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# Essays on Monetary Policy



ACADEMIC DISSERTATION

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Petri Mäki-Fränti

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## CHAPTER 1

### 1. INTRODUCTION

*“Having looked at monetary policy from both sides now, I can testify that central banking in practice is as much art as science. Nonetheless, while practising this dark art, I have always found the science quite useful.”* –Alan S. Blinder

#### 1.1 Transmission mechanisms of monetary policy

The integrated world economy has become increasingly dependent on the monetary policy of the two largest central banks, the Federal Reserve and the European Central Bank. Rises and cuts in the short-term interest rates are quickly transmitted to all sectors of the national economies through the changes the short rates induce in the prices of other assets like bonds, stocks and exchange rates. The importance of monetary policy has further increased due to the diminished slack of fiscal policy and the practical difficulties to successfully conduct stabilizing fiscal policy. Recent discussion about the role of the central bank has even touched upon such issues like should the central bank also be interested in stabilising the asset market or exchange rate volatility.

The four essays of the dissertation take both positive and normative viewpoints to some of the many still open problems in monetary policy and monetary economics. The essays touch upon quite a wide variety of issues, such as the nature of the transmission mechanism of monetary policy, a correct variable set the central bank should look at when making its policy decisions as well as some empirical analysis of the behaviour of the Federal Reserve and the German Bundesbank after the collapse of the Bretton-Woods system.

Between the collapse of the Bretton Woods system at the beginning of the 1970's and the present day, a vast body of literature concerning the ability of a central bank to affect inflation and output has emerged. Some extreme approaches – the rational expectations literature and the real business cycle literature – have actually gone as far as to state that the monetary policy

actions would have little or no effect on the real economy. Particularly along with the common acceptance of the existence of price and/or wage rigidities affecting the economies, these extreme views seem to have vanished, however.

Some kind of consensus view about the possibility of unexpected monetary policy shocks to affect economy can be found e.g. in Walsh (1998), who reviews recent empirical literature on both short-run and long run relations between money, inflation and output. According to Walsh, in the long-run there is a correlation of almost unity between money growth and inflation, while the correlation between money growth and real output seems to be close to zero, or even negative for high inflation countries. In the short run there is still some role for fine-tuning however, since an exogenous monetary policy shock seems to result in hump-shaped responses in the real output. It takes several quarters before the maximum response is reached, after which the output converges to its initial level. In the case of effects of the systematic monetary policy operations, no strong consensus can any longer be found, however, although e.g. the large structural econometric model used by the Federal Reserve provides qualitatively largely similar responses to short-term interest rate rises than do the VARs<sup>1</sup>.

When it comes to the structural interpretations of these empirical regularities, in addition to the interest rate channel, one can list numerous transmission channels to monetary policy, such as the exchange rate channel, equity price channels, the wealth channel, the bank lending channel and the balance sheet channels. Walsh (1998) classifies the currently dominating modelling strategies in monetary economics into three broad main approaches; the representative agent models, the overlapping generations models and the models that are based more on *ad hoc* assumptions than on the behaviour of optimising agents.

The roots of the new open economy macroeconomics lie in the seminal papers by Obstfeld and Rogoff from the middle of the nineties<sup>2</sup>. Obstfeld and Rogoff extended the closed economy macroeconomic models based on solid microeconomic foundations to cover also the problematic of the open economies. Nominal rigidities and market imperfections either in product or factor markets are the key assumptions needed to ensure a role for monetary policy in these models. Since the models are based on the behaviour of optimising agents, they allow for the explicit welfare analysis, which is a clear advantage when compared to the traditional

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<sup>1</sup> Walsh (1998), p.35.

<sup>2</sup> See e.g. Obstfeld and Rogoff (1995, 1996)

Mundell-Fleming models. Despite many of the desirable properties of the new open economy macromodels, there is still one important restrictive shortcoming related to them, namely the sensitivity of the basic results of the models on the exact assumption of the models. This makes the models somewhat problematic also from the point of view of practical policy making<sup>3</sup>. Thus, there still seems to be a role for the traditional ISLM type of models as workhorse models in practical monetary policy analysis.

In light of this, an interesting contribution to the practical monetary policy analysis has been the so-called New Keynesian models that combine the simplicity of the traditional ISLM models with solid microeconomic foundations. A typical New Keynesian model consists of a simple monetary policy rule, a forward-looking IS-curve representing the demand side and a Phillips-curve representing the supply side of the economy. In further contrast to the traditional ISLM-Phillips curve analysis, not only the IS curve, but also the Phillips curve is often modelled as forward looking. The New Keynesian models differ from the traditional, static ISLM models also in that the models are dynamic, stated in terms of difference equations and the both the IS curve and the Phillips curve are derived from the behaviour of optimising agents.

The international transmission mechanisms of monetary policy are dealt with in the first of the essays in Chapter 1. The essay examines empirically the transmission of unexpected monetary policy shocks between the US and Europe, using a simple structural vector autoregression (SVAR) model. The relevance of the research problem of the first essay of the dissertation hinges on the relative importance of the unexpected monetary policy shocks, compared to the anticipated monetary policy actions. An even more important problem addressed in the essay is how to correctly identify the unexpected shock component of the monetary policy in an open economy. In the closed economy context, the identification of the monetary policy shocks can be based on a simple Choleski decomposition, which assumes that the variables of the model are solved recursively so that the short interest rate (the policy instrument) cannot affect the other model variables, but the other variables can affect the interest rate. In the open economy context such a recursiveness assumption is no longer valid if the model includes variables like exchange rates that are contemporaneously connected to each other by the

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<sup>3</sup> Lane (2001)

central bank's policy variable. Thus, more structural approaches for setting the identifying restrictions between the model variables are called for.

Despite the favourable properties of the new open economy macromodels, it is quite difficult to derive a set of identifying restrictions to use in SVAR modelling<sup>4</sup>. Hence, the theoretical framework behind the identification scheme of the first of the essays is still characterized by the ISLM tradition. On the other hand, when interpreting the results, some insights have also been sought from the new open economy macroeconomics discussed above. Some of the results in particular contradict the traditional *beggar-thy-neighbour* view of the domestic effects of the depreciating currency were difficult to explain in the ISLM framework. In general, the results are however in line with the results obtained in previous studies about the effects of monetary policy shocks.

The most important results of Chapter 1 are as follows: After a negative US monetary policy shock, the outputs of both countries decline, which contradicts the *beggar-thy-neighbor* result. The nominal USD appreciates against the DEM and the long term interest rates decline. The effects of the German monetary policy shock closely resemble the US results above. The outputs of both countries still seem to decline in both countries, but surprisingly, the output effect of a monetary policy shock is greater from Germany to the US than the other way round. The DEM appreciates and the long term interest rates react with an initial rise, after which they fall.

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<sup>4</sup> Antipin and Luoto (2001) provide, however, an example of SVAR studies where the identifying restrictions are derived from a macromodel with optimising agents.

## 1.2 The goals of monetary policy and the Taylor rule

Whether the conduct of monetary policy is a purely technical matter, or whether a political point of view should be reflected in the decision-making of central banks is still an open question. The role of the central banks has been more or less increasing for the whole century, but the tendency has been as its strongest during the past fifteen years, while the preferences of public opinion have also turned more and more to favour anti-inflationary monetary policy. It was originally demonstrated by Barro and Gordon at the beginning of the 1980s that an independent central bank may have an important role guaranteeing the success of anti-inflationary monetary policy<sup>5</sup>. Barro and Gordon suggested that an independent central bank, perhaps even following a strict, mechanistic rule, would provide an efficient solution to the well-known time-inconsistency problem stemming from the politicians' attempts to make use of the short-run Phillips curve to achieve electoral gains<sup>6</sup>.

Whether a mechanistic policy rule provides a more efficient outcome in monetary policy than discretionary actions has been under debate. While a mechanistic policy rule would provide transparency and predictability for consumers, job markets and financial markets, the absence of stable causal links between the monetary policy instruments, inflation and income makes their use questionable. Unexpected macroeconomic events in particular, such as the stock market crash of October 1987 or the surge in the US productivity in the latter half of the 1990s inevitably call for flexibility in decision-making<sup>7</sup>. In addition, the role of a rigid policy rule in providing a shield against political pressure may not be relevant, at least in most of the developed world. As the disinflationary tendency in the industrialized world, beginning in the 1980's has shown, the central banks in these countries have in fact tended to avoid the Barro-Gordon bias. As Svensson (2002a) and Blinder (1999) have argued, this follows simply from the fact that after all, although the central banks have paid some attention to stabilising output, they still have succeeded in not pursuing overambitious output targets.

Although there always seems to be a need for discretion in actual monetary policy-making, rule-like behaviour may be a practical way to summarise some observed key regularities in

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<sup>5</sup> See Barro and Gordon (1983a, 1983b)

<sup>6</sup> Barro's and Gordon's views on the existing inflationary bias in the central bankers' preferences has been criticized interestingly by Blinder (1999, Ch. 2.)

<sup>7</sup> For a discussion on examples of successful, highly discretionary monetary policy decisions, see Greenspan (1997) and Mankiw (2001).

central bank behaviour. Also the essays of Chapters 2, 3 and 4 of this dissertation are at least implicitly based on estimating or specifying such a rule. Perhaps the best known example of simple monetary policy rules is the Taylor rule (see Taylor 1993), according to which the central bank should set the short interest rate by responding to deviations of both inflation and output from their desired target levels<sup>8</sup>.

Originally, the Taylor rule was found to match the US interest rate series well, but since its invention, the rule has become a popular tool for modelling the essential features of the behaviour of central banks all over the developed world. The performance of the rule has also turned out to be robust for the choice of the model characterising the monetary transmission mechanism. These characteristics include for instance, whether the monetary policy is transmitted through the financial market prices or the credit channel, whether the model is backward looking or forward looking, whether the exchange rate plays a role in the transmission mechanism or not, or how the nominal rigidities are modelled<sup>9</sup>. The second advantage of the instrument rules like the Taylor rule is its simplicity and transparency, which also makes it an efficient tool of communicating the central banks' strategies<sup>10 11</sup>.

An alternative approach to instrument rules like the Taylor rule as a basis for monetary policy would be forecast targeting – that is, setting the instrument variable of the monetary policy in a way that makes the central bank's conditional forecasts for its target variable(s) inflation (and output) reach their chosen target values. This is an approach promoted by Lars E. O. Svensson. In practice, forecast targeting means just inflation targeting, and in line with this approach, some countries, like UK and Australia have followed the initial example of New Zealand in 1990 and started to cast their monetary policy objectives simply in terms of an explicitly stated inflation target. The advantages of the forecast targeting approach over the simple decision rules is, first, that the former takes into account a large set of information, whereas the Taylor rule contains only a small subset of the information available. Secondly, if

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<sup>8</sup> Since the SVAR modelling exercise of Chapter 2 focuses on the unexpected part of the monetary policy, the underlying policy rules of these models can be characterized as a central bank reaction function in surprises, as opposed to the Taylor rule in the strict sense of the word, which is more concerned with the systematic part of the monetary policy. See Clarida (2001), p .3.

<sup>9</sup> See Taylor (1999)

<sup>10</sup> See eg King (1999), p. 24

<sup>11</sup> The Taylor rule has sometimes been associated with credibility problems, since there are no mechanisms that would actually bind the policymaker to follow the rule. This criticism is not very convincing, after all. Instead of being a rigid, mechanical rule to be followed blindly, the Taylor rule provides a simple tool for summarising the main cyclical developments of the economy for use in connection with other information sources.

followed too mechanistically, the rules do not allow the extent of discretion often necessary in practical policymaking.

According to Svensson (2002a, pp. 2), the strategy of inflation targeting is defined by three characteristics: At first, the inflation target can be expressed numerically, either as a target range or as a point target. Secondly, the decision-making process is based on the central bank's inflation forecast. Thus, when setting the stance of the monetary policy, the inflation forecast should be consistent with the inflation target. Thirdly, the monetary policy should be transparent and accountable. Allsopp (2001) in turn, highlights the last of the criteria by pointing out that if inflation targeting is to be successful, the monetary policy should stabilise expectations of the markets concerning *both* the inflation and growth.

Despite its popularity, neither the Fed nor the ECB has defined their strategies in terms of pure inflation targeting. The ECB rests on its famous two-pillar strategy, consisting of a quantitative definition for price stability, augmented by a reference value for the growth rate of M3 money and a broadly based assessment of the outlook for future price developments in the Euro area. According to the Maastricht Treaty, the ECB should also pursue other objectives like high employment, but only as long as it does not interfere with maintaining price stability, the primary objective of the ECB. The Fed, in turn, does not have any explicitly stated monetary policy strategy at all, although in the Federal Reserve Act the bank has been given the mandate of promoting “the goals of maximum employment, stable prices and moderate long-term interest rates”. On the other hand, it has been argued that in practice the Fed (and the German Bundesbank before the birth of the ECB and common monetary policy), pursued a monetary policy close to formal inflation targeting<sup>12</sup>.

Even if the inflation targeting central bank's target was expressed entirely in terms of inflation, the central bank can still also put some weight on stabilising the output gap. The positive weight to the output gap under an inflation targeting regime can be motivated on two grounds. At first, the output gap may have positive weight in the inflation targeting central bank's loss function. If the output gap is given some explicit weight in the inflation targeting central bank's loss function, the inflation regime is often called “flexible”, or “constrained” inflation targeting. On the other hand, even if the explicit weight put on the output gap target

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<sup>12</sup> See e.g. Mishkin (1999, 2002).

in the central bank's welfare function is zero ("the inflation nutter" case), the optimal policy still calls some attention to be paid to stabilising output because of the information content that the output gap may include about the future inflation.<sup>13</sup>

What the optimal long-run target value for inflation should be, is still an open question. Despite their anti-inflationary preferences, it is not typical for any central bank, even the inflation targeters, to strictly follow the so-called Friedman rule<sup>14</sup>, which states that the social optimum is achieved if the inflation target is set simply at zero. There are two classic arguments in favour of a small positive inflation target. At first, if there is some inflation in the economy, some flexibility for the real wages can be obtained even in the case of short-run wage rigidities present, as originally put forward by Akerlof, Dickens and Perry (1996). While at least with the US data the empirical evidence leaves the degree of downward rigidity of the nominal wages an open issue<sup>15</sup>, there still remains the second argument that is more difficult to refute: With a positive inflation rate, the zero bound for nominal interest rates prevents the central bank from achieving a negative real interest rate. This makes boosting the economy under recession a difficult, if not completely impossible task<sup>16</sup>. Moreover, during episodes with falling prices, there is the danger of the economy falling into "debt deflation", as originally proposed by Fisher (1933).

In this dissertation, questions related to the monetary policy rules are discussed explicitly in Chapters 3 and 4. The sort of VAR modelling exercise of the first essay in Chapter 2 was implicitly based on an assumption of a policy rule with stable parameter values over time. The relevance of this assumption is discussed in the second of the essays (Chapter 3), which estimates Markov regime switching models for the Taylor-type monetary policy rules of the Bundesbank and the Fed to detect possible structural changes in the parameters of the rules. Although empirical macroeconomic modelling seems to favour linear models, the non-linear models, such as Markov Switching, TAR or STAR models seem to gain popularity in modelling financial time-series like interest rates.

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<sup>13</sup> For a discussion on the output stabilisation objective of inflation targeting central banks, see e.g. Svensson (2002b).

<sup>14</sup> Friedman (1969)

<sup>15</sup> For a discussion, see Mishkin – Schmidt-Hebbel (2001), p. 27.

<sup>16</sup> Of course, the estimated positive responses to the output gap by the central banks could be interpreted only as reactions to the information content of the output over the future inflation trends. Clarida et al. (1998) however, provide empirical evidence according to which the output gap seems to have been included in the reaction functions of the G3 central banks.

Chapter 3 extends the previous literature on estimated policy rules of the Fed and the Bundesbank firstly, in that our non-linear econometric model allows for endogenizing the timing of the possible structural changes. It has been typical for the previous studies<sup>17</sup> on the subject to assume that the dates of these breaks are known *a priori*. The second contribution of the study was to shed further light on the debate on the robustness of the estimated Taylor type policy rules on the exact definitions of the output gap and inflation.

According to the results of Chapter 3, the policy rules of the Fed and the Bundesbank have experienced notable structural changes during the sample period, although the interpretation of the structural breaks was not always easy. In light of this finding, the results from our first essay should also be interpreted with caution, although the structural stability of the equations of the SVAR model was tested. Some additional evidence was also found supporting the views of Orphanides (2001), Kozicki (1999) and Cerra et al. (2000) that the empirical estimates of the Taylor rule may be significantly sensitive on the exact specification of the rule and the data used in the estimations.

Chapter 4 studies whether the ECB should start to stabilise the exchange rate of euro. The original motivation for the research problem was based on the sharp depreciation of the euro against the US dollar that the euro faced after its launch in 1999, which on the other hand has turned into a marked appreciation after the the essay was completed. The study discusses the desirability of an exchange rate target for the ECB both from the viewpoint of the whole union and from that of a single member state. Thus, for its part the study extends the literature on the optimal currency areas.

The way the central bank should react to exchange rate changes ultimately depends on the nature of the exchange rate shocks. Consider, for instance, depreciation of the currency. If the depreciation stems from pure portfolio shocks, the depreciation is likely to raise inflation, which calls for higher interest rates. If the depreciation, however, results from real shocks, the optimal response of the central bank may be as well tightening or loosening the monetary policy, depending on the exact nature of the shock. For example in the case of a negative terms-of-trade shock, which lowers aggregate demand through reducing demand for exports,

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<sup>17</sup> See e.g. Judd and Rudebusch (1998), Clarida and Gertler (1996) and Clarida et al. (1998)

deflation is a more likely outcome than inflation and therefore lower, rather than higher interest rates are needed.<sup>18</sup>

Rogoff (2001), in turn, argues in terms of a theoretical model that because of trade friction, both the global goods and capital markets are much less integrated than is commonly believed. It follows that in a highly segmented goods market, only a small change in fundamentals is needed to create large but fully rational changes in the exchange rate. In addition, the changes in the exchange rate have much less feedback to the real economy than is usually expected.

What might then have been the ultimate factors driving the exchange rate of the euro since its launch at the beginning of 1999? The causes for the rapid depreciation of the euro after its introduction have been examined empirically by de Grauwe (2000). The study actually fails to find any stable link between the fundamentals and the euro/USD exchange rate during the sample period. Instead, the euro/USD rate seems to have been driven by the investors' expectations<sup>19</sup> so that the marked weakening of the Euro rather resulted from more or less irrational behaviour among investors than from the productivity differences between the US and the euro area. Thus, the evidence was more in favour of pure portfolio, rather than real shocks. If de Grauwe's reasoning is correct, one consequence is that the effects of the central banks' interventions may be weaker than commonly believed, since the investors' expectations become more difficult to influence.

The previous empirical evidence on the role of the exchange rate in the policy rules of the largest central banks include Clarida et al. (1998). According to the results, the central banks of Germany and Japan seem to have reacted to deviations in their nominal exchange rates against the US dollar from purchasing power parity, although the reaction has been small. When interpreting this result, there are, however, the same problems present as when interpreting the estimated positive weight put on the output gap, since there might be difficulties to separate the case of the nominal exchange rate included in the policy rule from the case where the central bank has reacted only on the information that the exchange rate

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<sup>18</sup> See Mishkin and Schmidt-Hebbel (2001).

<sup>19</sup> According to de Grauwe's reasoning, there is a great uncertainty among investors about the relation between the exchange rates and fundamentals. Because of this uncertainty, the exchange rate movements themselves "frame" the investors' beliefs of the fundamentals of the economies. Using these frames, agents tend to concentrate on looking only at those economic fundamentals that can corroborate their initial perception of the fundamental strength of the economy. This process can continue until the discrepancy between the investors' beliefs and reality grows too large and the agents have to find another fundamental to look at.

contains onfuture inflation<sup>20</sup>. A special emphasis in Chapter 4 is put on the viewpoint of a small union member state with a more open national economy and asymmetric business cycles compared to the rest of the union. Thus, the study also contributes to the literature on optimum currency areas (OCA), originating in the seminal paper by Mundell (1961). The goal of the OCA literature is to compare the benefits that a country achieves by joining a currency union against the costs from losing the opportunity for independent monetary and exchange rate policies.

Beginning from the 1970's this literature has focused particularly on the problem of how to adjust to asymmetric economic shocks facing the member states of a monetary union. In the case of asymmetric shocks, the one-size-fits-all monetary policy of the common central bank of the union may no longer suit all the member states. The timing and magnitude of the effects of the monetary policy may also differ among the member states if they have different financial structures and wage-price processes. If the member states also differ from each other in their degree of openness against the world outside the union, the exchange rate will play larger role in the monetary transmission mechanism of the more open countries. Thus, for these countries, exchange rate adjustments could provide a shield for the economic shocks that is lost when joining a monetary union. If there are no other effective adjustment mechanisms like trade linkages, high factor mobility or automatic fiscal stabilisers, the increased adjustment costs for the economic shocks may greatly outweigh the benefits from the union.

The degree of asymmetry of the shocks facing the member states of the EMU has been examined e.g. by Bayoumi and Eichengreen (1992, 1996). In both papers the authors find a core group of countries with more highly correlated structural shocks than is faced by the periphery group. As originally put forward by Kenen (1969), the shocks facing the regions of the union are magnified if the manufacturing sectors of the economies are well diversified. Krugman (1993), however, argues that after monetary unification, factors such as scale sensitivity of production or reduced transportation costs may actually decline the diversification of the production structures of the member countries. According to Mongelli (2002) the production structures of most EU countries seem to be highly diversified, however. On the other hand, Tavlas (1994) argues that the empirical evidence available seems to give contradictory answers regarding the problem of symmetry. In Chapter 4 the covariance

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<sup>20</sup> See Clarida (2001).

structure of the shocks facing the member country is estimated with the Finnish data. In this case, major asymmetries were found and they turned out also to be economically significant.

The previous empirical evidence on the differences in the transmission mechanisms between the EMU member countries has been reviewed e.g. by Elbourne et al. (2001) and Dornbusch et al. (1998). Elbourne et al. focus on reviewing the evidence provided by the previous VAR studies, while Dornbusch et al. considers a wider array of models, including e.g. large econometric models used by central banks. Both of the papers point out that the previous findings on the monetary mechanism in Europe are sensitive to the selection of the econometric model. At least Dornbusch et al. (1998) concludes however that due to the differences in the labour markets and financial structures, evidence can be found supporting significant differences in the monetary transmission mechanisms of the member states.

