

Figure 14 plots the actual interest rates and the counter-factual target rates. While initially the interest rates set by the ECB were very similar to those the Bundesbank would have set, the rates started to diverge already in 2001. From then onwards, the Bundesbank would have set higher interest rates than the ECB did. When the non-linear rule suggests an upward adjustment of the rates in 2003, the difference of course further increases. The finding that the ECB set the interest rates lower than the Bundesbank would have, links nicely to a number of paper making a similar argument (Alesina, Blanchard, Gali, Giavazzi, and Uhlig, 2001; Faust et al., 2001; and Gali, 2002). Note that today's Bundesbank target rate is negative, which provides some support for unconventional monetary policy measures in the euro area.

## 9 Conclusions

In previous work (Beck and Wieland, 2007 and 2009), we proposed an interest rate rule that captures the idea of an add-on or cross-check with monetary information in a formal manner. The cross-check is characterized by a first-order condition that incorporates expected trend inflation, which is estimated from a simple monetary model. The cross-check is triggered in a nonlinear-fashion whenever a statistical test on the basis of the monetary model signals

a trend shift.

In this paper, we use our formalization of monetary cross-checking to examine the question to which extent monetary cross-checking would have signaled that interest rate adjustments were necessary in Germany before 1998 and in the euro area afterwards. Our results for Germany show that in the period from 1971 to 1998 interest rate adjustments during the early 1980s and during the unification boom (CF-Filter) are suggested by monetary cross-checking. In addition, we show that the Bundesbank did indeed react to filtered adjusted money growth when it increased above 1.4% over the inflation target.

The results of the model- and Taylor Rule based specification for the euro area show that monetary cross-checking would have suggested interest rate increases already from 2003 on. We therefore confirm the ECB's claim that the monetary analysis suggested an interest rate increase in December 2005. However, our results indicate that the reaction probably came too late and should have been larger. In general, euro area interest rates in the run-up to the financial crisis were low compared to the rates that the Bundesbank would have set.

Had the ECB consequently followed the suggestions of monetary cross-checking as outlined in this paper the increase in liquidity that helped build the foundation for excessive credit boom could maybe not have been avoided but certainly mitigated.

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