Although the OCA literature serves as a workhorse approach in analysing the different aspects of monetary unions like EMU, the approach can still be criticised. Part of the criticism stems from the discussion concerning the ultimate nature of the determination of the exchange rates. If the exchange rates are mostly driven by portfolio shocks and if are even prone to speculative bubbles, then they no longer provide an efficient tool of adjustment. Accordingly, a stable exchange rate introduced by the union in fact means a welfare gain in terms of reduced uncertainty and lower interest rates. In addition, it may be argued that the different OCA criteria to be met ex ante – symmetric shocks, openness, factor mobility, fiscal federalism – may in fact be endogenous variables. That is, the financial structures and labour markets may adapt themselves to the new environment created by monetary union.

The theoretical model used in Chapter 4 represents the so-called new normative macroeconomic research that has rapidly gained popularity in the field of applied research on monetary policy rules, both among academics and central bank research departments<sup>21</sup>. It is typical of these models that they combine features from both the traditional ISLM type of analysis, as well as from the models of the new open economy macroeconomics. The traditional ISLM models perhaps lack solid microeconomic foundation, but as simple and tractable models that often fit the data fairly well, they still serve as useful workhorses, at least for applied researchers. In short, the basic idea behind the new normative macroeconomic

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<sup>21</sup> For discussion on such models, see Clarida et al. (2001) and McCallum (1999)

research is to calibrate, solve and simulate small macroeconomic models that consist of a simple monetary policy rule and a set of equations describing the rest of the economy.

The results of Chapter 4 suggest that monetary union as a whole does not seem to benefit from an exchange rate target, but the ECB's attempts to stabilize the exchange rate of the euro may reduce particularly the volatility of output of the single member country with a more open economy than the union on average. On the other hand, our simulations revealed that the asymmetries in the business cycle pattern rather than the asymmetries in the structures of the economies, may after all be a more important source for the poorer performance of the member state. Thus, the conclusions of Chapter 4 of the dissertation are broadly in line with the OCA literature.

### **1.3. The role of money in monetary policy**

Beginning from the introduction of the quantity theory of money, money has been given a prominent role in economists' thinking about the transmission mechanisms of monetary policy. However, in the recent discussions on the optimal design of monetary policy, it has been taken for granted that targeting the short-term interest rate instead of some monetary aggregate provides the nominal anchor for the monetary policy. Indeed, after the monetaristic experiments in the US and in the UK at the turn of eighties, the interest rate has almost completely displaced the monetary aggregate as central banks' instrument variable. The debate for and against using some monetary aggregate as the policy instrument of a central bank can be organised around two necessary conditions that would have to be fulfilled in order for monetary targeting to be a viable strategy for a central bank. At first, there has to exist a stable money demand relationship. Secondly, the money supply has to be an exogenous variable, that is, it has to be controllable by the monetary authority.

The first of the conditions is related to Poole's famous analysis (Poole (1970)). According to Poole, if the shocks facing the economy mostly come from the real side of the economy, then the monetary aggregates would actually serve best as the central bank's target variables. If, however, the shocks originate more from the money markets, then the interest rate would be the best instrument. Intuitively, the first of the conditions can be explained by the fact that with large velocity shocks in the money demand present, the relationship between money and

the goal variables of the monetary policy, like the GDP, does not hold. Failure to estimate a stable money demand function points out to the breakdown of the relationship between the monetary aggregates and the goal variables at least in the US case, although in the case of the ECB the numerous recent attempts to estimate an EMU wide money demand equation have been more promising<sup>22</sup>. The evidence concerning the second necessary condition, the endogeneity of broad monetary aggregates such as M2 and M3, in turn, seems at least unclear<sup>23</sup>. All in all, the uncertainties regarding the two necessary conditions above have led the policymakers to universally adopt the short-term interest rate as their target variable.

Although monetary aggregates would be useless as instrument variables for the central banks, they may still serve as valuable indicators for future inflation. Even this role for money that still depends on the degree of stability of the underlying money demand relationship has recently been under debate however<sup>24</sup>. According to a recent empirical study by de Grauwe & Polan (2001), for example, even the long-run relation between inflation and the growth rate of money seems to break down for low inflation countries. King (2002) however criticises such literature as “tyranny of regressions”, that is, it relies excessively on simple reduced form econometric models instead of more structural econometric models. On the other hand, Meltzer (1999) examines a number of deflationary episodes of monetary history and, even relying on the simple regression, succeeds in finding evidence that the interest rate did not fully represent the monetary transmission process during those periods.

Allan H. Meltzer and Mervyn King have recently argued that there may be important channels other than the short-term interest rate through which monetary policy affects real activity<sup>25</sup>. They argue that economists should reconsider the possibility that, controlling for the role of the short real interest rate, money may have an independent role in the transmission mechanism of monetary policy through its effects on other asset prices than the short interest rate. Theoretical motivation for the link between the money and asset prices could be based on the idea that, in contrast to the assumptions of traditional finance theory, the equilibrium yields of the different assets may not be perfect substitutes and, accordingly, there may be supply effects on financial yields. The supply effects are seen particularly in the risk premia of

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<sup>22</sup> See e.g. Friedman and Kuttner (1996) and Estrella and Mishkin (1997) on the money demand of the Fed. The stability of money demand in the euro area is discussed in Kontolemis (2002).

<sup>23</sup> See Mishkin (1999), p. 13.

<sup>24</sup> For a discussion, see also Blinder (1999).

<sup>25</sup> See Meltzer (1999) and King (2002).

the yields (King (2002), p. 171). Further, King (2002) suggests that increase in the quantity of money in the economy may reduce the transaction costs due to frictions in the financial markets, and thus affect the financial yields. Accordingly, an increase in the supply of money makes investors reallocate their entire portfolios of assets, which then contributes to aggregate demand. Transaction costs also play a role in Nelson (2002), in which introducing portfolio adjusting costs to a general equilibrium model makes the long-term interest rate a relevant opportunity cost variable in the model. The presence of the long-term interest rate then strengthens the link between nominal money and real aggregate demand in the model. Nelson (2002) also examines the link between base money and output empirically, finding indeed evidence about a positive link between them.

Even in the face of the above reasoning supporting the role of money in the economy, the emphasis that the central banks put on simple sum monetary aggregates can be called into question however, since these monetary aggregates do not appropriately take into account the differing degree of liquidity of their component assets. One solution to both the theoretical and empirical criticism of the traditional monetary aggregates is provided by the Divisia monetary aggregates, originally developed by Barnett (1980). The concept of Divisia money is based on the idea that the monetary aggregates should be weighted averages over their components so that the weights take into account the different degrees of liquidity of the component assets. Although the long-run neutrality of money implies that when the forecast horizon is extended, the forecasts based on the Divisia money and the simple sum money are likely to converge, it would be expected that because of its favourable theoretical properties, the Divisia monetary aggregates may include valuable additional information about the short-run inflation pressures in the economy.

The last of the essays in Chapter 5 of the dissertation discusses the potential role of the Divisia money as a potential indicator variable for the future inflation for the ECB. The exact research problem of the study is to examine the relative information content of the Divisia M3 money in predicting the euro area inflation dynamics, compared with the information content of the simple sum M3 money. The empirical method used in the study is simulated out-of-sample forecasting. Because of the better theoretical motivation, Divisia monetary aggregates offer a tempting alternative for simple sum M3 as a source of information for future inflation in the euro area. Although it is the growth rate of the nominal money that the ECB is interested in, it has recently been argued that the *level of the real* money or the excess liquidity existing in the

economy, rather than the *growth rate of nominal* money might actually possess the best leading indicator properties for the euro area inflation<sup>26</sup>. Thus, in addition to the growth of nominal monetary aggregates, our study focuses on the forecasting performance on the real money gap and money overhang – two monetary indicators that measure deviation of the stock of real money from its equilibrium values.

According to the results of Chapter 5 then, some of the Divisia M3 money based monetary indicators seem to contain more information about the change of the future inflation than their simple sum M3 counterparts, while none of the simple sum M3 based indicator outperformed its Divisia money counterpart. Interestingly, the growth rate of the Divisia money yielded the best forecasts, also outperforming the real money gap and monetary overhang measures calculated for the Divisia M3 money. Although Chapter 5 focuses on forecasting change in inflation rather than inflation itself, the results are interesting in light of the previous studies referred above, according to which the real money gap and the monetary overhang variables have outperformed the nominal growth rate of the (simple sum) M3 money in forecasting euro area inflation.

#### **1.4. Implications of the results**

The introduction is concluded by briefly considering the possible policy implications of the results of the dissertation. The dissertation begins with an analysis of the transmission of monetary policy shocks between the US and Germany. The results mainly support the previous findings on the fairly important role of the foreign factors affecting the domestic economies. Perhaps the most interesting results were found in the output effects of the monetary policy shocks, since the outputs of both countries turned out to decline after an unexpected rise in the short-term interest rate in the other of the countries. The result contradicts the traditional *beggar-thy-neighbour* result, according to which a country could stimulate its economy at the cost of its trade partners: After a monetary shock in the home country the outputs of the countries should move in opposite directions, because of the effect the shock has on the exchange rate between the countries. In the light of our results it seems, however, that the exchange rate channel is dominated by the other output effects of the shock.

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<sup>26</sup> See e.g. Altinari (2001), Gerlach and Svensson (2001) and Trecroci and Vega (2000)

The topic of the second essay was motivated by the methodological discussion of Chapter 2, since it examines the possibility of estimating stable linear policy rules for central banks by trying to identify structural breaks in the estimated Taylor type policy rules for the Fed and the Bundesbank. Evidence supporting the existence of some regime shifts in the policy rules of the banks was indeed found. Furthermore, the results support the previous findings of the sensitivity of the policy rule estimates on the exact model specification and the data used to estimate the model. Both results imply that one should be careful when using simple empirical policy rules to model and interpret the behaviour of the central banks.

The Taylor type monetary policy rule also motivated the third of the essays that discusses the performance of a Taylor type policy rule extended to also take into account stabilising the exchange rate along with the standard targets of inflation and output gap. From the point of view of the average performance of the whole union area, the simulation exercise for its part supported the common view, according to which central banks cannot significantly increase the performance of the economy by adopting an exchange rate target. A relatively more open small member state could, however, benefit somewhat from a slightly more active exchange rate stabilisation. On the other hand, losing the opportunity for an independent exchange rate policy turned out not to be the only source for the possible costs from losing monetary independence. Asymmetries in the business cycle patterns between a member state and the rest of the union in fact seemed to be a relatively more important cause for the poorer performance of the former.

Since the Taylor type policy rules tend to be forward looking in nature, finding a set of reliable leading indicators for the target variables, particularly on the future inflation, is of utmost importance. The last of the essays that compared the information contents of the synthetic Divisia and the traditional simple sum M3 monetary aggregates on forecasting the euro area inflation suggests that the ECB should consider adopting the Divisia money based monetary indicators at least to be used along with the traditional aggregates. Another interesting finding was that, in contrast to some recent studies, when the Divisia money is used, the nominal growth rate of money that the ECB has given such a prominent role does indeed show a better performance relative to indicators measuring the abundance of the real money in the economy.

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## CHAPTER 2

### TRANSMISSION OF MONETARY POLICY SHOCKS BETWEEN TWO COUNTRIES

#### An Empirical Analysis with a Structural VAR Model

##### Abstract

The paper studies the transmission of monetary policy shocks between the US and Germany. The analysis is based on estimating a structural VAR model (SVAR) of eleven variables: the short and long term interest rates, industrial productions, inflation rates and the growth rates of M3 monetary aggregate of both countries, as well as the nominal DEM/USD exchange rate. The identifying restrictions of the model are connected to the traditional open economy ISLM type models. The most important results are as follows: After a negative US monetary policy shock, the outputs of both countries decline, which contradicts the *beggar-thy-neighbour* result. The nominal USD appreciates against the DEM, and the long-term interest rates decline. The effects of the German monetary policy shock closely resemble the US results above. The outputs of both countries still seem to decline in both countries but surprisingly, the output effect of a monetary policy shock is greater from Germany to the US than the other way round. The DEM appreciates and the long term interest rates react with an initial rise, after which they fall.

**KEY WORDS:** monetary transmission, monetary policy shocks, VAR models.

JEL Classification: E52, E58, F42

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## 1. INTRODUCTION

The US and the EMU form two large currency areas, which are related to each other by international trade and capital flows<sup>1</sup>. The interdependence between the two currency areas, however, is asymmetric in the sense that fluctuations in trade and capital flows from the US to Europe have traditionally had a stronger impact than the other way round. The US interest rates, in particular, are seen as a dominant factor affecting the European interest rates.

The purpose of this study is to examine empirically the extent and mechanisms of international transmission of monetary policy shocks, both from the US to Europe and the other way round. As an econometric method I use the structural vector-autoregression (SVAR) model that describes a world consisting of two large economies and two main currencies. The idea behind SVAR modeling is to identify structural economic shocks by imposing a set of restrictions to the contemporaneous (or long-run) interactions of the model variables<sup>2</sup>. After the model has been specified, the impacts of the monetary shocks are analyzed by means of impulse-response analysis. The variable set of the model consists of the short and long term interest rates, money stocks, inflation rates and outputs of both countries, as well as the nominal DEM/USD exchange rate. Because of the considerable difficulties in aggregating the data from all the EMS countries to single European variables, Europe is represented in this study by only one dominant European country, namely Germany<sup>3</sup>.

The emphasis in SVAR modeling is placed on dynamic interactions, the effects of shocks and data-oriented model building, rather than on issues related to testing the hypothesis of individual parameter values or elasticities. The economic theory is connected to the empirical model quite loosely and informally, and the link between the theoretical and estimable model is somewhat heuristic in nature. The identifying

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<sup>1</sup>In the euro area, the share of exports of goods and services over GDP was 19.7 %, and the share of imports 18.8 %. (See Gaspar and Issing, 2002, p. 343.) In the US, the corresponding figures are 11.0 % and 15.8 %. (Source: NBER.)

<sup>2</sup> Structural shock refers here to a shock which can be contributed to a change in only one single model variable.

restrictions of the SVAR model are usually not directly implied by any single theoretical model, while one set of identifying restrictions may be consistent with a whole family of theoretical models at the same time. Hence, no single macro model can be found as a theoretical framework for my study. Instead, the identifying restrictions are selected in a way, which is consistent with a broad class of models sharing some important common properties.

Examples of previous studies on the transmission of the US monetary shocks on foreign output, inflation or the exchange rate of the US dollar are provided eg by Schlagenhauf and Wrase (1995), Eichenbaum and Evans (1995) and Heimonen (1999). The first of the studies use unconstrained VARs to describe the time series relations between interest rates, exchange rates and outputs of some OECD countries. According to the estimated impulse-responses, a negative shock to US monetary policy is associated with increases in many foreign interest rates. The effect to the US output was first positive but eventually the US output declined. The foreign outputs for Germany, Canada and France responded initially positively to the negative monetary shock but eventually foreign outputs also declined. All of the estimated impulse responses indicated persistent effects of the shocks, although the foreign outputs responded to the monetary policy shocks to a lesser extent.

The effects of the US monetary shocks on (both nominal and real) exchange rates is discussed by Eichenbaum and Evans (1995). They found that a contractionary US monetary shock leads to sharp, persistent increases in US interest rates and sharp, persistent decreases in the spread between foreign and US interest rates. The results are inconsistent with the standard rational expectations overshooting model because the appreciation of the dollar was not temporary, instead the dollar continued to appreciate for a considerable amount of time. Heimonen (1999) in turn, investigates the extent of monetary autonomy of the EMU area and the US. The study focuses on the significance of the foreign money supply process to domestic inflation. It is carried out by impulse responses, tests for Granger causality and cointegration analysis. According to the tentative results, the US money supply does not seem to affect EU-wide inflation in the

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<sup>3</sup> Discussion about the difficulties related to using the European wide variables in the VAR model is provided by Monticelli and Tristani (1999), pp. 1 – 3 and 6 - 7.

short run. The cointegration analysis revealed, that the trends in EU inflation are independent of the US money supply / inflation processes even in the long run. The long run autonomy of the US monetary policy, however, came into question since the trend in the US inflation was affected by the European money supply and inflation.

## 2. METHODOLOGY

### 2.1. Identification of monetary policy shocks

There has not yet been a consensus in the literature on the problem of identifying the purely exogenous monetary policy shocks from the endogenous components of the monetary policy.<sup>4</sup> Here we follow closely one specific identification strategy proposed originally by Bernanke and Blinder (1992). This identification strategy assumes first, that there is some good single measure of the monetary policy stance available. Then, the “true” structure of the economy can be modeled as follows (see Bernanke and Mihov (1995)):

$$(2.1) \mathbf{Y}_t = \sum_{i=0}^k \mathbf{B}_i \mathbf{Y}_{t-i} + \sum_{i=0}^k \mathbf{C}_i p_{t-i} + \mathbf{A}^y \mathbf{v}_t^y$$

$$(2.2) p_t = \sum_{i=0}^k \mathbf{D}_i \mathbf{Y}_{t-1} + \sum_{i=1}^k g_i p_{t-i} + v_t^p,$$

where  $\mathbf{Y}_t$  denotes the vector of non-policy macroeconomic variables, and  $p_t$  is a variable indicating the monetary policy stance. Thus, equation (2.2) can be interpreted as the policymaker’s reaction function (or feedback rule), which characterizes relations among current and past  $\mathbf{Y}$ :s and  $p$ :s that hold exactly, when there are no shocks in the monetary policy. Equation (2.1) then, describes the dynamics of the non-policy sectors of the economy. The vector  $\mathbf{v}_t^y$  and scalar  $v_t^p$  are mutually uncorrelated structural error terms that reflect the non-policy sources of variation in the economy.

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<sup>4</sup> For a detailed discussion concerning the alternative approaches, see Christiano and al. 1998, pp. 3 - 4.

When it comes to the choice of the monetary policy variable  $p_t$ , the monetary policy shock is defined as an unexpected one time change in the short term interest rate under the central bank's control. The identification of the monetary policy shocks now involves making enough identifying assumptions for estimating the parameters of policymaker's reaction function. These necessary assumptions involve assumptions about the variables the monetary authority is interested in when setting the monetary stance and assumptions about the policymaker's operating instrument.<sup>5</sup> One also must make an assumption about the way the monetary policy variable ( $p$ ) and hence the monetary policy shocks, are related to the variables in the feedback rule.

## 2.2. Estimation of the monetary policy shocks using SVARs

To illustrate the identification of the structural shocks in SVAR modeling, it is convenient to denote both the policy and non-policy variables of the economy by  $k$ -dimensional vector of variables ( $\mathbf{Z}_t$ ). Now equations (2.1) and (2.2) describing the "true structure" of the economy can be written as a reduced form VAR model:

$$(2.3) \mathbf{Z}_t = \mathbf{B}_1 \mathbf{Z}_{t-1} + \dots + \mathbf{B}_q \mathbf{Z}_{t-q} + \mathbf{u}_t, \quad E\mathbf{u}_t \mathbf{u}_t' = \mathbf{\Sigma},$$

where  $\mathbf{Z}_t = [\mathbf{Y}_t, p_t]'$ ,  $\mathbf{B}_i$ 's are  $k \times k$  matrices and  $q > 0$ <sup>6</sup> ( $k$  = the number of variables).

It is possible to obtain consistent estimates of  $\mathbf{B}_i$ 's simply by running OLS for every single equation in (2.3). Covariance matrix  $\mathbf{\Sigma}$  can then be estimated from the fitted residuals. Each element of the vector of error terms ( $\mathbf{u}_t$ ) consists now of a linear combination of the effects of all structural economic shocks. This relationship between the reduced form VAR disturbances  $\mathbf{u}_t$  and the structural economic shocks can be

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<sup>5</sup> There are at least three possible intuitive economic interpretations for a monetary policy shock: First, the monetary policy shock may reflect exogenous shocks to the preferences of the monetary authority. Secondly, the variation in central bank's actions may reflect the strategic considerations arising from the desire to avoid disappointing private agent's expectations. The third source of monetary policy shocks may be the technical factors like measurement errors.

<sup>6</sup> This chapter follows closely Christiano, Eichenbaum and Evans (1998), pp. 7 - 10.

expressed as  $\mathbf{A}_0 \mathbf{u}_t = \boldsymbol{\varepsilon}_t$ .  $\mathbf{A}_0$  is an invertible, square matrix and  $E \boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t' = \mathbf{D}$ , where  $\mathbf{D}$  is a positively definite matrix.

The structural form representation of VAR is obtained by premultiplying (2.3) by  $\mathbf{A}_0$ :

$$(2.4) \quad \mathbf{A}_0 \mathbf{Z}_t = \mathbf{A}_1 \mathbf{Z}_{t-1} + \dots + \mathbf{A}_q \mathbf{Z}_{t-q} + \boldsymbol{\varepsilon}_t$$

$\mathbf{A}_i$  is a  $k \times k$  matrix of constants,  $i=1, \dots, q$ ,  $\mathbf{A}_i = \mathbf{A}_0 \mathbf{B}_i$ ,  $i=1, \dots, q$  and  $\boldsymbol{\Sigma} = \mathbf{A}_0^{-1} \mathbf{D} (\mathbf{A}_0^{-1})'$ .

For computing impulse responses of variables in  $\mathbf{Z}_t$  to the structural shocks  $\boldsymbol{\varepsilon}_t$ , it is necessary to know both  $\mathbf{A}_0$  and  $\mathbf{B}_i$ 's. While the parameters of  $\mathbf{B}_i$ 's can be estimated by OLS, obtaining  $\mathbf{A}_0$  is not so straightforward. The only information about  $\mathbf{A}_0$  in the data is given by the equation  $\boldsymbol{\Sigma} = \mathbf{A}_0^{-1} \mathbf{D} (\mathbf{A}_0^{-1})'$ , in which there are many solutions for  $\mathbf{A}_0$ . Hence, in order to identify  $\mathbf{A}_0$ , some restrictions for  $\mathbf{A}_0$  itself and  $\mathbf{D}$  are needed. It is a standard assumption to set  $\mathbf{D} = \mathbf{I}$ , which corresponds to the assumption that the structural economic shocks,  $\boldsymbol{\varepsilon}_t$ 's, are uncorrelated with each other. Now, in the set of solutions

$$(2.5.) \quad \mathbf{Q}_\Sigma = \{ \mathbf{A}_0 : \mathbf{A}_0^{-1} (\mathbf{A}_0^{-1})' = \boldsymbol{\Sigma} \}$$

$\mathbf{A}_0$  still has  $k^2$  parameters while there are only  $k(k+1)/2$  distinct numbers in  $\boldsymbol{\Sigma}$ . This implies that in addition to the restriction  $\mathbf{D} = \mathbf{I}$ , we must impose  $n(n-1)/2$  identifying restrictions on  $\mathbf{A}_0$  so that there is only one element in  $\mathbf{Q}_\Sigma$  satisfying them. These identifying restrictions form one necessary assumption for the exact identification of the model parameters. Under- or over-identification of the model can then be tested by numerical methods, and the parameters of the model (2.4.) can be estimated by maximum likelihood estimation. The identification of the monetary policy shocks in many previous VAR studies in the closed economy context has been based on an assumption of recursive structure of the economy so that the central bank's instrument variable responds to all the other variables of the model, which in turn are not

contemporaneously affected by the policy variable<sup>7</sup>. Choleski approach is a special case of these identification schemes: Given a positive definite symmetric matrix  $\Sigma$ , there is a unique factorization into  $\mathbf{A}_0^{-1}(\mathbf{A}_0^{-1})' = \Sigma$ , such that  $\mathbf{A}_0$  is a lower triangular matrix with positive diagonal elements. The Choleski decomposition in fact implies a completely recursive structure between the model variables, so that all the simultaneous feedbacks between the variables are excluded from the model.

The assumption that the central bank's policy variable does not contemporaneously affect the rest of the economy causes some difficulties in open economy settings, however<sup>8</sup>. Although it may be a realistic assumption in the U.S. case that the central bank reacts only to changes in domestic variables (See e.g. Eichenbaum and Evans 1995), this may not be the case for economies more open than the US. In an open economy, monetary policy may contemporaneously affect the rest of the economy through the contemporaneous changes it induces to the exchange rates. Thus, in Cushman and Zha (1997) and Kim and Roubini (1995), for instance, it has been assumed that the central bank does not only look at predetermined variables when setting its policy instrument but also at the contemporaneous values of variables like the exchange rate, which are not orthogonal to the monetary shocks<sup>9</sup>.

### 2.3 Theoretical framework

From a theoretical point of view, identifying restrictions used in this study are loosely based on the traditional open economy ISLM framework in the sense that the basic structures of the two economies of the model can be summarized by means of three equilibrium conditions: One for goods markets, one for money markets and one for labor markets describing the adjustment for prices and linking the determination of prices and outputs together. The ISLM model, however, may not be held as any complete and unique description of the theoretical framework of this study. For

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<sup>7</sup> In terms of the Equations (3.1.) and (3.2.), this assumption would simply mean that  $C_0 = 0$ , (see Christiano et al. (1998, p. 14).

<sup>8</sup> Sims (1998) has criticized the recursiveness assumption as unrealistic in the closed economy context.

<sup>9</sup> For a more detailed discussion on the realism of the recursiveness assumption in the open economy context as well. (See Grilli and Roubini (1996), pp. 856 – 857 and Christiano et al. (1998), pp. 27 – 28.)

example, it is assumed that the commodity prices and outputs are fixed relative to the immediate effects of the monetary policy shocks in one period horizon. The ISLM type models have lately been criticized fiercely as lacking solid microeconomic foundations. The empirical relevance of the ISLM model has been studied by Gali (1992) who, however finds support for the empirical relevance of the ISLM-Phillips curve paradigm as a descriptive tool at least for the postwar US-data. Rapach (1998) and Monticelli and Tristani (1999) provide other two examples of previous studies with an ISLM type theoretical framework behind the specification of a VAR model.

The variable set of the model consists of the outputs, inflation rates, short and long-term interest rates and the money supplies of the two countries, along with the nominal USD/DEM exchange rate. The restrictions imposed on the coefficient matrix  $A_0$  are represented in Table 2.1 in the next page. The unrestricted parameters are denoted by 1's, while the 0's refer to the zero restrictions. The restrictions were selected after testing several slightly differing alternative sets of restrictions. The differences between these alternative structuralizations were mainly related to the specification of the "sluggish sectors" of the economies. Thus, the reaction functions, the money demand equations as well as the exchange rate equation do not considerably change between the specifications.<sup>10</sup>

The final choice between the alternative sets of identification restrictions was based on the informal criterion for plausibility and reasonableness of the impulse responses. This criterion does not differ in any significant way from what has commonly been done in empirical research in economics: The model is adjusted until it both fits the data and gives reasonable results and is thus theoretically acceptable.<sup>11</sup> Hence, if the estimation seemed to yield results that are overall unamenable to any economic interpretation, this was considered as a sign of misspecification of the given structuralization.

The previous VAR literature has become familiar with a set of puzzling impulse responses, obviously resulting from specification errors in identifying the monetary

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<sup>10</sup> The money demand equations were estimated both with and without the long term interest rates. The problem whether to include the foreign output in the reaction functions was also solved by comparing both specifications.

policy shocks. These specification errors in turn, can be explained by the difficulties in extracting all the other significant determinants of the selected monetary policy variable from the pure policy effects.

Perhaps the best known of these previous anomalous findings is the so called *price puzzle*, in which an expansionary monetary shock is associated with strong and persistent decline in the price level<sup>12</sup>. Price puzzle may be interpreted as reflecting the impacts of the increased inflation expectations, which result in the tightening of the systematic part of the monetary policy. If the information set of the estimated reaction function does not capture these expectations, a part of endogenous part of the monetary policy will be misinterpreted as representing a shock to the policy.

Including the nominal exchange rate among the variables in VAR has given rise to two additional puzzles, namely the *exchange rate* and *forward discount bias puzzles*. The exchange rate puzzle refers to the empirical findings, according to which the currencies of some G6 countries have temporarily depreciated against the US dollar after a monetary contraction. In the case of the forward discount bias in turn, a monetary contraction has first induced a positive interest rate differential, which is then associated with a persistent appreciation of the domestic currency. This appreciation, in turn, implies a failure of the uncovered interest parity condition.<sup>13</sup>

## 2.4 The identification restrictions

To avoid the under-identification problem, the number of the zero restrictions should be at least  $(n * (n-1)) / 2$ , where  $n$  is the number of variables in the model. Because the final model actually includes 56 instead of 55 zero restrictions, it's exact identifiability had to be checked by numerical methods (see Appendix IV). According to the results, the model seems to be exactly identified.

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<sup>11</sup> See e.g. Leeper and al. (1996) pp. 3 – 5.

<sup>12</sup> See e.g. Litterman and Weiss (1985) and Sims (1986)

<sup>13</sup> See e.g. Eichenbaum and Evans (1995) and Grilli and Roubini (1996)

**Table 2.1. Identifying restrictions**

	$r$	$r^*$	$M$	$M^*$	$e$	$R$	$R^*$	$P$	$P^*$	$Y$	$Y^*$
$r$	1	1	1	0	1	1	0	1	0	1	0
$r^*$	0	1	0	1	1	0	1	0	1	0	1
$M$	1	0	1	1	1	1	0	1	0	1	0
$M^*$	0	1	1	1	1	0	1	0	1	0	1
$e$	1	1	1	1	1	1	1	1	1	1	1
$R$	1	1	1	0	1	1	1	0	0	0	0
$R^*$	1	1	0	1	1	1	1	0	0	0	0
$P$	0	0	1	0	1	0	0	1	0	1	0
$P^*$	0	0	0	1	1	0	0	0	1	0	1
$Y$	0	0	0	0	0	1	0	1	0	1	1
$Y^*$	0	0	0	0	0	0	1	0	1	0	1

The rows of the table refer to the coefficients of the contemporaneous values of the 11 explanatory variables (shown in columns) in the 11 VAR equations. If the coefficient is unrestricted, it is denoted by 1 while 0 refer to a zero restriction.  $r$  = call money rate,  $r^*$  = federal funds' rate,  $M$  = the growth rate of German M3,  $M^*$  = the growth rate of US M3,  $e$  = the nominal DEM/USD exchange rate,  $R$  = the German long term government bond rate,  $R^*$  = the US long term government bond rate,  $P$  = the German inflation,  $P^*$  = the US inflation,  $Y$  = the German industrial production,  $Y^*$  = the US industrial production.

The first two rows of the matrix correspond to the reaction functions of the central banks of the Fed and the Bundesbank, with short-term interest rates as their policy instruments<sup>14</sup>. The reaction functions can be interpreted as variants of a Taylor-rule type policy rule, although in the specification of Table 2.1 the central banks react to larger sets of variables compared with the original Taylor rule, which has only inflation and output gaps as its arguments<sup>15</sup>. The specification here corresponds to an assumption that the policymaker considers a broad array of information when forming expectations of inflation and output, in addition to the own histories of these variables.

<sup>14</sup> The identification of the reaction functions has been influenced by the empirical results of Clarida and al. (1998), who estimated reaction functions for Germany, Japan, the US, France, Italy and UK. Their specification of the reaction function was also consistent with many theoretical studies about central bank behavior with quadratic loss functions over inflation and output.

<sup>15</sup> Since the SVAR modeling focuses on the unexpected part of the monetary policy, the first two equations of the model could best be characterized as central bank reaction functions in surprises, as opposed to the Taylor rule in the strict sense of the word, which is more concerned of the systematic part of the monetary policy. See Clarida (2001), p. 3.

Because the model is estimated with monthly data, the reaction function should only consist of variables from which there are real-time information available to the central bank within one month's time. In practice, the problem boils down to the question whether to include contemporaneous values of outputs and prices themselves in the reaction functions or not. According to previous research, it is not clear how much formal or informal information the monetary authority can collect about the contemporaneous values of those variables<sup>16</sup>. Partly motivated by the need to avoid too large a number of zero restrictions, the contemporaneous values of the domestic output and inflation are, however, included in the reaction functions.<sup>17</sup>

The money stock, long-term interest rate, output and inflation of the respective foreign country are omitted from the reaction functions of both central banks simply because these variables are assumed not to be of interest to the policymakers. The specifications of the reaction functions differ from each other in that the Bundesbank is expected also to look at the foreign short-term interest rate while the Federal Reserve is not. The domestic long-term interest rates are included to the reaction functions because the long rates may reflect information about expected inflation.

The third and the fourth row characterize the money demand equations of the countries. In both countries the change in demand for nominal money is affected by the contemporaneous values of output, inflation, foreign money growth, nominal exchange rate and nominal short and long term interest rates<sup>18</sup> of the respective country<sup>19</sup>. This specification of money demand is close to the standard specifications where the demand for real money depends on the short-term nominal interest rate and output. The inclusion of the foreign money in the money demand equations is theoretically motivated by the

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<sup>16</sup> According to Eichenbaum (1998) for instance, the assumption that the Federal Reserve looks at the current output and price level when setting the monetary policy stance, seems at least as plausible as assuming that it does not.

<sup>17</sup> For a more detailed discussion of the reasonableness of this kind of restrictions for the central banks' information set, see Sims et al. (1998), p. 25, or Christiano, Eichenbaum and Evans (1998), p. 18.

<sup>18</sup> It is assumed in this specification of the money demand that the two alternative assets to the agents are cash and bonds. Hence, the opportunity cost of holding cash balances is the nominal rather than real interest rate.

<sup>19</sup> The real balances are implicitly defined in terms of consumer prices. Hence, the coefficient of the nominal exchange rate is not restricted to zero in the money demand equations.

need to take into account the currency substitution and the growth rate of world money for the money demands of the countries<sup>20</sup>.

The row describing the determination of the nominal DEM/USD exchange rate ( $e$ ), is an “information market equation”, which contains all the variables contemporaneously. The motivation behind this kind of specification for the determination of the exchange rate is based on the idea that in efficient exchange markets the exchange rate can respond quickly to all relevant information in both countries. The specification is inspired by the examples of Cushman and Zha (1997) and Sims (1996) and the equation reflects the existence of disturbances to the private sectors of the countries that cannot be defined in terms of the sticky non-financial variables included in the model.

The next two rows describe the determination of the long-term interest rates. The inclusion of the long-term interest rates as variables to VAR is motivated by three considerations: Firstly, there are some a priori reasons to believe that for many long-term consumption and investment decisions, the long-term interest rate should be a variable of more interest than the short run rate (see e.g. Taylor (1995), p. 17). Secondly, as has been argued by Grilli and Roubini (1996), the movements in long-term interest rates might be capturing agents’ expectations about long-term inflationary trends. Finally, according to the empirical evidence provided by Bagliano and Favero (1998), the contemporaneous long-term interest rate may be relevant variables in the policymaker’s reaction function.<sup>21</sup> The long-term interest rates of both countries are assumed to respond contemporaneously to movements in all other interest rate variables of the model, in the exchange rate and in the money supply growth of the home country. Just like the nominal exchange rate, the long-term interest rates are assumed to be determined in the capital markets, reflecting a broad array of information of different variables affecting the investor’s expectations.

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<sup>20</sup> For a discussion about the foreign money supply for the monetary autonomies of the US and the ERM countries, see Heimonen 1999, p. 2. For a more general discussion about the international currency substitution, see McKinnon (1982).

<sup>21</sup> There is actually one problem in including the long-term interest rate as a variable in the VAR model designed to study monetary transmission which is related to distinguishing the structural shocks to long-term rates from structural shocks to short-term rates. This identification problem is due to the feedbacks between interest rates of the different maturities.

Rows 8 –11 constitute the sluggish sectors of the two economies. The variables in this block are assumed not to respond contemporaneously to monetary innovations, but instead, to be predetermined relative to the monetary policy shocks.<sup>22</sup> According to the rows 8 and 9, inflation is driven by the contemporaneous domestic output levels, changes in the growth rates of money and the exchange rate. The last two rows of Table 3.1 refer to the outputs (industrial productions) of both countries ( $Y$  and  $Y^*$ ). The outputs are supposed to be affected contemporaneously by the domestic long term interest rates and inflation rates. In addition, the German output is supposed to instantly react to changes in the US output, but not the other way round.

### **3. REDUCED FORM VAR**

#### **3.1. Data**

Estimating a SVAR model requires first estimating the VAR model in its reduced form. The reduced form VAR model is estimated using monthly data over the sample period 1974:1 to 1998:10. The sample period starts shortly after the collapse of the Bretton-Woods system and the beginning of the flexible exchange rate regime between the US and Germany. The number of observations is 297. The source of the data has mainly been the IMF financial statistics CD-ROM except for the German M3 monetary aggregate time series, which was provided by the German Bundesbank. Seasonally unadjusted data is used whenever it has been available to avoid the loss of information caused by filtering which may also create some artificial structure to the time series processes. Exceptions had to be made with the output series that are seasonally adjusted by IMF. The data set of the model consists of the following series:

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<sup>22</sup> The specification where the monetary policy variable is assumed not to have any contemporaneous effect on the real sector variables is in accordance with many previous empirical studies (Gali 1992, Sims 1998 etc.) which assume some kind of inertia in the real variables. Sims (1996) provides discussion about the significance of this specification for the identifiability of the VAR model.

- Logarithmic levels of **industrial production** volume indices of both countries<sup>23</sup>. These series are seasonally adjusted because of difficulties in obtaining seasonally unadjusted data. The changes of industrial productions reflect changes in GDP which would have been more natural choice of variable. However, it was not possible to find monthly data of the GDP.
- **Short term nominal interest rates** of the countries. The representative German short rate is the call money rate, while federal funds' rate represents the US short rate. Both of these interest rates are 'day to day rates' reflecting the borrowing costs in the interbank lending market. The series are seasonally unadjusted and expressed on levels.
- **Long term nominal interest rates of both countries**, also on seasonally unadjusted levels. Both rates are 10-year government bond rates and both the short term and long term interest rates are expressed as monthly averages.
- Seasonally unadjusted logarithmic differences of the **consumer price indices** of the countries.
- Seasonally unadjusted logarithmic differences of **M3 monetary aggregate** of both countries.
- The nominal **DEM/USD exchange rates** on logarithmic levels. The figures are monthly averages.

The data is represented as line graphs in both levels and differences in Appendix I. It is known a priori, and it can be seen in the graphs, that some important institutional changes have taken place during the sample period. The most important possible structural breaks can be listed as follows:

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<sup>23</sup> In all of the index numbers used as variables the base year is 1990 (=100).

- In the periods 1973 – 1975 and 1978 – 1980, the western economies were hit by two oil price shocks, which resulted in a sharp rise in both inflation and unemployment.
- At the turn of the 1970's and the 1980's, strict monetarist principles were introduced into US monetary policy, due to an attempt to fight against inflation. In practice, the regime shift was implemented by changing the operating procedures of the Federal Reserve from interest rate targeting to the targeting of monetary aggregates. The years from the late 70's to mid 80's were also a period of sharp and steady appreciation of the US dollar against DEM due to the sharp rise in the US interest rates.
- The reunification of Germany at the beginning of 1990 made the monetary management a more complex issue for the Bundesbank. For example, the one for one currency exchange resulted in a peak of 13% in the German M3 aggregate within a single month. The response of the Bundesbank to this increase in the money stock was the aggressive tightening of the monetary stance, which for its part contributed to the collapse of the EMS system in September 1992.

The graphs of Appendix I show that probably there are deterministic trends in the series of price levels, industrial productions and money supplies of both countries, as expected. In addition, a visual inspection of the German M3 graph shows evidence of seasonal components in the respective data generating process. It is natural also to expect some seasonality for the US M3 and the outputs and prices of both countries. There is, however, no need to remove the deterministic trends before estimation of the VAR model, because in the VAR modeling it is possible to approximate a variable with a trend with a sum of random walk and a drift<sup>24</sup>. The possible seasonality in the variables, if necessary, can be taken into account simply by including seasonal dummies to the estimable VAR model.

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<sup>24</sup> When a VAR model with a constant and a deterministic trend contains one or more variables that are random walks with drifts, the estimators of the parameters other than the deterministic trend vector will be consistent. (Starck, 1990, p. 41.)

The preliminary data analysis was supplemented by looking at the skewness and kurtosis of the series, as well as the correlograms (the results not reported). The variables appeared clearly not to be normally distributed, while skewness seemed to be a more difficult problem than kurtosis. The correlograms of the series show peaks in the first partial autocorrelations while the autocorrelations die away very slowly. The result may be interpreted as an obvious sign of the existence of unit roots in the processes.

The order of integration of the variables was examined by the ADF-, Philip-Perron and KPSS tests. Great caution must be exercised in interpreting these results, on the other hand, because of the low power of the unit root tests. The results of the unit root tests are summarized in Table II.1 in Appendix II. All variables except call money appear to be integrated at least of order one (I(1)) in 1 % significance level according to all of the tests. For call money, however, neither the null hypotheses of stationarity nor the null of unit root are rejected. These contradictory results can be interpreted as showing that the time series has not been long enough to properly capture the long run properties of the data.

For price levels and M3:s of both countries the ADF tests do not reject I(2):ness at 5% significance level. In addition, the KPSS test rejects I(1):ness at 5% level for prices of both countries and US M3. Further, there is also some previous empirical research which provides some support for specifying these variables as I(2). Juselius (1998) suggests that inflation follows random walk<sup>25</sup> and Gali (1992) and Rapach (1998) specifies M1:s to be I(2). Thus, the specification of the VAR model was based on the conclusion of one unit root in all variables except the prices and the M3:s which are modeled as I(2):s.

In the case of nonstationary variables in the VAR model, there are three alternative ways to proceed in the analysis. At first, it is possible to estimate a stationary VAR by differencing the nonstationary series before estimation. The second possibility to handle nonstationarity is simply not to care about it and estimate the model in levels. The OLS regressions of the equations in the VAR model yield consistent, although inefficient

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<sup>25</sup> Juselius (1999) provides a more detailed explanation why the prices should in general be modeled as I(2).

estimates of the parameters describing the system's dynamics even in the case of I(1) variables (Phillips and Durlauf 1986, Hamilton 1994, p. 652.), and the primary goal of VAR analysis is just to investigate the dynamic relationships between variables, not to yield exact estimates of the model parameters<sup>26</sup>. Moreover, in the case of cointegrated system with trends in the variables and with some additional preconditions fulfilled, OLS is a superconsistent estimator<sup>27</sup>. In addition, Sims and al.(1987) have showed, that the LR test for lag length has the usual asymptotic distribution, when the test concerns linear restrictions on coefficients on mean zero stationary regressors. Cointegrated variables would also make it possible to estimate the model in an error correction (ECM) form, which is the third way to handle nonstationarity.

The cointegration properties of the model variables were examined both by looking what economic theory and previous empirical research have to say, and by formal testing using the Johansen cointegration test. (For the details of the cointegration analysis, see Appendix II). Summing up the results, the variables seem to be cointegrated, although the a priori information and the formal testing provided fairly contradictory results for the exact number of cointegration relations in the data.

The alternative methods to examine the cointegration rank of the variable set produced rather conflicting results, which might lead to incorrect specification of an ECM model and make the results difficult to give a precise economic interpretation. Thus, our problem of handling the nonstationarity in the data is reduced to a choice whether to estimate the model in levels or differences. Although the exact number of cointegration relationship remains unclear, the existence of the cointegration between the variables implies that estimating the model in difference form would lead to omitting valuable information about the long run properties of the data, and hence to misspecification of the model. From the apparent existence of cointegration between the variables it

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<sup>26</sup> Phillips (1998), however, has shown that the estimated impulse responses of the unrestricted VAR:s with some unit roots are inconsistent in the long run. Chan et al. (1977), in turn, have shown that if the components of VAR include random walk components and the model is estimated in levels with deterministic trends, low frequency movements in the estimated impulses will be exaggerated and high frequency movements will be attenuated.

<sup>27</sup> Superconsistent estimators converge at a rate  $n$  instead of the usual  $\sqrt{n}$ , where  $n$  is the sample size.

therefore follows that we estimate the VAR in logarithmic levels<sup>28</sup> except for the I(2) variables, which are included to the model as differences.

### 3.2. Building and testing the reduced form VAR

The lag length of the reduced form VAR model was examined firstly by the LR tests to detect the possibility to sequentially drop out lags from the model, secondly by the AIC, SBC and HQ information criteria<sup>29</sup> and thirdly, by examining the statistical properties of residuals of the equations. (To save space, the details of the information criteria and the LR tests are not reported.) The outcomes of the two different methods for testing the lag length conflicted sharply with each other, however, since the LR tests proposed using long lag structures, while the information criteria suggest more parsimonious specifications with two (AIC) or three (SBC and HQ) lags.<sup>30</sup>

The examination of the residuals also suggests estimating a model with long lag structure, because the residuals of the equations for the short interest rates tend to show signs of autocorrelation when short lag structures are used<sup>31</sup>. The desire to save degrees of freedom, however, finally led us to adopt a short lag structure of four lags<sup>32</sup>. With this lag structure, the stability of the equations and the statistical properties of the residuals are improved, compared to the alternative of three lags recommended by the information criteria<sup>33</sup>.

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<sup>28</sup> For a proof of the consistency of VAR representation in levels when there are cointegrated variables in the system, see Hamilton (1994), p. 579.

<sup>29</sup> Paulsen (1984) has shown that both the SBC and HQ information criteria are weakly consistent in the case of variables with unit roots. AIC, however, has been shown to overestimate the true lag order with positive probability irrespective of the existence of any unit roots. (see also Jansson 1994, pp. 35-36.)

<sup>30</sup> Clarida and Gertler (1996) solved the problems in choosing the lag length, due to a large number of parameters relative to the length of sample period, by including only the lags 1,2,3,6,9 and 12 in their model. For comparison, this kind of staggered lag structure was adopted also here. Only the AIC criteria preferred the models with staggered lags to models with full lag structures of three or four lags, however.

<sup>31</sup> The normality of the residuals was examined with the Jarque-Bera statistics and the results showed non-normality in most cases irrespective of the lag structure

<sup>32</sup> One reason for rejecting the long lag structures was that the impulse responses estimated with the long lag structure of the lags 1-8 and 12 overall yielded impulse responses that were more difficult to interpret than those computed from models with more parsimonious lag structures.

The diagnostic tests for the VAR(4) residuals are summarized in Table III.1 in the Appendix III. (The significance levels are in brackets.) Autocorrelation was detected by the LM(1) and Ljung-Box Q(20) tests. The LM(1) test rejects the null hypothesis of no autocorrelation only in the cases of industrial productions of the countries (at 5% level). According to the Q(20) statistics, six of the residual series are, however, autocorrelated, when the horizon for detecting the autocorrelation is extended beyond one lag. Luckily, the autocorrelated residuals leave the OLS estimator unbiased, although its efficiency is reduced.

The ARCH(1) statistic measures the heteroscedasticity of the residuals which was found at 1% significance level in the series of short term interest rates and monetary growths of both countries, the German inflation rate and the US government bond rate. Visual inspection suggests that the reported heteroscedasticity seems to be due to some outliers among the observations.

The Jarque-Bera statistics maintains the null hypothesis of normality in the cases of the US inflation, M3 growth, industrial production and DEM/USD exchange rate. The residuals of call money, federal funds' rate, German inflation rate, German money growth and German production however all appear to be non-normally distributed at the 1% significance level. In addition, the residuals of the government bond rates of the countries seem to be non-normal at the 5% level. Luckily, again, the non-normality appeared to be mainly due to kurtosis, which is a less serious problem than skewness, because the kurtosis leaves the OLS estimator unbiased.

A possible source for the observed non-normality of the residuals is provided by the few outlier observations in the data. Thus, the model was re-estimated by introducing some observation specific dummy variables into the model<sup>34</sup>. The dummies were set on three periods. The first one was set just at the beginning of the sample period to take into account the fluctuations in the German short-term interest rate. The regime change in

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<sup>33</sup> The normality of residuals is not a critical assumption in VAR modeling, because the properties of OLS estimator are not affected by nonnormality. The autocorrelation in error terms leaves the OLS estimator unbiased but reduces its efficiency.

US monetary policy at the turn of the 1970's and 1980's was taken into account with a whole set of dummies. Finally, the unification of Germany was considered in the modeling with a single observation specific dummy for period 1990:6. The non-normality of the residuals was reduced in some cases when the dummies were introduced (results not reported in detail). Surprisingly, however, the residuals showed fewer signs of autocorrelation without than with the dummies. Thus, only the dummy representing the currency exchange of Germany in the period 1990:6 was included into the final model.

The stability of the model was preliminary examined by the Cusum-tests, while more formal testing of the VAR residuals was performed by the RESET, Chow and the Goldfeld-Quandt tests. The line graphs of the Cusum tests are shown in Appendix III. It is seen that the V-mask representing 5% confidence levels is slightly crossed in the cases of only call money rate and German industrial production, when overall, most of the equations seems to be quite stable.

The results of the formal stability tests are presented in Table III.2 in the Appendix III. The F-statistics of RESET(3) tests show a possibility of misspecification at the 5 % significance level only for the US government bond rate. F-values of Chow tests, in turn, find signs of a structural break in the cases of German inflation and growth rate of M3. Chow tests, could not, however, be computed for the DEM/USD exchange rate, because the computer program reported near singular matrix.

The Goldfeld-Quandt tests for the VAR equations were performed as LR tests which are used to find the most possible date for the regime switch. It is seen that the regime switch dates suggested by the Goldfeld-Quandt tests differ from those proposed by visual inspection of the Cusum-test figures, since now the most likely date of a regime switch is at the turn of the 1970's and the 1980's for most of the variables. For the US variables these results get a natural explanation for the change that occurred in the operating procedure of the Federal Reserve at that time. Unfortunately, the large number

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<sup>34</sup> There are some drawbacks in introducing dummy variables into the model, however, since the outlier observations may include valuable information about the dynamics of the model. Also some degrees of freedom are lost when using the dummies.

of parameters in the model prevents us from taking the possible regime switch into account by estimating separate models for both regimes.

Overall, we see that some signs of misspecifications or instability were found in some of the equations. It has to be noted however that when the coefficients from different sub-periods are estimated with very high precision, statistically significant differences are easily found, although the differences are necessarily not large enough to also imply economically significant differences between the periods. Further, the changes in the coefficients of a dynamic model with large number of parameters may offset each other, thus leaving many important dynamic relationships unaffected.<sup>35</sup>

#### 4. EFFECTS OF THE US MONETARY POLICY SHOCK

##### 4.1 VMA representation and impulse responses

After the reduced form VAR has now been estimated and plausible set of identifying restrictions found, it is possible to calculate the impulse responses for the system. Estimating the impulse response function of a given VAR system is based on deriving first the vector moving average (VMA) representation of the model, which can be written in the form

$$(4.1) \mathbf{Z}_t = \mathbf{C}(\mathbf{L})\boldsymbol{\varepsilon}_t, \text{ where } \boldsymbol{\varepsilon}_t \text{ is a vector of structural disturbances.}$$

The relation between the VMA and the structural VAR representation can be seen by writing the reduced form VAR from Equation (3.3.) as  $\mathbf{B}(\mathbf{L})\mathbf{Z}_t = \mathbf{v}_t$ , and the structural form VAR (3.4) as  $\mathbf{A}(\mathbf{L})\mathbf{Z}_t = \boldsymbol{\varepsilon}_t$ , where  $\mathbf{A}(\mathbf{L}) = \mathbf{A}_0\mathbf{B}(\mathbf{L})$  and  $\boldsymbol{\varepsilon}_t = \mathbf{A}_0\mathbf{v}_t$ .

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<sup>35</sup> See Starck (1990), pp. 73 - 74

Now it is seen that the structural form VAR is equivalent with the VMA representation when  $\mathbf{C(L)} = \mathbf{A(L)}^{-1}$ . The 11\*11 elements in the matrix  $\mathbf{C(L)}$  are lag polynomials, which represent the impact of j:th structural shock to the i:th variable.

Because of computational difficulties, the impulse responses are presented without any confidence bounds. Thus, the statistical significance of the responses is evaluated on the basis of the magnitude of the peak responses of the variables, measured in terms of standard deviations. Overall, the magnitude of the responses seems to be quite modest. The robustness of the impulse-response estimates with respect to the selected pattern for the identifying restrictions seemed to vary across the variables. The responses of industrial productions, government bond rates and exchange rates seemed to be more robust than the responses of short-term interest rates, inflation rates and monetary growth rates<sup>36</sup>.

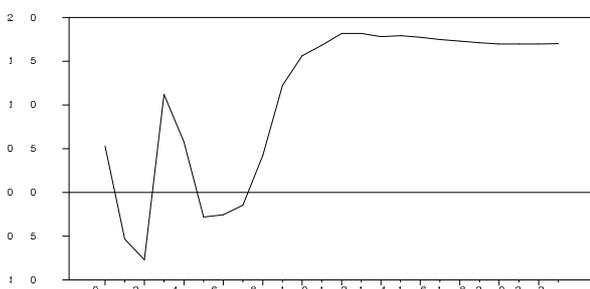
In some cases (e.g. the effect of the US monetary policy to the German short interest rate and the effects of the German shock to the inflation rates of both countries) the impulse responses still seemed somewhat implausible and difficult to give a reasonable economic interpretation. One possible explanation for these findings may be provided by the observed signs of kurtosis, autocorrelation and heteroschedasticity in the VAR residuals that were not possible to remove even by adding observation specific dummy variables into the model. Although the skewness, autocorrelation and heteroschedasticity leave the estimates unbiased, the reduced efficiency of the estimates may have caused some spurious regression between the model variables.

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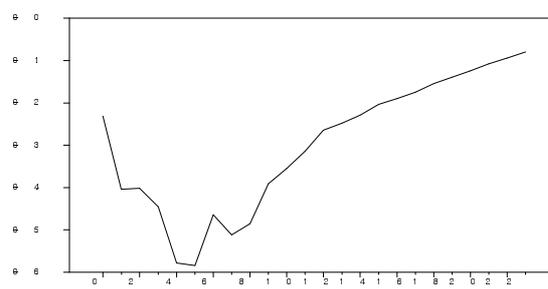
<sup>36</sup> It is unfortunately not possible to report all the hundreds of estimated impulse-response pictures.

## 4.2 Short term interest rates

The impulse responses of the short-term interest rates to a contractionary US monetary policy shock are shown in Figures 4.1. and 4.2<sup>37</sup>. The shock is defined as a one period unexpected rise in the federal funds' rate and it is one standard deviation in magnitude. It is seen that right after the shock, the call money rate also shows a small negative response, while the peak response (about 0.6 standard deviations in magnitude) is reached about four months after the shock. The sign of the response of the call money rate is puzzling, since the interest rate arbitrage should ensure that the short-term interest rates of both countries should move to the same direction. The result is also contrary to earlier empirical evidence by Clarida and Gertler (1996), who reported a positive, although quantitatively negligible response of call money rate to a rise in the federal funds' rate. One explanation may be offered simply by the fact that the patterns of the estimated impulse responses for the short term interest rates were not very robust, although the overall responses of the call money rate rather were negative than positive.



**Figure 4.1** Federal funds' rate



**Figure 4.2** Call money rate

The response of the federal fund's rate itself is positive overall, although modest, and the level of the federal funds' fund rate seems to permanently stay above the initial level, although it declines temporarily just after the shock. The result is consistent with the findings of Christiano and al. (1996) and Ranki (1998), who also estimated for the federal fund's rate a persistent impulse responses for its own shock. In a standard open economy ISLM framework, an unexpected rise in the domestic short term nominal interest rate results in a rise in the real rates as well, due to short run price

<sup>37</sup> The estimations were carried out by RATS 4.32, using "bernanke.src" procedure for which the starting values of the parameters were first estimated by "find" command, which is based on the simplex algorithm. The starting values for the "find" command were set equal to zero's.

sluggishness<sup>38</sup>. Since the inflation rates were included as differences, that is, as growth rates of inflation, the exact effect of the monetary policy shock on the inflation rate remains unknown. In addition, the estimation results for the impulse responses of the growth rates of inflation even turned out not to be very robust. Thus, it is not possible to make firm conclusions about the effects of the monetary contraction to either the short or long-term real interest rates of the countries.

### 4.3. Long term interest rates

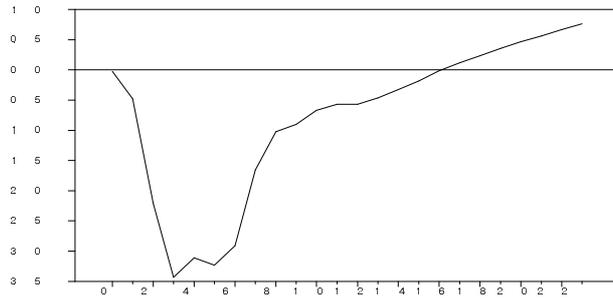
It is seen in figures 4.3 and 3.4 that the negative US monetary policy shock has similar effects on the long-term interest rates (the government bond rates) of both countries. The impulse responses show a modest but relatively persistent decline, beginning almost immediately after the shock. Interestingly, the German long-term rate seems to be affected more strongly by the US shock than the US domestic long-term rate, when the response is measured in terms of standard deviations. The respective peak responses amount to  $-0.6$  for the German and  $-0.3$  std. dev. for the US long rate. After the peak responses, which take place roughly half a year after the shock, both long rates start to converge on the original level again.

According to the standard theories, not only the short-term interest rates, but also the long rates should actually initially rise, due to the arbitrage between bonds with different maturities. The expectation hypothesis of the term structure however, also allows for explaining the initial negative impulse response of the long interest rates observed here. According to that theory, the long term interest rates should be determined by the average of the current and future short rates. If the negative monetary policy shock leads to lower inflation expectations and also easier monetary policy in the future, the natural consequence is the decline of the long rates. It would, however, be expected that before that decline, the foreign monetary contraction would have led to a temporary increase in the long rate due to the asset substitution between the maturities<sup>39</sup>.

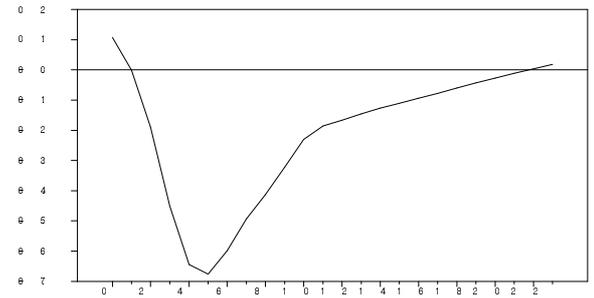
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<sup>38</sup> Sluggishly adjusting prices are no more a characteristic feature of only ISLM type models, because short run nominal rigidities have recently become a common assumption also in the general equilibrium framework.

<sup>39</sup> Empirically, the monetary policy usually shifts the whole yield curve to the same direction.



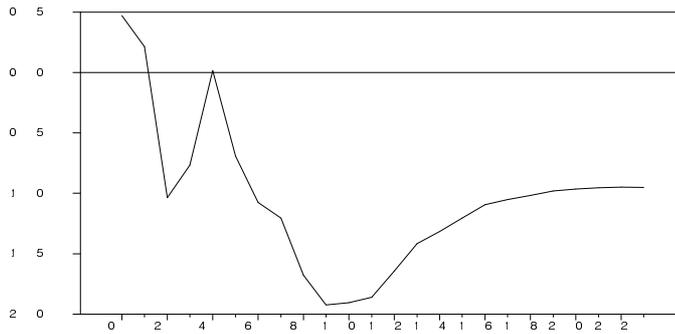
**Figure 4.3** US government bond rate



**Figure 4.4** Government bond rate of Germany

#### 4.4. Exchange rate

The response of the DEM/USD nominal exchange rate is a very modest nominal appreciation of the US dollar. This appreciation is followed by a temporary return to the original level, but the overall response seems to be a persistent appreciation so that the peak response (-0.2 std. dev.) is reached after 9 months. The sign of the response in Figure 4.5 is as expected and it is consistent with some previous evidence. Eichenbaum and Evans (1995) and Ranki (1998) also found that there is a link between monetary policy and interest rates so that a contractionary shock to the US interest rate leads to persistent nominal appreciation of the DEM/USD exchange rate. The sign of the response is in accordance with the predictions of the open economy ISLM models, according to which the short run rise in the real interest rates in the home country should result in a spread between the interest rates of the two countries, and therefore, to a nominal and real appreciation of the nominal (and real) exchange rate of the home currency. On the other hand, it is again difficult to draw conclusions about the effect of the monetary policy shock on the real DEM/USD exchange rate, because the inflation is included into the model as a differenced series.



**Figure 4.5** DEM/USD exchange rate

#### 4.5. Industrial productions

Compared with previous empirical results, the output responses seem to be fairly plausible, when it comes to their sign, overall shape and magnitude<sup>40</sup>. According to the standard results of previous empirical research, a monetary contraction should have a negative hump-shaped impact on the domestic production, the peak response occurring after several quarters<sup>41</sup>. Here, too, in Figure 4.6, the US monetary policy shock seems to have a modest negative effect on domestic output, while the magnitude of the peak response is approximately  $-1.10$  standard deviations. The pattern of the response, however, is not clearly hump-shaped, and the peak response is achieved relatively early, after only four months.

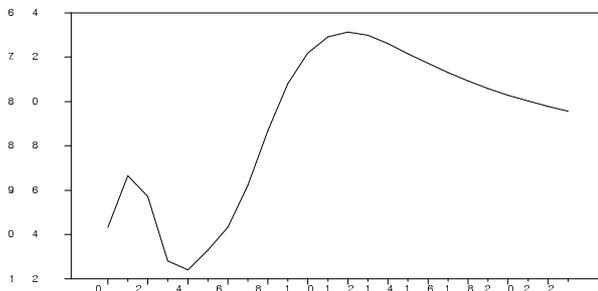
According to the standard Mundell-Fleming model, the contractionary US monetary policy shock should be transmitted by at least two channels to Germany. First come the monetary effects via increased world interest rate level and then comes the demand switching induced by the depreciated DEM<sup>42</sup>. The interest rate effect is negative, but the exchange rate effect positive as its sign. According to the results, the US monetary shock seems to be transmitted to German output only weakly, but it seems that the negative effects dominate. As shown in Figure 4.7, the German production starts to decline almost immediately after the shock, and the peak response is reached after six

<sup>40</sup> For a survey about the commonly accepted results of the short run effects of the monetary policy shocks to the output, see Walsh (1998), Ch.1. Kim (1999) is a recent study about the short-run effects of monetary policy in G-7 countries.

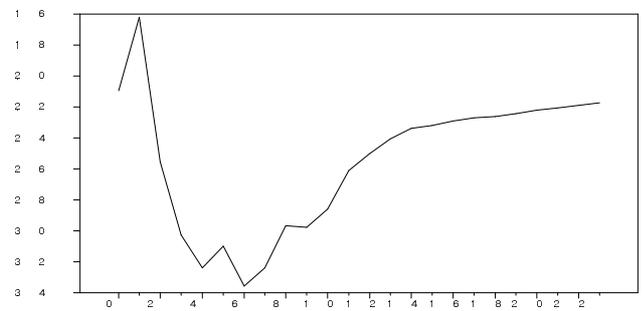
<sup>41</sup> For a discussion about these results obtained with US data, see Walsh (1999).

months. The peak response of the German industrial production is only  $-0.32$  standard deviations, and eventually production starts to gradually converge at its initial level

Instead of applying the Mundell-Fleming framework, the estimated output responses may in fact be easier to interpret in terms of the new open economy macroeconomics<sup>43</sup>, which puts less emphasis on the effects via exchange rate changes than the Mundell-Fleming type models. Corsetti and Pesenti (1997), for instance, present a simple two-country macromodel with closed form solutions. The paper concludes that in the face of asymmetric monetary policy shock between two countries, the outputs of both home and foreign country can move to the same directions. The intuition behind this reasoning lies on the output effect of the changes in world demand. Depending on parameter values of the consumer's utility function, these effects may actually outweigh the exchange rate effects. Further, it is a characteristic feature of the new open economy macroeconomics to emphasize the total welfare effects of the policy. When these welfare considerations are taken into account in the analysis, the traditional beggar-thy-neighbor policy results become even more questionable.



**Figure 4.6** US industrial production



**Figure 4.7** German industrial production

<sup>42</sup> Because it is assumed that the prices adjust sluggishly, the nominal depreciation of the DEM means also real depreciation in the short run.

<sup>43</sup> The new open economy macroeconomics refers to doctrine, which was initiated by Obstfeld and Rogoff (1995, 1996). Instead of ISLM framework, these two-country models are based on behavior of intertemporally maximizing agents.

#### 4.6. Inflation rates

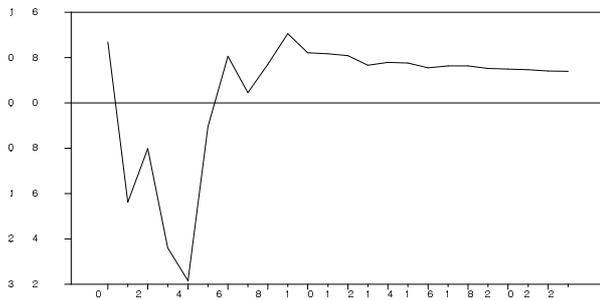
Because the (monthly) inflation rates and the monetary growth rates of the countries are differenced variables, their impulse responses tell how the growth rates of these variables react to the monetary policy shocks. Thus, a positive (negative) response is a sign of accelerating (decelerating) inflation. Since the graphs also show quite ragged shapes, they are slightly more difficult to interpret than the responses of the variables on levels.

Fairly soon after the shock, the growth rates of both US and German inflation show negative responses. Interestingly, the response seems to be relatively stronger in Germany (-0.8 std. dev.) than in the US (only 0.32 std. dev.) The responses, however, are not persistent, because the growth rates of the inflation in both countries start to converge to their initial levels already after a couple of months. The monetary policy shock seems to leave the US with permanently slightly accelerating inflation, however. In a way the result is in line with the previous studies reporting a *price puzzle*, in which an expansionary monetary shock have been associated with strong and persistent decline in the price level<sup>44</sup>.

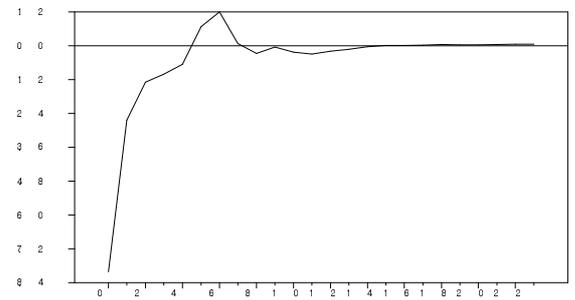
The impulse responses of the growth rates of inflation were not among the most robust results of the study. In fact, many of the alternative sets of identification restrictions that were tested, led to impulse responses which in the short run indicated accelerating rather decelerating inflation rates after the US monetary policy shock. However, the result that a monetary policy shock has only temporary effect on the growth rates of inflation, turned out to be robust with respect to the selected identification restrictions.

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<sup>44</sup> See eg Litterman and Weiss (1985) and Sims (1986).



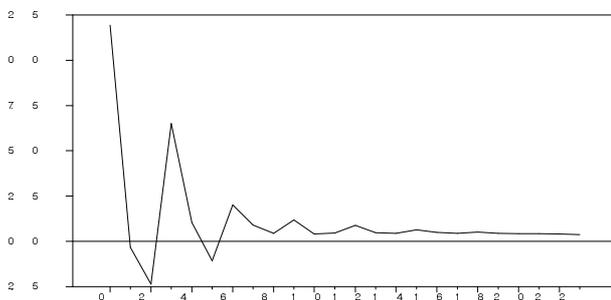
**Figure 4.8** US inflation rate



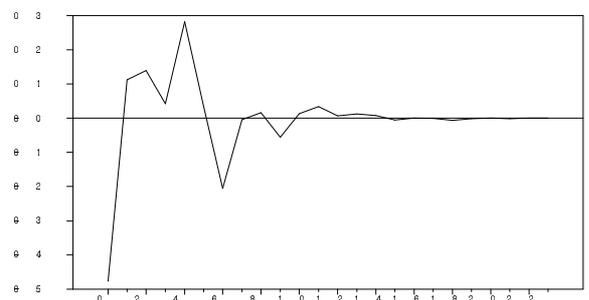
**Figure 4.9** German inflation rate

#### 4.7. Growth rates of money

Like inflation rates, also the growth rate of the M3 monies are included as differences into the model. The change of the growth rate of the US M3 money reacts with a rather puzzling way to the US monetary policy shock: After a rise in federal funds' rate, the growth rate of US money seems to increase by an amount of more than one standard deviation. The reaction is, however, short-lived, since already after four months the US monetary growth rate has returned near its original level. It is difficult to give any economic interpretation to this result. In the case of the growth rate of German M3, in turn, the impulse response seem much more plausible. The sign of the response is negative and size is -0.5 standard deviations. The original level is reached after about eight months after the shock.



**Figure 4.10** Growth rate of US M3



**Figure 4.11** Growth rate of German M3

## 5. EFFECTS OF THE GERMAN MONETARY POLICY SHOCK

### 5.1. Short term interest rates

An unanticipated rise in the German call money rate seems not to result in as anomalous a short-run response of the foreign short rate, as it was in the case of the US monetary policy shock. As it is seen in Figure 5.1, there is a temporary positive peak of 0.4 standard deviations in the federal funds' rate right after the shock, and still after 24 months the federal funds' rate seems to stay at a level above the baseline. The call money rate itself seems at first to fluctuate around the original level, the peak responses ranging from  $-0.2$  to  $0.2$  standard deviations. In the long run, however, the German domestic short-run interest rate also remains above its original level before the shock.

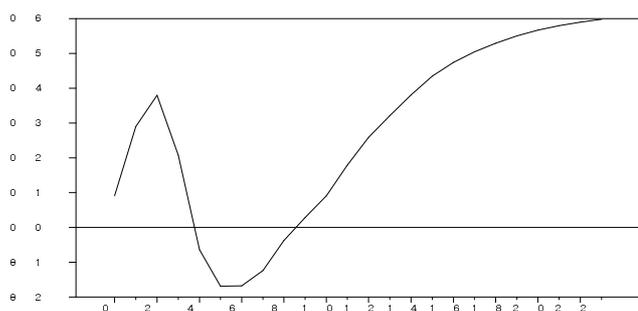


Figure 5.1. Federal funds' rate

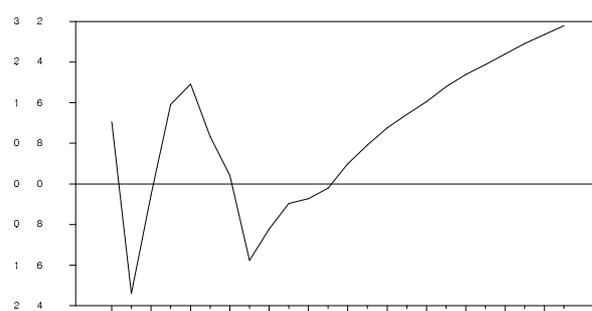


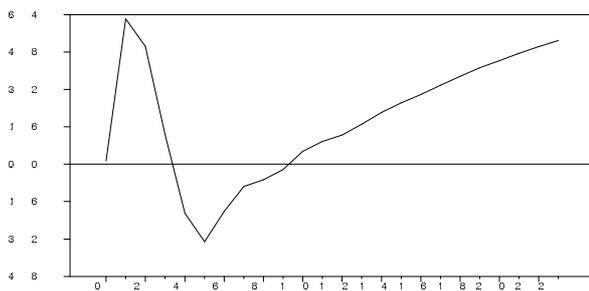
Figure 5.2. Call money rate

### 5.2. Long term interest rates

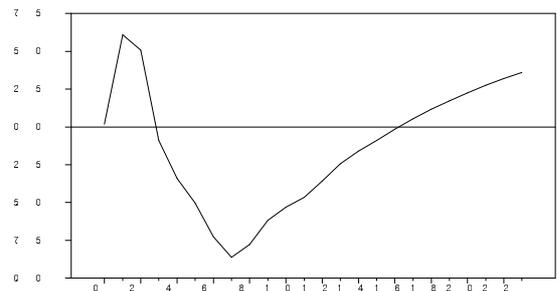
It is now easier to give the short-run behavior of the responses of the government bond rates an economic interpretation than in the case of the US monetary policy shock. The US government bond rate reacts to the German monetary policy shock first with a short-lived positive peak, which is followed by a decline to a level slightly below the original level. The initial rise in the government bond rate can be interpreted as a natural consequence of interest rate arbitrage, while the relatively rapid decline after two months can be explained by the expected reduction in the future short rates as in the case of the US shock. Quantitatively, the foreign transmission effects of the German monetary policy to the US long rate are small, since the response of the US government

bond rate ranges from  $-0.32$  to  $0.64$  standard deviations from the original level during the time-horizon under investigation.

The short-run response of the German long rate does not differ greatly from the behavior of its foreign counterpart. Right after the shock, there is also a short-lived positive peak in the German long rate, and after two months the German government bond rate starts to decline, again possibly due to the expectations of reduction in the future short rates. These expectations seem to affect now more powerfully than in the case of the US long rate, since on the horizon of 1 – 7 months the German rate fluctuates in a range of  $-0.8$  to  $0.7$  standard deviations from the original level. When the horizon is extended beyond 11 months in the case of the US long rate, and beyond 16 months for the German long rate, the results become to more difficult to interpret. In this horizon the long rates of both countries start to rise again, and they seem to permanently stay at a level higher than before the shock.



**Figure 5.3.** US government bond rate

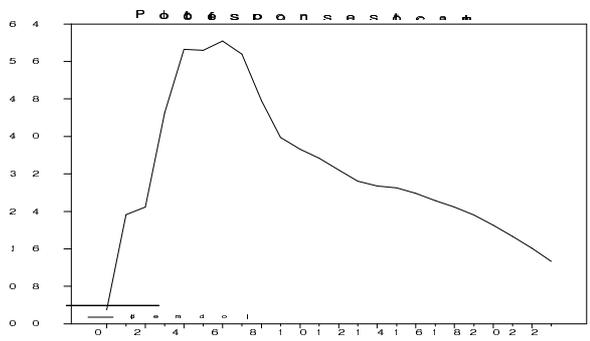


**Figure 5.4.** Government bond rate of Germany

### 5.3. DEM/USD exchange rate

The response of the nominal DEM/USD exchange rate in Figure 5.5 is a rapid appreciation of the DEM, which is followed by a gradual return towards the original level. The sign of the response is consistent with the exchange rate effects of the US monetary policy shock. Quantitatively, however, the DEM/USD rate seems to be slightly more sensitive to the German than to the US monetary policy, although the peak response still is modest, only about 0.6 standard deviations above the original level. Compared with the case of the US shock, the shape of the exchange rate response is now better in accordance with Dornbusch’s overshooting model: The DEM/USD rate

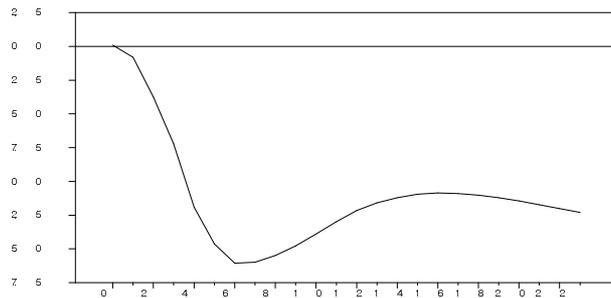
shows now stronger initial response to the monetary shock. It also shows more clearly a gradual return to the original level.



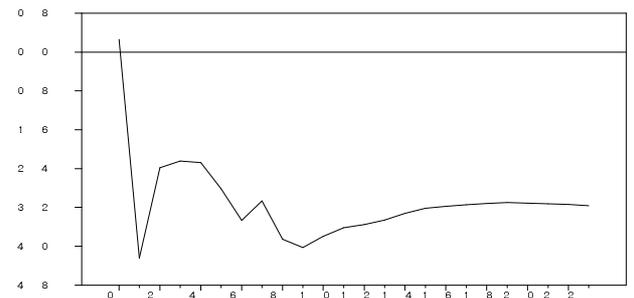
**Figure 5.5.** DEM/USD exchange rate

### 5.4. Industrial productions

The industrial productions of both countries respond negatively to the shock, but now the responses do not show any hump shapedness, as is seen in Figures 5.6 and 5.7. The shock has its maximum effect on the German production a couple of months before the peak response of the US production is reached. It is seen, that the productions do not converge their original levels after their peak responses. Instead, the output effects of the German monetary policy shock seems to be rather permanent in both countries, at least in the horizon of 24 months. Anomalously, the German monetary policy shock seems to have more effect on the US than to the domestic industrial production, when these effects are measured in terms of standard deviations. The peak response of the US output is about -1.6 and the German output about -0.45 standard deviations below the baseline. Further, the transmission effect of German monetary policy on foreign output seems to dominate the corresponding effect of the US monetary shock to the German production, which amounted to only about -0.32 standard deviations. The result appears somewhat puzzling, since according to the common wisdom the US is the locomotive of the world economy, not Germany.



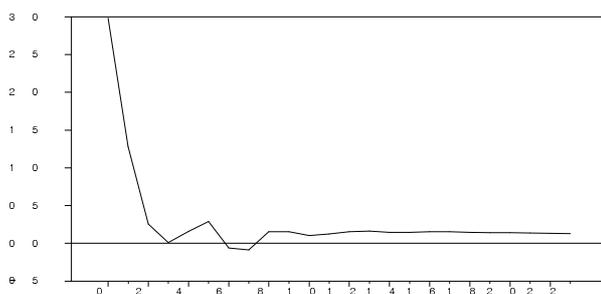
**Figure 5.6.** US industrial production



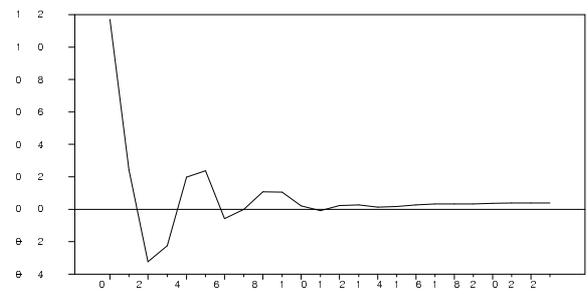
**Figure 5.7.** German industrial production

### 5.5. Inflation rates

The inflation of both countries seem to temporarily accelerate after the contractionary German monetary policy shock, after which the inflation rates quickly return to their original levels. The respective magnitudes of the peak responses are 3.0 std.dev. for the US and 1.2 std.dev. for the German inflation. As already discussed in Ch. 2.3, the phenomenon called *price puzzle*, that is, increased inflation after a monetary contraction, is also familiar from previous VAR studies. A possible economic interpretation for the puzzle is provided by the central bank behavior, as the central banks try to immediately respond to expectations of the increased future inflation by tightening the monetary policy. If the variables of the VAR model do not include enough information for controlling these inflation expectations, the estimated response to the monetary contraction is a positive response of inflation. It has to be borne in mind however that the signs of the responses of the inflation rates were not robust with respect to the identification restrictions used. The findings that the inflation rates react immediately to the shock, and that the responses are short-lived, however, turned out to be robust.



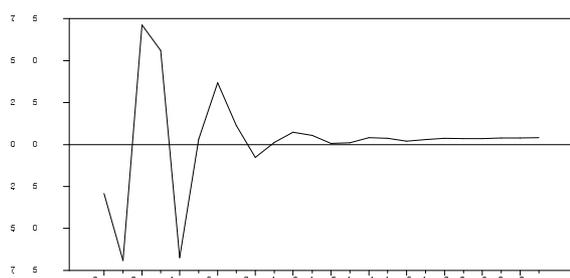
**Figure 5.8.** US inflation rate



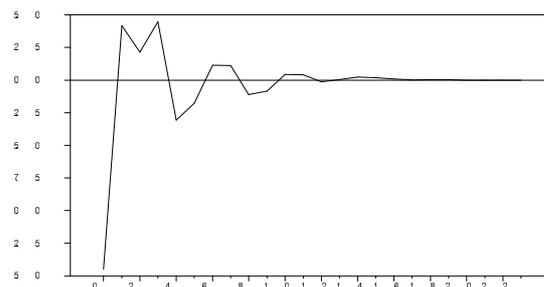
**Figure 5.9.** German inflation rate

## 5.6. Growth rates of money

The growth rates of the M3 monetary aggregates of the countries respond negatively to the unanticipated rise in the call money rate. The responses of the monetary growth rates are, again, quite temporary. In Germany the original level is reached about half a year and in the US ten months after the German monetary policy shock. The magnitude of the response varies between  $-1.4 - 0.45$  standard deviations for the German, and between  $-0.6$  and  $0.7$  standard deviations for the US M3 growth.



**Figure 5.10.** Growth rate of the US M3



**Figure 5.11.** Growth rate of the German M3

## 6. CONCLUSIONS

This paper discusses the transmission of monetary policy shocks between the US and Europe, represented by Germany, using a structural VAR (SVAR) model. The structural interpretation of the set of identifying restrictions of our SVAR model is based on the idea that the equations of the SVAR with short-term interest rates as dependent variables can be interpreted as Taylor rule type reaction functions of the central banks of the two countries. The empirical results are represented by impulse responses.

According to the results, the short-term interest rates of the two countries seem to react in different ways to the US monetary policy shock. The federal funds' rate itself shows a permanent but modest increase, while the call money rate actually falls after the shock. The result is rather counterintuitive, since the short rates should move to the same direction because of the interest rate arbitrage. The responses of the government (long-term) bond rates, instead, showed rather similar patterns between the countries, since both long rates seemed to decline immediately after the shock. As expected, the nominal

DEM/USD exchange rate reacted to the US monetary policy shock with a modest, temporary appreciation of the USD. Because the inflation was included into the model as differences, the total effect of the monetary policy shock to the level of inflation and thus, to real exchange rates or real interest rates remains unknown. The effects of the monetary policy shock to the growth rates of inflation of the countries in turn, seem to be quite temporary, although the US monetary contraction seems to leave the US inflation with slightly accelerating inflation. Same sort of results have also been obtained with some previous studies, with the difference that in those studies a monetary expansion has permanently increased the price level (*prize puzzle*).

The responses of the industrial productions to the US monetary policy shock were negative in both countries, although the responses did not show the hump shaped patterns often found in previous empirical research. Interestingly, the peak responses were reached fairly soon after the shock while according to the common wisdom, the effects of monetary policy need some time to fully materialize. The magnitude of the German output response for the foreign monetary policy shock seems to be quite modest. An intuitive explanation for the transmission of the output effect of the foreign monetary policy was firstly detected from the channels through both the interest rate and exchange rate movements, typical to ISLM type models. Because the impulse-responses, however, did not show beggar-thy-neighbor pattern, it was concluded that instead of Mundell-Fleming type models, the theories of “the new open economy macroeconomics” might provide a more plausible explanation for the results.

Summing up the effects of the monetary policy shocks originating in Germany, they do not seem to greatly differ from the effects of the US shocks. An unexpected rise in call money leaves however both the federal funds’ rate and the call money rate permanently above their original levels. The long-term government bond rates of both countries react to the German monetary policy shock first by a rise, which can be explained by the interest rate arbitrage between the maturities. Eventually, the government bond rates start to decline, potentially because of the expected easing of the monetary policy stance in the future, just as in the case of the US interest rate shock.

As expected, the rise in the call money rate seemed to result in appreciation of the nominal DEM against the USD. The industrial productions of both countries decline and remain permanently (in the horizon of 24 months) at a level below the baseline. The maximum response of the German output is reached already two months after the shock, while the transmission of the output effect to the US takes a couple of months more time to fully materialize. It is noteworthy that when measured in terms of standard deviations the US output seems to react to the German monetary policy shock more strongly than the other way round. This finding contradicts the commonly accepted view according to which the US should be the locomotive of the world economy. The variant of price puzzle discussed above is also faced with the German monetary contraction, since the German shock seems to permanently accelerate the inflation of both countries.

The robustness of the impulse-response estimates with respect to our identifying restrictions seemed to vary across the variables. The responses of the industrial productions, government bond rates and exchange rates seem to be fairly robust, while the responses of the short-term interest rates, inflation rates and monetary growth rates are more sensitive to the identifying restrictions used. The sample period considered include some possible structural breaks in the data generating process, particularly at the turn of 1970's to 1980's, which may have caused some instability in the estimated SVAR model.

At the end of the paper, we propose some ideas for the future analysis in the field of our research problem. First, trying to estimate a more parsimonious model with a smaller number of variables could make the estimated impulse responses less sensitive to the identification used. The second opportunity to extend the analysis would be linking the analysis more closely to economic theory, and possibly this way to provide empirical findings with economic interpretations that are based on more solid microeconomic foundations.

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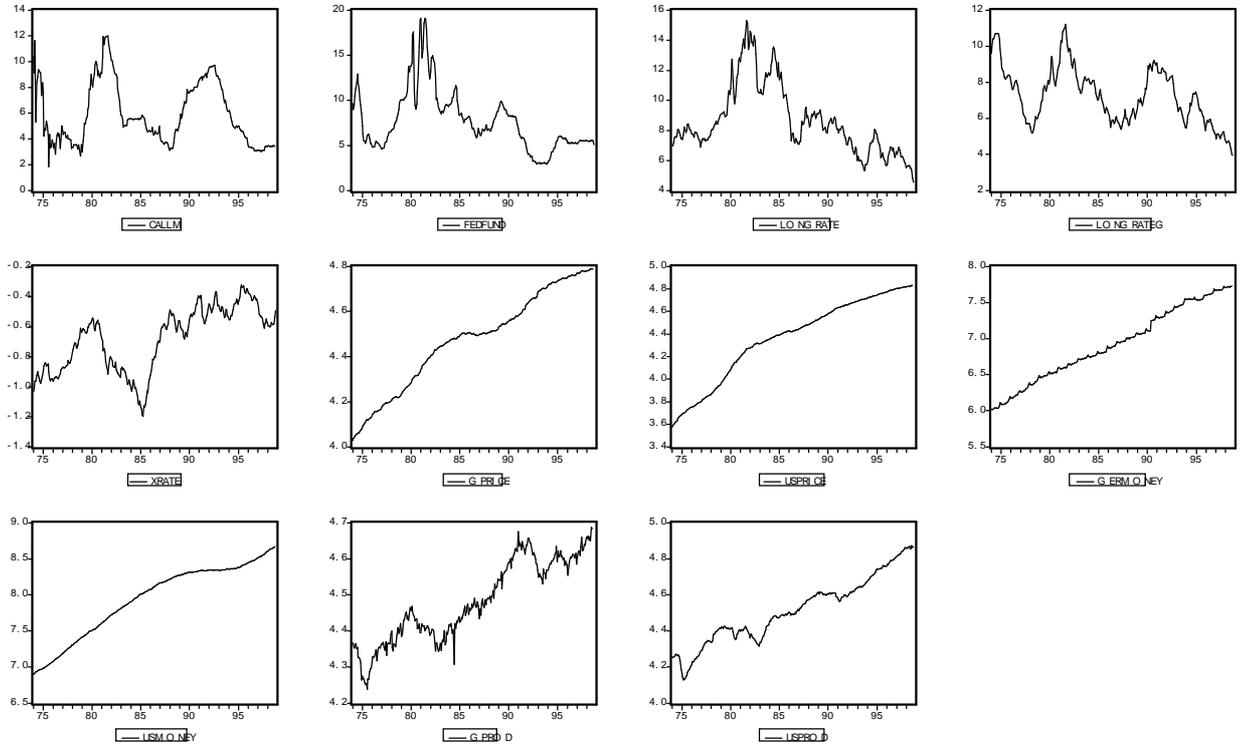
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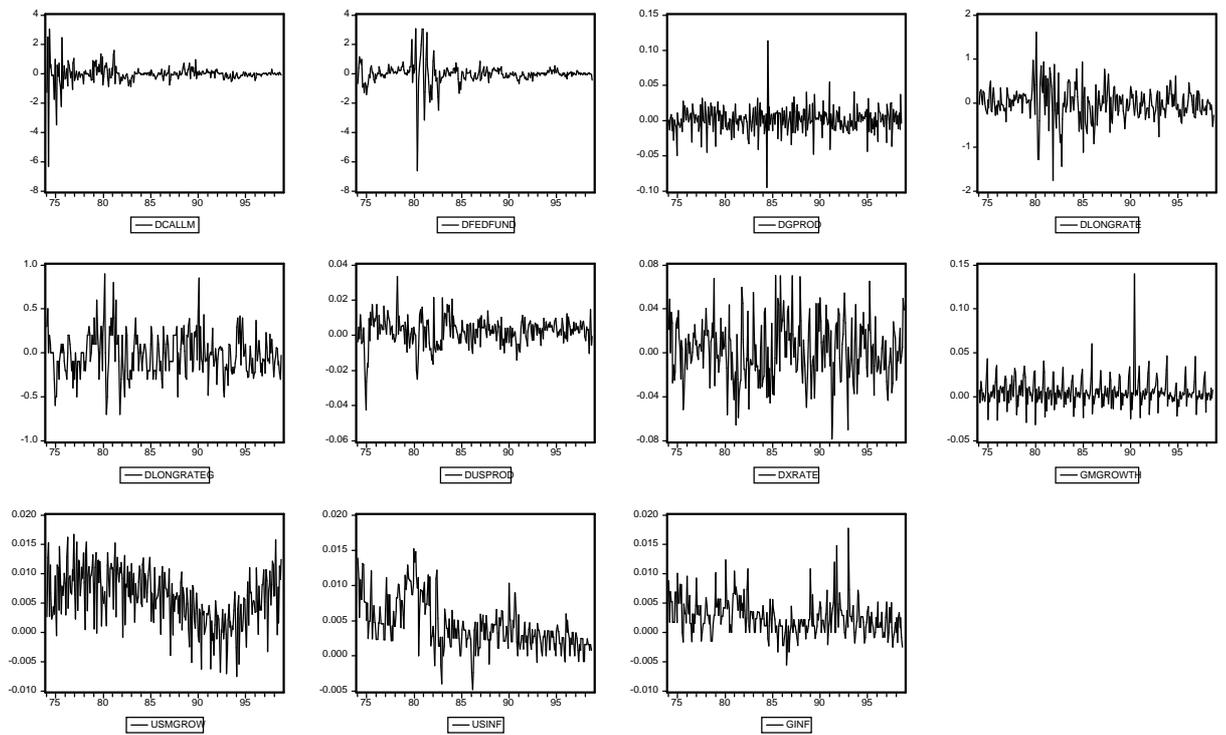
# APPENDIX I

## Line graphs of the time series data

The series in levels



The series in differences





## The cointegration analysis

The analysis of the cointegration properties of the data is started by examining, what economic theory and previous empirical research have to say about the cointegration properties of our VAR system. Following the reasoning of Jacobson et al. (1999)<sup>45</sup> we may assume that the nonstationarity in the variables of the VAR model is due to only four independent stochastic trends: Production in both countries is driven by stochastic shocks to domestic technology<sup>46</sup> and inflation rates are determined by stochastic shocks to the growth rates of domestic money supply<sup>47</sup>. Hence, a priori we might expect to find  $r = 11 - 4 = 7$  cointegration relationships in the data.

If there are only two stochastic trends among the German variables and other two stochastic trends among the US variables, all the domestic variables of both countries may be cointegrated with each other. According to Juselius (1999 p. 272 - 273), this kind of cointegration relationship between output, real money supply and the spread between the short run and long run interest rates can be interpreted as representing either the money demand equation or the central bank reaction function, depending on the parameter values of the cointegration vector.

Two other cointegration relations may be dictated by the term structures of the interest rates, that is, the differences between the short and long term interest rates of both countries<sup>48</sup>. The fifth and the sixth relations are suggested by the uncovered interest rate parity (UIP) relation which suggests that the interest rate differential between the countries should equal the expected change in the exchange rate. Accordingly, if the exchange rate expectations are I(1), the differential between both short and long term interest rates between the countries should be stationary.

The cointegration relation suggested by the purchasing power parity (PPP) condition provides the last possible cointegration relation. The PPP condition relates the inflation differential between the countries to the change in the exchange rate

### *Johansen cointegration test*

The results of the  $\lambda$ -trace and  $\lambda$ -max tests are summarized in Table III.1. below<sup>49</sup>. The test were made for variables in levels, except the prices and the growth rates of M3, which are differenced to obtain I(1) series. The series appear to be cointegrated,

---

<sup>45</sup> Jacobson et al. (1999) study the effects of various economic shocks in the small open economy (Sweden) context, estimating an ECM model with seven variables, some of which are from a large foreign economy.

<sup>46</sup> Starck (1990) found the outputs of some industrialized countries to be cointegrated after the Bretton Woods era, proposing that the outputs of different countries may be driven by one common, instead of two separate, stochastic trends.

<sup>47</sup> Actually, in Jacobson and al. (1999) the prices were assumed to be I(1) variables, whereas here both the price levels and M3:s of the countries are considered to be I(2). With this specification adopted, shocks to the money stock can permanently affect its growth rate as well as the rate of inflation.

<sup>48</sup> The stationarity of the interest rate spread is proposed e.g. by Campbell and Schiller (1987).

<sup>49</sup> The tables for the critical values for the test statistics are sensitive for including deterministic or dummy variables in the model. Hence, because our model includes a dummy variable, we have computed tables using appropriate option of the CATS computer program, instead of using the standard tables.

although the formal testing suggests a lower number of cointegrating relations than does the economic theory. In addition, the cointegration vectors (not reported) seem quite difficult to be given any precise interpretation in light of the theoretical discussion above.

The  $\lambda$ -trace test rejects (at 10 % significance level) the null hypothesis that the number of cointegration vectors ( $r$ ) is at most five. The  $\lambda$ -max test, in turn, rejects the null hypothesis of the  $r$  being exactly a given number, up to  $r=7$ . Hence, according to lambda max, the number of cointegration relations is equal to 8, while the lambda trace propose that it equals only to 6.

**TABLE II.2.** Johansen cointegration test for the variables of the VAR model.

Eigenvalue	Lambda- Max	lambda- trace	H0: r=	Ho: p-r=	lambda- max 90%	lambda- trace 90%
0.44	165.22	579.21	0	11	43.48	272.03
0.31	104.73	413.99	1	10	42.72	228.55
0.27	91.66	309.26	2	9	35.84	185.83
0.20	64.95	217.61	3	8	32.26	149.99
0.18	58.54	152.65	4	7	28.36	117.73
0.12	37.95	94.11	5	6	24.63	89.37
0.07	22.35	<b>56.16</b>	6	5	20.9	64.74
0.06	17.71	33.81	7	4	17.15	43.84
0.04	<b>10.65</b>	16.1	8	3	13.39	26.7
0.02	5.42	5.45	9	2	10.6	13.31
0.00	0.03	0.03	10	1	2.71	2.71

The Johansen test was performed with lagged differences 1-4, a constant, and a dummy variable which took a value of 1 on 1990:6 and 0 otherwise. Because the prices and M3:s appeared to be I(2) variables, they are included in the test model as logarithmic differences, while the other variables are on logarithmic levels. It is assumed that the series had means and linear trends but the cointegrating equations had only intercepts.

The statistical significance of the adjustment coefficients,  $\alpha_{ir}$ , as well as the roots of the companion matrices of the corresponding ECM models, were examined as an alternative procedure for determining the cointegration rank. The roots of companion matrix tell us whether there still remain some near unit root processes in the ECM model when the number of the cointegration relationships ( $r$ ) is supposed to be known. Such less formal testing (results not reported in detail) is useful, since the formal testing was still plagued by the small sample bias. The results of this testing now lead us to slightly different conclusions than the  $\lambda$ -trace and  $\lambda$ -max tests, since now the number of cointegration relations seems to be equal to only four<sup>50</sup>.

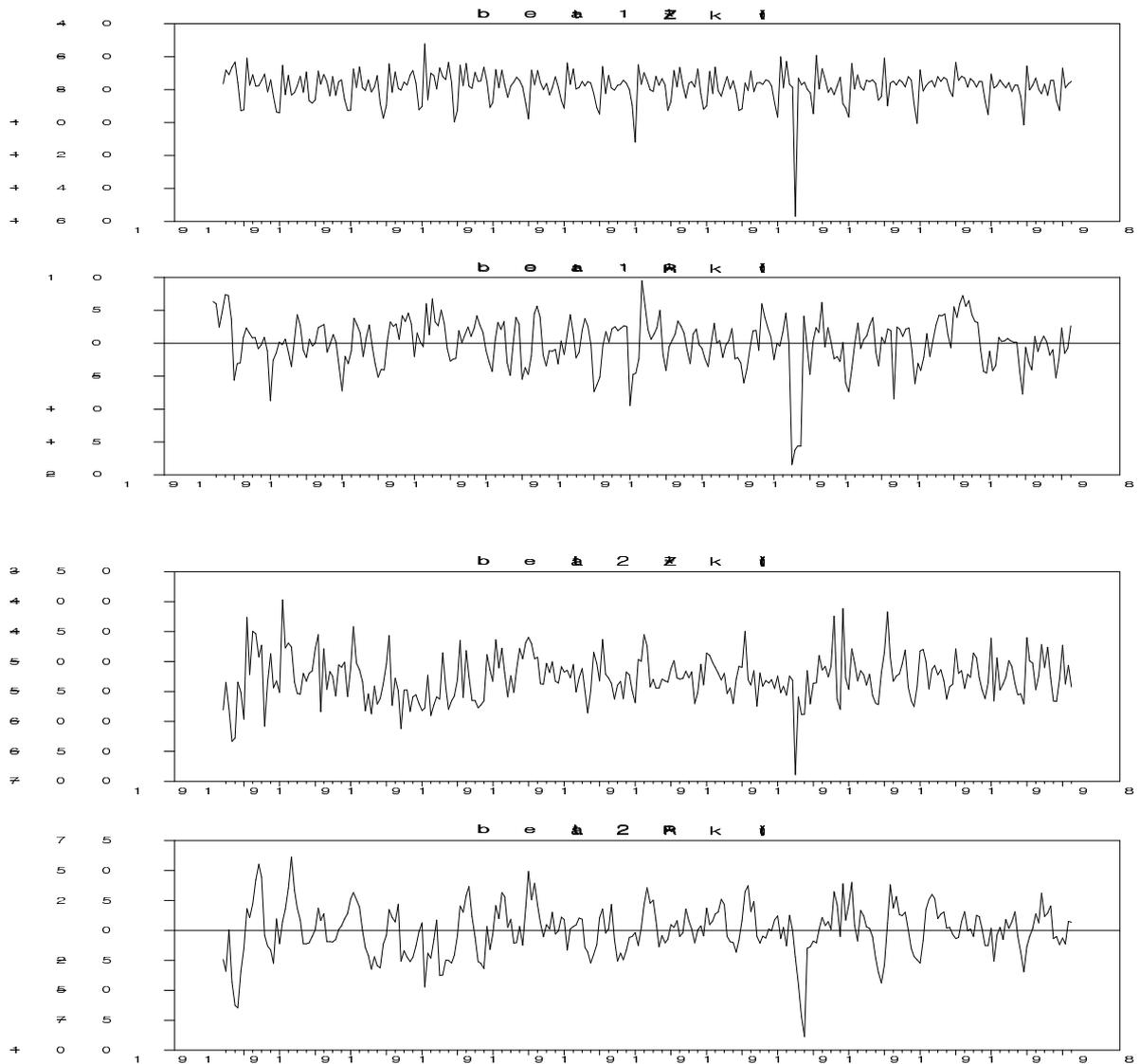
By looking at the statistical significance of the adjustment coefficients,  $\alpha_{ir}$ , it is possible to see whether a given cointegration relationship does have explanatory power in the given equation of the ECM model<sup>51</sup>. When  $r$  was set equal to four, every

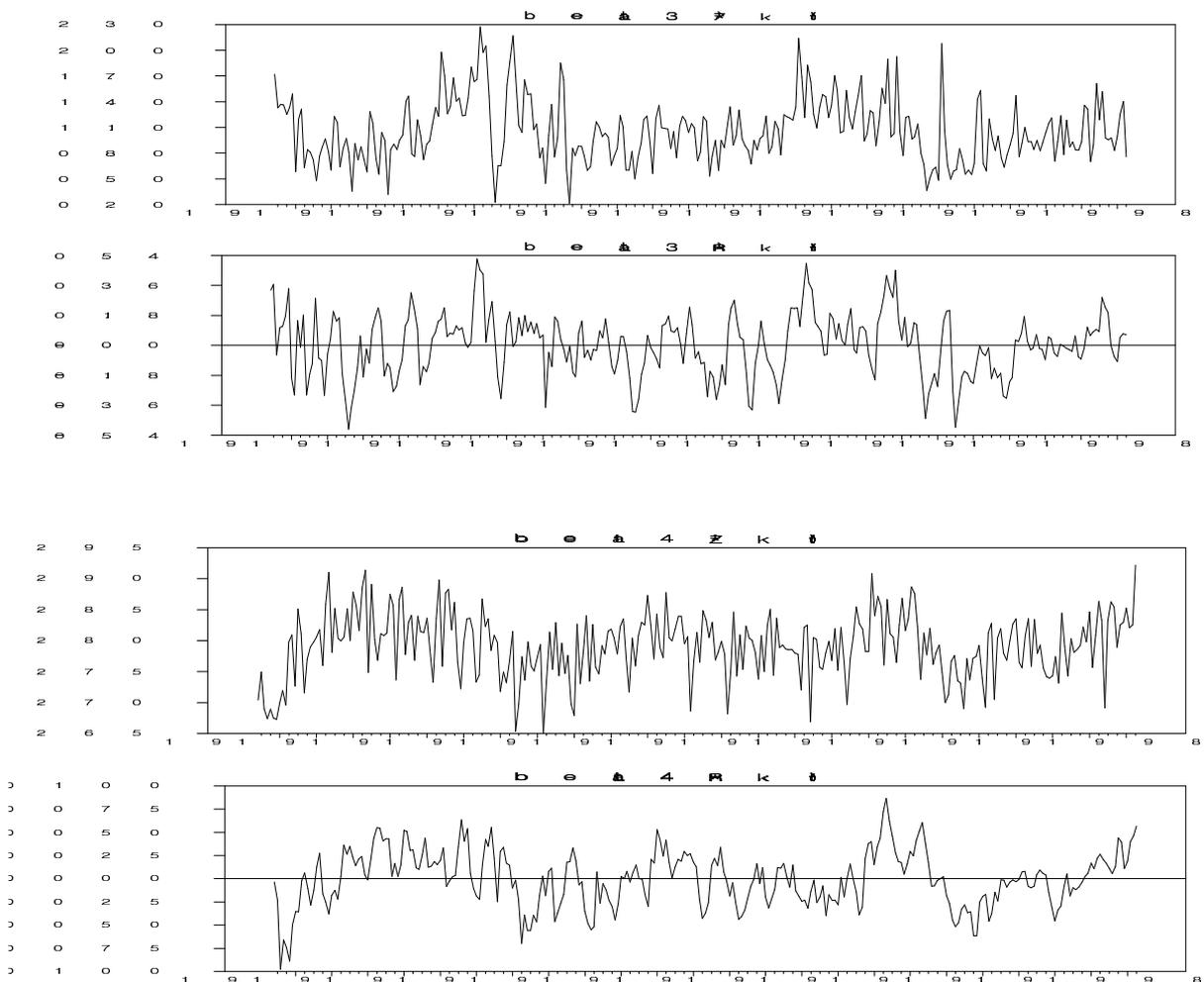
<sup>50</sup> When the number of cointegration relations in the ECM model was set above 4, there were roots  $>0.9$  in the companion matrix.

<sup>51</sup> Weak exogeneity, that is, the joint hypothesis  $H_0: \alpha_{ij} = 0, j = 1, \dots, r$ , was also tested. When  $r$  was set equal to 4, the federal funds' rate, the US money growth, the DEM/USD exchange rate, the US government bond rate and German production seemed to be weakly exogenous to the long-run adjustment relationships of the ECM model.

cointegration relationship was statistically significant explanatory variable for at least one of the equations in the ECM model. The cointegration relationships in the case of  $r=4$  are graphed below. The processes seem to be stationary, although some of the processes seem to be driven only by the cyclical variables of the countries.

**Figure II.3. Graphs of the cointegration relations between the variables**





The cointegration relations below are estimated setting the rank of the cointegration matrix in the estimated ECM-model equal to four. Every cointegration relation is presented using a pair of graphs. The upper one of the graphs denotes the cointegration relations  $\hat{\beta}'x_t$  themselves, while the lower one describes the relation  $\hat{\beta}'R_{kt}$ . These latter series are cointegration relationships “cleaned” of the short-run variation<sup>52</sup>. Particularly these lower graphs are of interest, since they represent the series which actually are tested for stationarity and which determine the rank of the error correction matrix in the Johansen maximum likelihood procedure.

<sup>52</sup> Hansen and Juselius (1995), p. 22 – 23.

### APPENDIX III Diagnostic tests of the VAR model

**Table III.1.** The residual diagnostics of the VAR equations.

Equation	LM(1)	Q(20)	ARCH(2)	SKEW	KURTOSIS	J-B
callm	3.55	44.34**	4.84**	-1.05	11.95	1027.15**
	0.06	0	0.01			0
fedfund	0.11	40.87**	7.1**	-1.47	19.69	3493.11**
	0.75	0	0			0
ginf	0.8	47.83**	0.22	0.83	6.12	152.19**
	0.37	0	0.8			0
gmgrowth	0.34	120.42**	5.53**	0.42	3.88	18
	0.56	0	0			
gprod	8.16**	25.84	6.02**	-0.82	7.66	295.28**
	0	0.17	0			0
longrate	1.56	32.31*	17.54**	-0.14	5.54	79.36**
	0.21	0.04	0			0
longrateg	0.25	21.18	0.51	-0.09	4.08	14.66**
	0.61	0.39	0.6			0
usinf	1.77	15.29	6.89**	-0.09	3.18	0.81
	0.18	0.76	0			0.67
usmgrow	0.78	37.91*	0.93	-0.09	2.6	2.3
	0.38	0.01	0.4			0.32
usprod	5.07*	19.19	2.04	0.27	3.86	12.49**
	0.03	0.51	0.13			0
xrate	0	17.98	0.87	0.16	3.43	3.5
	0.95	0.59	0.42			0.17

The LM(1) and Q(20) tests are used to detect autocorrelation, and the ARCH(1) test to measure the heteroscedasticity of the residual series. The skewness and kurtosis of the series are reported in their own columns and the J-B test statistic is a measure of the normality of the residuals. The figures below test statistics show the respective significance levels.

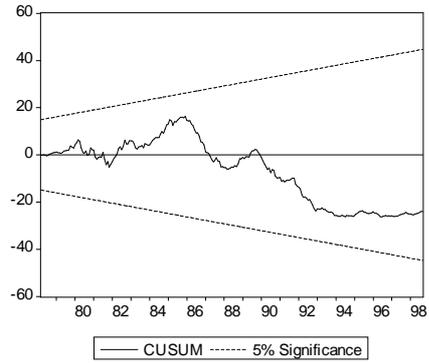
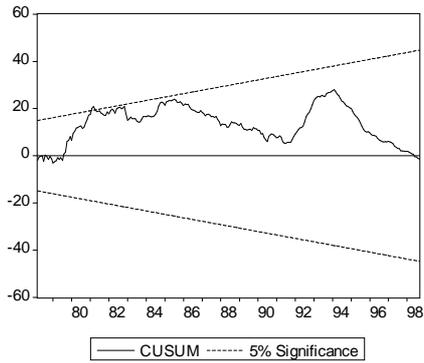
**Table III.2 The results of the RESET, Chow and Goldfeldt-Quandt tests**

Equation	Chow-test		RESET(3)		G-Q LR-test	
	F-stat.	Date	F-stat.	Chisq.	Date	
callm	0.57	1990:1	0.34	347.49**	1979:10	
	0.99		0.80	0.00		
fedfund	0.41	1990:1	2.50	386.15**	1987:11	
	0.99		0.06	0.00		
gmgrowth	2.96**	1990:1	1.52	225.01**	1992:9	
	0.00		0.21	0.00		
usmgrowth	1.35	1984:1	0.68	226.12**	1979:9	
	0.08		0.56	0.00		
xrate			1.42	188.74**	1979:9	
			0.24	0.00		
longrateg	0.92	1983:1	2.90*	152.15**	1987:5	
	0.67		0.04	0.00		
longrate	0.44	1989:1	2.49	244.69**	1979:9	
	0.99		0.06	0.00		
ginf	1.49**	1990:1	2.45	200.07**	1979:10	
	0.01		0.06	0.00		
usinf	0.74	1984:1	2.17	175.90**	1991:3	
	0.94		0.09	0.00		
gprod	0.75	1990:1		154.44**	1979:10	
	0.94			0.00		
usprod	0.48	1983:1	1.16	182.66**	1980:5	
	0.99		0.33	0.00		

The Chow forecast test is used to find possible structural breaks in the residual series, when the date for the break is supposed to be known. Here these dates are selected on the basis of CUSUM tests. RESET(3) test, in turn, reveals possible misspecifications, like nonlinearities and missing regressors.

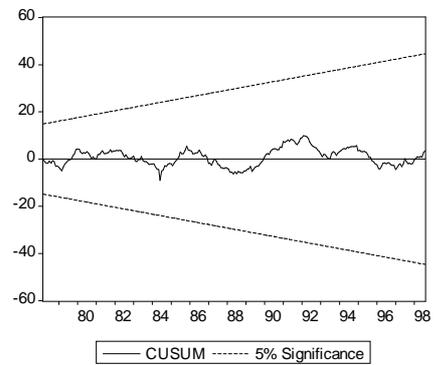
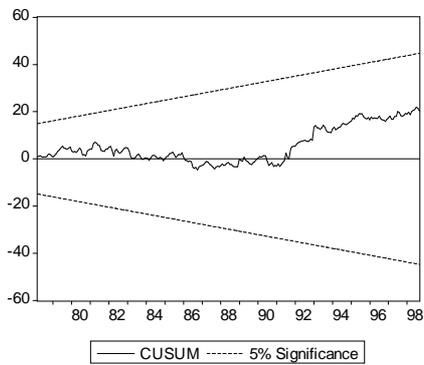
The G-Q test is used to find the most likely dates of regime switches for the residual series. The Chow test could not be performed for the DEM/USD exchange rate and the RESET(3) test for German production, because the computer program reported near singular matrix.

## Cusum tests for the VAR equations



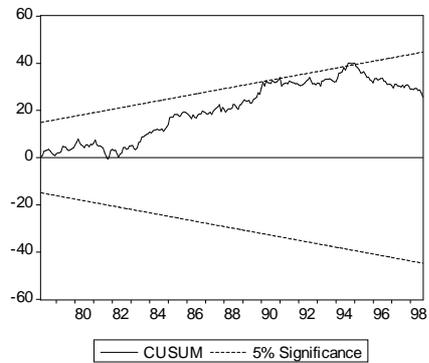
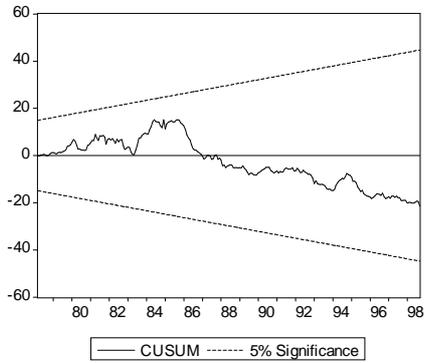
Callm

fedfund



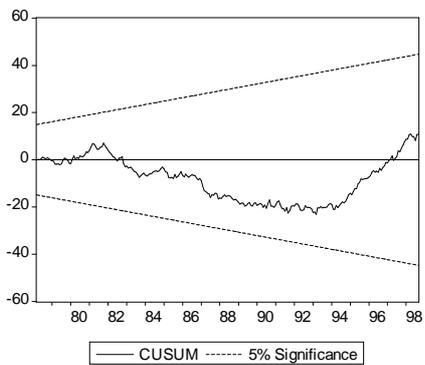
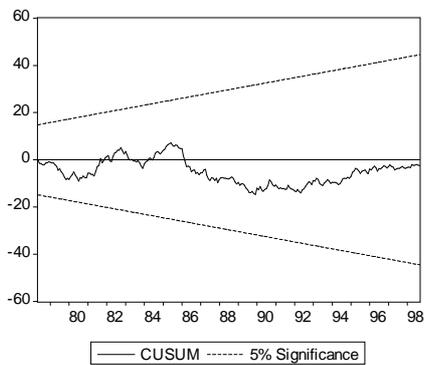
Ginf

Gprod



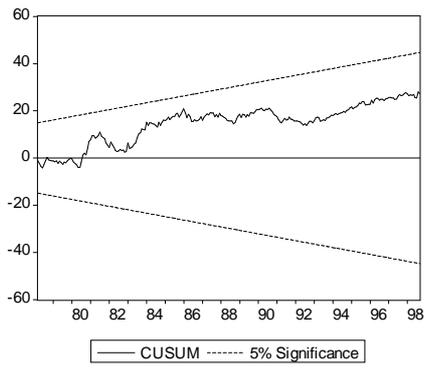
Longrate

Longrateg

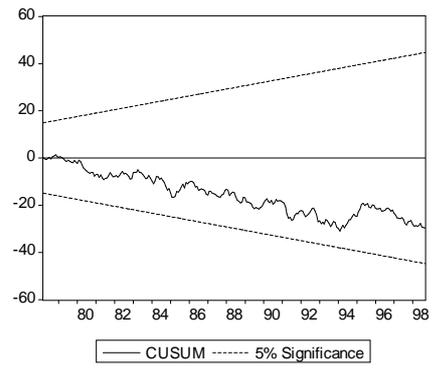


Usinf

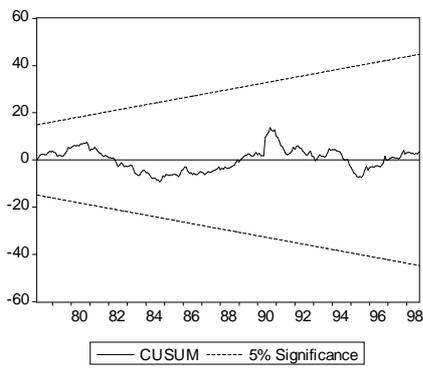
Usmgrow



Usprod



Xrate



Gmgrowth

## APPENDIX IV

### Numerical analysis of the identifiability of the SVAR model

The identifiability of our SVAR model is analyzed numerically, where we follow closely the analysis of Giannini (1992, p. 10 – 19.).

Assuming the invertibility of the matrix  $\mathbf{A}_0$ , the vector  $\text{vec}(\mathbf{A}_0)$  is locally identified if and only if the system

$$\mathbf{R}(\mathbf{A}' \otimes \mathbf{I}) \tilde{\mathbf{D}}_n \mathbf{x} = \mathbf{0} ,$$

has the unique admissible solution  $\mathbf{x} = \mathbf{0}$ , when the matrix  $\mathbf{R}(\mathbf{A}' \otimes \mathbf{I}) \tilde{\mathbf{D}}_n$  is evaluated at  $\mathbf{A}_0$ .

$\mathbf{R}$  is a  $(r \times n^2)$  matrix of full row rank, satisfying the condition  $\mathbf{R} \text{vec}(\mathbf{A}) = \mathbf{d}$ ,  $r$  is the total number of the restrictions imposed on the matrix  $\mathbf{A}_0$  and  $\tilde{\mathbf{D}}_n$  is a matrix defined in Magnus (1988, p. 94 – 95).

There is an equivalent way to express this condition, namely that the matrix

$\mathbf{R}(\mathbf{A}' \otimes \mathbf{I}) \tilde{\mathbf{D}}_n$  evaluated at  $\mathbf{A}_0$  has full column rank  $n(n-1)/2$ , where  $n$  is the number of variables in the model. This condition can be numerically checked by assigning numbers to the elements of the matrix  $\mathbf{A}_0$  by using the formula

$$\text{vec}(\mathbf{K}) = \mathbf{S}\boldsymbol{\gamma} + \mathbf{s}, \text{ where } \mathbf{S} \text{ is a } n^2 \times (n^2 - r) \text{ matrix with the property that } \mathbf{R}\mathbf{S} = \mathbf{0}$$

and assigning “random” numbers to the vector  $\boldsymbol{\gamma}$ . The column rank of the  $67 \times 55$  matrix  $\mathbf{R}(\mathbf{A}' \otimes \mathbf{I}) \tilde{\mathbf{D}}_n$  is equal to its non-zero singular values. These singular values, in turn, are obtained using the result

$$sv_i(\mathbf{X}) = \sqrt{ev_i(\mathbf{X}\mathbf{X}')}, \text{ where } sv_i \text{ denote to the singular values and } ev_i \text{ to the eigenvalues of a given matrix } \mathbf{X}.$$

The singular values for the case under study are reported in the table IV.1 below. The number of restrictions,  $r = 67$ , consists of 56 null restrictions and 11 restrictions, which set every diagonal element of the  $\mathbf{A}_0$  matrix equal to 1. Because the computer program (RATS) computes the singular values numerically, it reports figures differing negligible from zero even in the case when the singular values in fact are zero<sup>53</sup>.

It may be easily seen, however, that the values reported in the table suddenly drop from 0.0877 to 4.0118e-008 after the 55<sup>th</sup> singular value. Hence, we may conclude that the matrix under study has 55 singular values differing from zero and is therefore of full column rank. Thus, the model is exactly identified.

**Table IV.1. The singular values of the matrix  $\mathbf{R}(\mathbf{A}'\otimes\mathbf{I})\tilde{\mathbf{D}}_n$**

4.0819	2.6318	1.5810	0.3481
3.8212	2.5949	1.4672	0.2393
3.7697	2.5304	1.3766	0.1663
3.7187	2.4534	1.2860	0.0877
3.6889	2.3361	1.2004	4.0118e-008
3.6237	2.2994	1.1332	3.5354e-008
3.5604	2.2861	1.0838	NA
3.4996	2.2257	1.0108	NA
3.3854	2.1776	0.9642	NA
3.3570	2.0360	0.9389	2.5059e-008
3.3072	2.0269	0.9025	2.5059e-008
3.1895	1.9947	0.8018	2.4273e-008
3.0480	1.8881	0.6903	1.6727e-008
3.0242	1.8472	0.6464	1.6727e-008
2.9405	1.7707	0.6409	NA
2.8322	1.7699	0.5583	NA
2.7200	1.7474	0.4861	

---

<sup>53</sup> NA in the table denotes to cases, where RATS has approximated the eigenvalues  $ev_i(\mathbf{X}\mathbf{X}')$  to be slightly below zero. Now the singular values, which are square roots of these eigenvalues clearly do not exist.

## CHAPTER 3

# Regime Switches in the Reaction Functions of the Federal Reserve and the Bundesbank in the post Bretton Woods era

### Abstract

The purpose of this paper is to study whether there were sudden changes in the parameter values of the Taylor rule type reaction function of the Federal Reserve and Bundesbank during the period 1970 – 1998. The reaction functions are estimated as Markov switching models with state dependent coefficients. The robustness of the results on the exact specification of the policy rule and on the measure for inflation and the output gap used in the estimation are examined by considering several alternative data sets and model specifications in the estimations. According to the results it is possible to characterize the behaviour of the Fed as a switching between two regimes with different weights put on resisting inflation and stabilizing fluctuations in output. The regimes of the Bundesbank, in turn, were classified as a regime without any response to either inflation or output gap, and a regime when the Bundesbank responded to both of the gaps. On the other hand, the results supported some previous findings according to which Taylor-type policy rule estimations are sensitive to the specification of the rule and the choice of the data.

**KEY WORDS:** monetary policy rules, Markov-switching models, data uncertainty.

JEL Classification: C82, E42, E52, E58

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## 1. INTRODUCTION

Many macroeconomic studies involve modelling central bank behaviour in terms of a single, stable reaction function. For example, the literature on the effects of monetary policy shocks based on vector-autoregressive models is implicitly based on estimating such a rule. Macro models with rational expectations provide another example, because knowing the correct policy rule is an important element of estimating the entire model. Since the publication of the seminal paper by Taylor (1993), it has become a common practice to model central bank behaviour on a rule that relates short-term nominal interest rate to deviations of inflation and output from their desired values.

The interpretation of such a rule is straightforward: Because the monetary policy is transmitted to the economy through changes in the real interest rate, it is the real rate which is the ultimate target variable of the central bank. When output and inflation are at their desired levels, the central bank sets its policy rate equal to the sum of the equilibrium real interest rate and inflation target. When the inflation is above its target or output is above its potential, the real interest rate will be increased above its equilibrium level by the central bank to calm down the overheated economy. Similarly, in the case of deflation and high unemployment the real interest rate is decreased.

It is however not always wise to blindly assume the existence of a stable, linear decision rule for a central bank, since there might have happened regime changes during the sample period that have to be taken into account when estimating these policy rule (see e.g. Judd and Rudebusch 1998). Thus, the purpose of this study is to examine potential regime shifts in the monetary policy reaction functions of the Federal Reserve and the German Bundesbank during the post Bretton-Woods period of 1970 - 1998.

The motivation of the study is twofold. First, our approach differs from the previous literature on regime changes in central bank policy rules in that now the timing of the possible regime breaks is endogenised, whereas the previous studies have assumed that the dates of possible regime changes are known a priori. Thus, instead of dividing the sample period into sub-periods and estimating a different linear model for each period, I estimate Markov switching (MS) models, which allow for discrete regime shifts among a set of alternative parameter

values in the central bank reaction function at different points in time. Secondly, the study discusses the robustness of the estimation results on exact specification of the rule and the way the inflation and output gap are measured. Using linear models, the issue has previously been studied e.g. by Orphanides (1997) and Kozicki (1999) and Cerra et al. (2000). Perhaps the most well-known of these studies is Orphanides (1997) who found that the Taylor rule estimates are sensitive on whether the estimations are based on real-time data available to the policymaker at the moment the stance of monetary policy was set. Kozicki (1999) and Cerra et al. (2000) in turn studied the robustness of the Taylor rule estimates with respect to the way the output gap has been defined. Kozicki (1999) also examines the robustness issue with respect to a number of modifications of the rule, including the way the inflation is measured and whether the estimated rule includes an interest rate smoothing term or not.

Although the MS models are based on endogenising the timing of the regime shifts, some less formal prior knowledge about the possible regime changes is used for evaluating the plausibility of the results. The important institutional events that have occurred during the sample period include e.g. introducing the currency snake system in 1972, which was followed by the more rigid ERM system later in 1979. The reunification of Germany at the turn of 1990's also took place during the sample period. In the case of the US, the most important potential regime shifts include at least the changes in the operating procedures of the Federal Reserve during the years 1979-1982 and 1984.

It is important to note that the changes in parameter values of the policy rule do not necessarily directly link to concurrent changes in the underlying preference parameters describing the relative weights of inflation and output variability in the policymaker's welfare function. Instead, the regime changes may reflect changes in the transmission mechanism of the monetary policy, observed by the policymaker. If there is, for example, a regime switch in the channel through which the monetary policy affects the economy, a welfare maximizing policymaker might have to raise interest rates just in order to keep inflation variability at its previous level.

In the previous literature, Taylor (1998), Judd and Rudebusch (1998) and Clarida et al. (2000) are examples of previous attempts to detect regime changes in the US monetary policy in a Taylor rule framework. Taylor (1998) focuses on changes in the Fed's policy rule in a longer perspective examining several episodes with different monetary policy regimes. He concludes

that a simple interest rate rule, in which the interest rate responds to changes in inflation and output, is a useful framework for examining the U.S. monetary history, since the simple policy rule may be implied by many different monetary systems. It was found that the Fed's policy rule has changed dramatically from the early periods of gold standard to the fixed exchange rate regime in the Bretton-Woods era and the modern flexible exchange rate era. The conclusion is that a good policy rule is characterized as one in which the interest rate responds to deviations in inflation and output relatively aggressively, as during the 1980s and 1990s.

Judd and Rudebusch (1998)<sup>1</sup> in turn, try to find changes in the Fed's reaction function resulting from compositional changes in the Federal Open Market Committee. Judd and Rudebusch divide their sample period (1970:1 – 1997:4) into three sub-periods according to the respective chairmen of the Fed. Then, a Taylor-rule type reaction function is estimated for each of the sub-periods. According to the results, Greenspan's (1987:3 – 1997:4) period has been the one that could best be characterized by a Taylor rule type feedback rule. For Volcker's period (1979:3 – 1987:2) the estimates were less precise, but they suggested an implicit inflation target well below that inherited from the late 1970's. Finally, in the Burns period (1970:1 – 1978:2) the link between inflation and monetary policy seemed to respond more to the state of business cycle than to inflation. The authors conclude that a Taylor-rule framework is a useful tool for the description of the key elements of monetary policy.

Clarida et al. (2000) finally, detect differences in the Fed's policy regimes between the periods before and after Volcker's appointment as a chairman of the Fed. A forward-looking reaction function is estimated and the estimated parameter values are discussed in light of a small quantitative macromodel. Some sources of instability were found from the Fed's monetary policy during the pre-Volcker period, when monetary policy seemed to be accommodating increased inflation.

Ang and Bekaert (1998), Sill and Wrase (1999) and Linde (2000) provide examples of studies on regime changes in the monetary policy that are based on a different approach than the Taylor rule framework. Ang and Bekaert (1998) study the non-linearities in the behaviour of the short-term interest rates of the US, Germany and UK using a multivariate Markov-switching framework. Instead of estimating reaction functions for the central banks, the

authors use the term spread and international interest rates as well as the own history of the short rate as explanatory variables. It is concluded that the regime switching models outperform their linear counterparts when it comes to forecasting. On the other hand, due to small sample problems with the regime switching models, the moments implied by the linear models tend to fit the data better than those of regime switching models.

Sill and Wrase (1999) examine the regime changes in the joint money supply processes of the US and Canada by estimating a Markov-Switching VAR model. According to the results, there have been two regime changes during the sample period. In the middle of 1971, there seems to have been a switch from a high monetary growth regime to a low growth regime. In mid 1981, the policy returned to the high growth regime again. Linde (2000) in turn, examines the parameter changes of the Fed's reaction function during the periods of different chairmen. Linde uses the monetary base instead of the short-term interest rate as the dependent variable when he estimates his reaction functions for the periods of the different chairmen. The results corroborate the finding that the Fed has adjusted the monetary base most radically in response to inflation during Greenspan's period. During Burn's chairmanship the response was at its lowest.

The previous empirical studies on the monetary policy rules of Germany include e.g. Clarida and Gertler (1996), Clarida et al. (1998) and Peersman and Smets (1999). All the studies, however, estimate only a single linear rule, paying no attention to the possible regime breaks. The main findings of Clarida and Gertler are, firstly, that despite the publicly announced focus on monetary targeting, the German monetary policy also involved managing short-term interest rates, while the monetary targets provide only one of the reference points for the policy. Further, the authors suggest that while achieving and maintaining low inflation was the main concern for German monetary authorities, the Bundesbank at least implicitly has also pursued countercyclical monetary policy. That is, it has adopted more or less gradualist approach to disinflating, being ready to ease the monetary policy when the real economy has weakened.

Overall, Clarida and Gertler found that German monetary policy can be characterized by a modified forward looking Taylor type feedback rule. The estimated coefficients in the basic

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<sup>1</sup> The article can be downloaded from the web site of the Federal Reserve Bank of San Francisco:

specification for the response of the call money rate was 0.78 on changes in the inflation gap<sup>2</sup> and 0.64 on output gap, when the full sample period was considered. Clarida and Gertler, however, found evidence of asymmetry in the Bundesbank's reactions to inflation. When the inflation has levelled above its target value, the Bundesbank has reacted to inflation more aggressively than during the periods with negative inflation gap. Thus, the study by Clarida and Gertler can also be interpreted as providing evidence about the existence of two separate regimes in the Bundesbank's monetary policy.

Clarida et al. (1998), in turn, estimate reaction functions for all G3 countries after 1979. The authors find evidence of an implicit form of inflation targeting with interest rate smoothing and some allowance for output stabilization. Further, the results again suggest that the central banks respond anticipated rather than to lagged inflation. This hypothesis of the forward lookingness of the Bundesbank's monetary policy was, however, called into question by Peersman and Smets (1998). When they re-estimated the study by Clarida et al. (1998) they found that the coefficient of current inflation remained significant when added to the baseline specification. Instead, the two-year ahead annual inflation did not. This finding cast some doubt on the interpretation that the Bundesbank cares also about stabilizing output.

## **2. METHODOLOGY**

### **2.1 Markov switching models**

Markov switching models are based on the idea that the parameter values of the empirical model are driven by two or more unobservable states ( $s_t$ ) that follow first-order Markov process. In our set-up, specifically, each state ( $s_t$ ) corresponds to some specific set of parameters in the central bank reaction function under estimation. Intuitively, the states can now be interpreted as indicating stronger or weaker responses to changes in the inflation or

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<http://www.frbsf.org/econsrch/econrev/index.1998.html>

<sup>2</sup> These estimated low coefficients for the inflation gap may perhaps be interpreted as a sign of "non Wicksellian" monetary policy during the estimation period. The definition and the problems of the non-Wicksellian monetary policy will be addressed in more detail later when the estimation results are discussed.

output gap. More formally, the Markov switching models considered in this study take the form of (2.1) representing a single equation Markov switching model.

$$(2.1) y_t = a_{st} + \mathbf{b}'_{st} \mathbf{x}_{st} + \varepsilon_{st}, s = 1,2 \text{ and } t=1, \dots, T$$

where  $y_t$  is the dependent variable,  $a_{st}$  is the state-dependent constant term,  $\mathbf{x}_{st}$  is a vector of explanatory variables,  $\mathbf{b}_{st}$  is a vector of coefficients and  $\varepsilon_{st}$  is the state-dependent error term.

The economy is assumed to be in either of the two states, which change with the probabilities  $1 - p_{11}$  and  $1 - p_{22}$ , while  $p_{11}$  and  $p_{22}$  give the probability of staying at a given state  $s_t$  during period  $t+1$ , if it has been reached at period  $t$ . More compactly, the transition probabilities are summarized by Markov matrix

$$P = \begin{bmatrix} p_{11} & 1 - p_{22} \\ 1 - p_{11} & p_{22} \end{bmatrix}, \text{ where } p_{ij} = \Pr(s_{t+1} = j | s_t = i)$$

The estimation of the Markov switching methods is carried out by maximum likelihood method. Thus, the error terms of the model are assumed to be normally distributed.

The relation between the empirical model (2.1) and the Taylor rule becomes clear by writing our baseline specification for the rule as

$$(2.2) i_t = r^* + \pi^* + \alpha(\pi - \pi^*) + \beta(y - y^*),$$

where  $i_t$ =nominal interest rate,  $r^*$ =the real interest rate target of the central bank,  $\pi^*$ =inflation target of the central bank,  $y_t$ =real output,  $y_t^*$ =the natural level of output and  $\alpha$  and  $\beta$  are parameters. Thus, the vector of explanatory variables in the eq. (2.1) consists of inflation gap  $(\pi - \pi^*)$  and output gap  $(y - y^*)$ , while the constant term is made up of the sum of the real interest rate target and the inflation target  $(r^* + \pi^*)$ .

Before estimating a Taylor-type central bank reaction function, one has to take a stand on some problems related to the selection of the data. The problems include questions such as how to correctly measure the output and inflation gaps of the economy, or what information set was available to the policy maker at the time the policy decisions were made? Should one use lagged or current values of inflation and output gaps as explanatory variables? Because there are no definitive answers to most of these questions, and in order to examine the robustness of the results on the different solution to these problems, several alternative model specifications are estimated.

## **2.2 Measuring the output and inflation gaps**

The problems with measuring the natural level of output, even for a single point of time, are well known. These problems are further highlighted here, because the natural level of output has likely changed substantially during the relatively long sample period. A commonly applied practice to obtain a crude measure of the potential output is simply to apply time-series methods like fitting a linear or quadratic trend to the data or to use Hodrick-Prescott filtering. These procedures are implicitly based on the notion that the deviations of the output of its potential level are always transitory and average out in the long run. The unobserved-components methods, such as the univariate or multivariate Beveridge-Nelson decomposition are based on estimating unobserved variables, such as potential output or the NAIRU, using information from observed variables. The structural VAR method, in turn, identifies potential output with the aggregate supply capacity of the economy and cyclical fluctuations with changes in aggregate demand.

Central banks or organizations like IMF and OECD use more elaborate structural economic models. The production-function approach, for instance, is based on estimating the economy's aggregate production function e.g. in the Cobb-Douglas form. The sensitivity of the parameter values of the estimated Taylor's rule on different methods of measuring the potential output has been examined by Kozicki (1999). Cerra et al. (2000) in turn, compare the pros and cons of six differing methodologies to measure the potential output, with an application to Swedish data. Both studies suggest that the parameter estimates for the Taylor rule may be sensitive to the methodology that is used to estimate the output gap. None of the competing methods for measuring the output gap was considered superior to the others, however. In this study, two

alternative estimates of the potential output are used in the case of both countries. The first estimates are based on structural economic methods, while the alternative measure of the potential output is obtained by Hodrick-Prescott filtering the data. In the case of the U.S. economy the structural estimates of the output gap were published by the US Congressional Budget Office (CBO) and in the case of Germany the structural estimates are from the OECD Economic Outlook database.<sup>3</sup>

Kozicki (1999) discussed the correct choice between various measures of inflation when estimating the parameters of the policy rule of the Fed. He found that the estimates of the parameters of the Taylor's rule are also sensitive on the way the inflation is measured. When the Taylor's rule was estimated with the US data for a sample period of 1983 – 1997 with four different inflation measures (CPI, core CPI, GDP deflator, expected inflation) the best fit was obtained in a model with expected inflation. The finding suggests that central banks may be forward looking when setting the policy instrument. The results are also in line with the somewhat controversial results of Clarida et al. (1998) cited above, according to which at least the Bundesbank has been forward-looking when setting its monetary policy.

In this study, both backward-looking and forward-looking policy rules are estimated. In the forward looking models, the inflation expectations for the US are based on professional forecasters' forecasts of the U.S. GDP inflation, while for Germany the inflation expectations were CPI inflation forecasts published by the OECD. The backward looking data consist of the realized values of these same inflation measures.<sup>4</sup>

Neither the Fed nor the Bundesbank have had any publicly announced, explicit inflation target for the sample period. Thus, some implicit measures for the inflation targets have to be found. Clarida and Gertler (1996) calculated the inflation target by estimating a long run equilibrium level of the German inflation using a structural VAR model. Another possibility would be to simply calculate long run averages of the inflation series, as was done by Judd and Rudebusch (1998). In Clarida and Gertler (1996) the equilibrium inflation of the Bundesbank was

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<sup>3</sup> The main difference between the methods of measuring the potential output seems to be, according to the visual inspection that the output gap seems to fluctuate less during the sample period when the potential output is measured by H-P filtering.

<sup>4</sup> Obviously, the results for the Fed and the Bundesbank would have been more comparable if the inflation would have been defined and measured in the same way for both central banks. There were, however, problems in obtaining the series for the inflation expectations.

estimated to be 3.2 % while Judd and Rudebusch (1998) estimate that the Fed's inflation target has ranged between 3.03% and 6.47 % during the period 1970.Q1 – 1987.Q3, depending on who held the chairmanship of the bank<sup>5</sup>. Obviously, the estimates for the inflation target seem to be fairly high. A simple Barro-Gordon model, however, provides a plausible interpretation for the high estimates of the equilibrium inflation. According to the model, if the central bank has practised some leaning against cyclical variation in the real activity during the sample period and if the central bank's output target has been below the potential output, then the theory predicts that the actual inflation rate may include some premium over the target rate. Whether or not any such inflation bias is present, depends on the central bank's output target.<sup>6</sup>

Another problem with measuring target inflation using sample average or VAR is that these approaches implicitly are based on the assumption of a constant inflation target of a central bank for the whole estimation period. Moreover, even if the sample average were calculated separately for each sub-periods, there would still be the problem left that the inflation target probably changes gradually, rather than in rapid discrete shifts. In this study, the problems with calculating the inflation targets and the inflation gaps are handled by measuring the inflation gap for both the expected and realized inflation in two different ways. The first way is to calculate the inflation gap simply by the difference between the inflation rate (either the expected or the realized one) and the equilibrium inflation obtained by H-P filtering the data. The second way is to avoid the calculation of the equilibrium inflation and the inflation gap altogether. This is possible by substituting for the inflation gap on the right hand side of Equation (2.2.) with the inflation rate itself. This procedure is justified since Equation (2.2) can always be written as Equation (2.3) below. Now the equilibrium inflation only appears in the constant term ( $r^* + (1 - \alpha)\pi^*$ ) of that equation.

$$(2.3) \quad i_t = r^* + (1 - \alpha)\pi^* + \alpha\pi + \beta(y - y^*)$$

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<sup>5</sup> Judd and Rudebusch (1998) also considered an alternative measure for the inflation target, namely the end of period level of inflation for the terms of each three chairman of the Fed. These estimates took much more reasonable values, since the inflation target for Greenspan's era was now only 1.77 %.

<sup>6</sup> For an interesting criticism of the inflation bias argument of Barro and Gordon, see Blinder (1999, pp. 40 – 43.)

### 2.3 What is the information set that is available to the policymaker?

Economic data usually go through considerable revisions and corrections after it has been published for the first time. If the data available to the policymaker at the moment the policy decisions are made are not the same than that used for the ex-post estimation of the policy rule, severe biases in the estimates of parameters of the policy rule may follow.<sup>7</sup> In this study the problem is under control at least in the case of inflation, since in some of the models inflation was measured by the inflation forecasts that were available to the policymakers at the moment the policy decisions were made.

It is also possible to include the lagged policy instrument variable as an explanatory variable to the policy rule specification. Many alternative interpretations for the existence of the lagged interest rate in the monetary policy rule have been suggested. Usually the interest rate lag has been interpreted as reflecting smoothing behaviour on the part of the central bank<sup>8</sup> because of the central bank's concern about the stability of the financial markets (see Kozicki (1999, pp. 8.)). On the other hand, by avoiding too rapid actions in its monetary policy, the central banks can take into account the inherent uncertainties in its information set. In addition to the sort of uncertainty pointed out by Orphanides (1997), these uncertainties include the uncertainties related the structure of the "true model" of the economy and the correct parameter values of that model. As Blinder (1999) has argued, in the presence of parameter uncertainty the policymaker should be conservative in its actions. In the study at hand, some of the alternative policy rule specifications also contain the lagged interest rate term, which provides an additional dimension in which to discuss the robustness of the results. As it will turn out, the

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<sup>7</sup> The problem has been discussed e.g. by Runkle (1998), Evans (1998) and Orphanides (1997). Runkle (1998) demonstrated that the initial estimates of the output growth and inflation are not unbiased forecasts of the final estimates of these variables and that the bias may be substantial. In addition, a comparison of revision uncertainty and forecast uncertainty revealed that the former forms a significant fraction of the quite large uncertainty about forecasts of real activity and inflation. Evans (1998) tried to solve the problem by measuring inflation by the CPI instead of the GDP deflator and output by unemployment, because the information on these variables is more quickly available to the policymaker.

<sup>8</sup> Instead of being a sign of an explicit interest rate smoothing objective, including the lagged interest rate into the reaction function may reflect an attempt of a central bank to make effects of the monetary policy more permanent. If the market participants believe that the rises and declines in the policy rates are not only a transitory phenomenon, the monetary policy becomes more effective. A related interpretation is provided by Sack (1999) who provides evidence that the observed gradualist policy of the Fed may be motivated both by the dynamic structure of the economy and the uncertainty surrounding that structure.

results support Kozicki (1999), who also found evidence on the sensitivity of the Taylor rule estimates on whether the models include interest rate smoothing or not.

## 2.4 Data

I use quarterly data over the sample period of 1970:1 – 1998:1. As already mentioned, a variety of different model specifications was estimated for both the Federal Reserve and the German Bundesbank. Thus, aside from tracking the structural changes in the policy rules, the study pursues an additional goal by extending and contributing to the discussion by Kozicki (1999) and Cerra et al. (2000) cited above, on the robustness of the monetary policy rule estimates on the exact specification of the rule and the way the inflation and output gap are measured. Tables (2.1) and (2.2) on the next page summarize the features of all twelve specifications used for both the US and Germany. The specifications differ from each other regarding the definition of the inflation and output gaps, or with respect to whether they include the lagged dependent variable as one of the explanatory variables or not.

The data set for the estimation of the policy rule of the Fed consists, firstly, of the federal funds' rate that represents the Fed's policy instrument. The inflation gap variable is defined as the difference between the GDP inflation and the equilibrium inflation estimated by H-P filtering<sup>9</sup>. The inflation is defined either as the realized GDP inflation (backward looking specifications) or as the expected inflation (forward looking specifications). In addition to the explicitly calculated inflation gap series, the inflation variable itself is used as an explanatory variable in some of the specifications. When estimating the forward looking models, two different estimates of the output gap are used. The first measure is based on the potential output estimate provided by the Congressional Budget Office of the US (CBO), while the second one is based on the potential output gap calculated by H-P filtering. In all of the backward looking specifications the output gap is defined as the CBO estimates.

For Germany, I use call money rate as representing the Bundesbank's monetary policy instrument. Again, the policy rules are estimated both as backward and forward looking

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<sup>9</sup> The series for the inflation expectations are the Livingston survey data published by the Federal Reserve Bank of Philadelphia.

versions, and the inflation gap is measured either as an explicitly calculated inflation gap or as the inflation variable itself. In the backward-looking models, the inflation gap is calculated as the difference between the realized values of CPI inflation<sup>10</sup> and the equilibrium inflation, obtained by H-P filtering. In the forward looking models the expected inflation is measured by the inflation expectation published by the OECD. As an output gap measure for the German economy I have used either the OECD's output gap estimates (both the backward and forward looking models) or the difference between the actual output and the H-P-filtered potential output estimate (the forward looking models). The inflation expectation and the output gap series provided by the OECD were semi-annual data and the missing observations were obtained by interpolation.

**Table 2.1** The model specification for the U.S.

Model nr.	model type	inflgap	outpgap	lagged i
1	single eq.	exp. infl.	cbo	
2	"	exp. inflgap	"	
3	"	exp. infl	hp	
4	"	exp. inflgap	"	
5	"	exp. Infl.	cbo	x
6	"	exp. inflgap	"	x
7	"	exp. Infl.	hp	x
8	"	exp. inflgap	"	x
9	"	realized inf.	cbo	
10	"	realized inflgap	"	
11	"	realized inf.	"	x
12	"	realized inflgap	"	x

“exp” refers to the expected value of the variable, while “realized” refers to the realised values. Infl = inflation, inflgap = inflation gap, “cbo” denotes to the CBO estimates of the output gap and “hp” to the output gap estimate based on the potential output estimate based on HP-filtering.

<sup>10</sup> The series for GDP inflation for Germany were not available.

**Table 2.2** The model specifications for Germany.

Model nr.	model type	inflgap	outpgap	lagged i
1	single eq.	exp. infl.	oecd	
2	"	exp. infgap	oecd	
3	"	exp. Infl.	hp	
4	"	exp. infgap	hp	
5	"	realized inf	oecd	
6	"	realized infgap	oecd	
7	"	exp. Infl.	oecd	x
8	"	exp. Infgap	"	x
9	"	exp. Infl.	hp	x
10	"	exp. infgap	hp	x
11	"	realized inf	oecd	x
12	"	realized infgap	"	x

“exp” refers to the expected value of the variable, while “realized” refers to the realised values. Infl = inflation, infgap = inflation gap, “oecd” denotes to the OECD estimates of the output gap and “hp” to the output gap estimate based on the potential output estimate based on HP-filtering.

## 2.5 The time-series properties of the data

When time-series data is used, the danger of spurious regressions is always present if the series are unit root processes. With unit roots present, the estimations should be carried out using the differences rather than the levels of the variables. (The graphs of both US and German data are shown in the figure in APPENDIX I.) When it comes to the time series considered here, previous empirical research suggests that the short-term interest rates and the inflation may contain unit roots. There are not many, if any, empirical studies of the stationarity of the output and inflation gaps. According to economic theory, however, they should be stationary, since the deviations of inflation and output from their desired levels should always be transitory in nature. Formal unit root tests were carried out (the results not reported to save space), although they should not be relied too much because of the well known low power of the tests. The results of the tests were somewhat contradictory, although for every series except the German inflation gap the tests suggested that the series are stationary. Hence, bearing in mind the a priori information provided by economic theory, the analysis was based on assuming that the series are stationary.

### 3. RESULTS

#### 3.1 Estimation results

All models were estimated using maximum likelihood method ultimately based on Hamilton (1994). The estimations were carried out using MSVAR package for Ox, which applies the EM algorithm. If the economic relationships to be modelled could be adequately characterized by a linear model, there is no sense in estimating a non-linear model, like the Markov switching model. Thus, the estimations were started by comparing the adequacy of the linear model against the Markov switching model using both the conventional AIC and SBC information criteria as well as the LR tests. Using the LR tests is actually problematic, since the parameters  $p_{11}$  and  $p_{22}$  appear only in the MS model but not in the linear model. The information matrix of the model with two states would then be singular if the null hypothesis of only one state holds. Accordingly, the asymptotic distribution of the LR test is not known<sup>11</sup>. The problem was handled by using the conservative  $\chi^2(1)$  distribution. The LR tests still always suggested that the hypothesis of a linear model should be rejected at 99 % confidence level. The information criteria also suggested estimating a non-linear model.

The number of states in the Markov switching model was chosen to be two for the models for both the Fed and the Bundesbank. Actually, the information criteria suggested models with three states, but these models turned out to be too difficult to interpret, mainly because of the very ragged shapes of the line graphs of the smoothed probabilities of the regimes. The Markov switching modelling also allows for estimation of the error term variance separately for each of the states, which is clearly an advantage in our estimation. The assumption of a constant variance is not likely to hold for short-term interest rates as it is the case for also many other financial time series. The estimated parameter values for the policy rules of the Fed and the Bundesbank are presented in Tables 3.1 and 3.2 below. The timing of the regimes is represented by the time paths of the filtered, smoothed and predicted probabilities of the two regimes that are shown in Appendix II. The filtered probability is the optimal inference on the state variable at time  $t$  using only the information up to time  $t$ , i.e.  $\Pr(s_t = m|Y_t)$ . The smoothed probability refers to the optimal inference on the state variable at time  $t$  using the

information of the full sample,  $\Pr(s_t = m|Y_T)$ . The predicted probability in turn, stands for the optimal inference on the state variable at time t using only the information up to time t-1, that is,  $\Pr(s_t = m|Y_{t-1})$ .

**Table 3.1** Coefficient estimates for the policy rules of the Fed.

	Model 1		Model 2		Model 3		Model 4	
	State 1	State 2	State 1	State 2	State 1	State 2	State 1	State 2
Const.	1,99 (3,87)	0,77 (2,89)	6,16 (41,36)	10,55 (22,84)	1,94 (3,92)	0,89 (3,8)	5,98 (43,77)	10,79 (22,08)
Infgap	0,88 (9,39)	1,79 (31,82)	0,86 (5,88)	2,55 (7,06)	0,92 (9,29)	1,75 (36)	0,21 (1,66)	1,94 (4,88)
Ygap	0,61 (7,63)	0,15 (3,39)	0,98 (10,26)	0,37 (2,64)	0,82 (8,79)	0,25 (4,37)	1,22 (10,66)	0,67 (3,92)

	Model 5		Model 6		Model 7		Model 8	
	State 1	State 2						
Const.	1,29 (5,14)	0,04 (0,05)	1,61 (5,97)	2,73 (2,1)	0,97 (4,57)	1,75 (1,23)	1 (4,53)	3,13 (2,37)
Interest	0,75 (20,36)	0,73 (6,55)	0,77 (18,94)	0,76 (6,52)	0,72 (19,88)	0,6 (4,19)	0,84 (23,64)	0,7 (5,67)
Infgap	0,11 (3,37)	0,45 (2,07)	-0,08 (1,48)	0,65 (1,72)	0,17 (4,51)	0,42 (1,64)	-0,15 (2,42)	0,57 (1,72)
Ygap	0,34 (8,14)	0,13 (1,64)	0,35 (7,71)	0,22 (2,14)	0,42 (9,22)	0,31 (2,28)	0,35 (6,54)	0,36 (2,71)

	Model 9		Model 10		Model 11		Model 12	
	State 1	State 2						
Const.	4,05 (12,89)	4,52 (8,45)	6,18 (38,83)	9,85 (39,98)	0,98 (4,85)	0,48 (0,56)	1,22 (5,32)	0,68 (0,82)
Interest					0,82 (27,28)	0,94 (10,64)	0,83 (24,29)	0,95 (10,93)
Infgap	0,31 (4,69)	1,03 (10,82)	1,88 (8,91)	3,16 (14,97)	0,08 (2,93)	0,05 (0,37)	0,04 (0,55)	-0,01 (0,05)
Ygap	0,23 (2,76)	-0,21 (2,67)	0,9 (10,2)	-0,1 (1,27)	0,28 (7,85)	0,19 (2,1)	0,3 (7,4)	0,19 (2,16)

The different specifications are numbered according to Table 2.1. The figures in the parenthesis show the absolute values of the t-values of the coefficient estimates.

<sup>11</sup> See e.g. Kajanoja (2001), p. 117.

**Table 3.2** Coefficient estimates for the policy rules of the Bundesbank.

	Model 1		Model 2		Model 3		Model 4	
	State 1	State 2	State 1	State 2	State 1	State 2	State 1	State 2
Const.	3.35 (10.99)	6.71 (8.71)	5.11 (28.95)	9.19 (45.18)	4.04 (15.03)	7.43 (9.3)	5.21 (36.74)	8.85 (36.37)
infgap	0.23 (2.83)	0.43 (2.7)	0.88 (7.87)	0.64 (4.23)	0.16 (1.85)	0.28 (1.75)	0.73 (5.5)	0.24 (1.36)
ygap	-0.26 (3.49)	-0.16 (1.42)	-0.13 (1.78)	-0.49 (4.75)	0.11 (1.65)	0.1 (1.42)	0.14 (2.12)	0.15 (2.08)

	Model 5		Model 6		Model 7		Model 8	
	State 1	State 2						
Const.	0.59 (3.35)	0.92 (0.77)	0.28 (2.21)	0.96 (1.66)	-0.12 (1.06)	1.68 (1.92)	-0.09 (0.44)	1.37 (1.89)
infgap	-0.09 (1.33)	-0.07 (0.39)	-0.01 (0.15)	-0.01 (0.04)	-0.04 (0.92)	-0.09 (0.69)	0.02 (0.38)	0.06 (0.3)
ygap	0.13 (4.32)	0.35 (1.88)	-0.04 (1.1)	0.23 (3.14)	-0.09 (4.97)	0.05 (0.43)	-0.09 (4.92)	-0.01 (0.09)
interest	0.94 (34.14)	0.96 (8.1)	0.89 (38.85)	0.88 (3.14)	1.01 (36.01)	0.83 (8.84)	0.98 (27.08)	0.83 (8.48)

	Model 9		Model 10		Model 11		Model 12	
	State 1	State 2	State 1	State 2	State 1	State 2	State 1	State 2
Const.	3.6 (8.41)	4.17 (5.2)	4.73 (23.8)	8.54 (23.15)	0.48 (3.3)	-2 (1.3)	0.63 (3.53)	1.69 (2.11)
infgap	0.2 (1.84)	0.94 (5.45)	0.59 (2.98)	0.74 (2.59)	-0.02 (0.61)	0.57 (1.84)	0.09 (1.53)	1.49 (3.23)
ygap	0.05 (0.4)	0.26 (3.84)	0.03 (0.31)	-0.03 (0.24)	0.11 (4.6)	0.45 (2.7)	0.12 (4.79)	0.51 (3.61)
interest					0.93 (31.4)	0.88 (7.33)	0.89 (31.47)	0.71 (5.98)

The different specifications are numbered according to Table 2.2. The figures in the parenthesis show the absolute values of the t-values of the coefficient estimates.

It can be seen in Table 3.1 that for the Fed, the statistically significant coefficients during both regimes were of the “right” sign, that is, positive. It is more difficult to give the results for the Bundesbank a sensible interpretation, because the parameter estimates are insignificant in many of the models and sometimes they even have wrong (negative) signs. This is the case especially for the coefficient on the inflation gap in the models with the interest rate smoothing term. The transition probabilities between the two estimated regimes show that both the Fed’s and the Bundesbank’s regimes are fairly persistent. When the economy has reached either of the two states, the probability for staying at that state is more than 90 %.

Note that the estimated transition probabilities  $p_{11}$  and  $p_{22}$  for both the Fed and the Bundesbank, although high, still differ more than only negligibly from unity. Thus, neither of the two central banks seems to have been driven by a pure “inflation nutter ” regime during the sample period, since this kind of regime should be fully absorbing with the transition probabilities very close to unity. This follows from the obvious fact that once a central bank has committed to very strict policy against inflation, abandoning that regime would be very costly in terms of the lost credibility.

Considering then the robustness of the estimation results on our alternative sets of explanatory variables, both the timing and the parameter values of the Fed’s regimes seem to be somewhat sensitive on the exact specification of the model, particularly on whether the specification contains lagged interest rate term or not. The finding is in line Kozicki (1999) and Cerra et al. (2000) who found the estimation results to be remarkably sensitive on the way the inflation and output gaps are measured.

The estimation results for the Bundesbank seem to be even more sensitive on the specification. As in the case of the Fed, the parameter estimates are again particularly sensitive on the inclusion of the lagged interest rate term in the model. In the specifications with the interest rate smoothing term, the estimates of both the constant term and the inflation gap coefficient get significantly lower values than in the models without the interest rate smoothing. In addition, if the models are divided into models with and without the lagged interest rate term, the variation in the estimation results within the two sort of specifications is greater in the case of the Bundesbank than in the case of the Fed.

The coefficient estimates of the inflation and output gaps reveal that the monetary policy of the Fed clearly seems to have been switching between two regimes during our sample period. The first of the regimes is characterized by a stronger response to the inflation gap, while a stronger response to the output gap is associated with the second of the regimes. This finding also seems to be robust to the model specification, although the difference between the two regimes seems to be less clear in the specifications with the interest rate smoothing term. It is possible to also find some differences between the two regimes of the Bundesbank, although the differences between the regimes are not very clear. The coefficients for both the inflation

and output gap of the Bundesbank tend to either get higher values or enter as significant parameters to the model slightly more often during the regime two.

### 3.2 Model evaluation

There exists a set of misspecification tests available for the Markov switching models, including the tests for remaining autocorrelation or ARCH in the residuals, a test for misspecification of the Markovian dynamics and a test of omitted explanatory variables. Because of both some technical difficulties<sup>12</sup> and the poor small sample properties of the residual diagnostics, the model residuals were analysed less formally, by visual inspections of the correlograms, histograms, graphs and Q-Q plots, which are provided by the MSVAR procedure for Ox<sup>13</sup>. Overall, according to both the histograms and the Q-Q plots, the residuals of the models for both the Fed and the Bundesbank seemed to behave fairly well in terms of normality, particularly when the lagged interest rate was included in the model.

For the Fed, the histograms of the residuals from the models without the lagged interest rate term showed signs of kurtosis or skewness. The Q-Q plots also showed signs of skewness for one of the specifications (model 5). For the Bundesbank, the histograms showed some signs of non-normality for both the specifications with and without the lagged interest rate. The Q-Q plots did however suggest non-normality of the residuals of the Bundesbank models.

Signs of autocorrelation were found in some of the residual series of the specifications without the lagged interest rate term for the models of both the Fed and the Bundesbank. This finding has to be taken into account when looking at the t-values of the parameter estimates, since the residual autocorrelation makes the standard errors of the parameter estimates inaccurately estimated. No signs of heteroskedasticity were found in any of the models, at least according to the visual inspection, when the residuals were plotted against time. The problem of heteroskedasticity was at least partly avoided by estimating the error term variance as state-dependent. According to the estimation results, the error term variances did indeed differ

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<sup>12</sup> The computer program used for estimating the model did not allow for calculating the test statistics.

<sup>13</sup> For more discussion about calculating the test statistics for Markov switching models, see e.g. Sierimo (2002), p. 116.

considerably between the two regimes in the cases of both the Fed and the Bundesbank. In both cases it was the regime marked as regime two during which the variance was higher.

During the sample period, the reunification of Germany at the turn of 1980's and 1990's created a major break in the institutional environment, which may have contributed to our estimation results. The robustness of the estimation results to the sample period chosen was examined by re-estimating six of the models (models 3,4,5,6,9,10) for two sub-samples of 1970:1 – 1990:4 and 1991:1 – 1997:4. According to the results, up until the end of the 1980's, our previous conclusions about both the timing and the parameter values of the estimated regimes remains largely unchanged. Apparently due to the small number of observations, the estimation results for the latter sub-period were not plausible, however.

### **3.3 Regimes of the Fed**

The regime of the Fed with the higher value for the coefficient of the inflation gap is marked as regime two in Table 2.1. It can be seen that in the models without the interest rate smoothing term (models 1 – 4, 9 and 10) the inflation gap coefficient always exceeds unity in regime two but tends to remain below unity in regime one. Thus, according to the results for the specifications without the interest rate smoothing term, the Fed seems to have followed the so-called Taylor principle during regime two, according to which the central bank should react to the increased inflation by increasing also the real interest rate. The estimates for the output gap coefficients mostly get statistically significant values in both regimes, although regime one is characterized by higher coefficient values.

As already noted, including the lagged interest rate as an explanatory variable to the policy rule somewhat changes the estimation results<sup>14</sup>. The coefficient for the lagged interest rate itself takes fairly high and statistically significant values (in a range of 0.6 – 0.95) in both regimes so that the Fed seems to have had fairly strong motive to smoothe its policy actions. When the policy rule specifications with lagged interest rate are compared with the specifications without the lagged interest rate, it can be seen that including the lagged interest rate results in markedly lower coefficient estimates for both inflation and output gap. Regime

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<sup>14</sup> The result of the sensitivity of the estimation results to including the lagged interest term in the equation is broadly in line with Kozicki (1999).

two is still associated with higher values for inflation gap coefficient and regime one with higher output gap coefficient, but the result that the Fed followed the Taylor-principle during regime two no more holds.

As noted before, a statistically significant coefficient estimate for the output gap in a central bank's reaction function need not be a sign of the central bank's willingness to stabilize output. Instead, the central bank may be interpreting the widening output gap as an indicator of increased inflation pressure in the near future. If this really is the case here, our estimates for the output gap coefficient should get a higher values in the specifications with inflation measured as realised, rather than expected inflation. This is because the public's inflation expectations are likely to already contain the information on the future inflation, carried by the output gap. Comparing the specifications based on realised inflation (specifications 9 – 12) with those based on the expected inflation (specifications 1 – 8) reveals, in fact, that the output gap rather seems to get higher weight when inflation is measured as expected inflation. Thus, the estimated value for the coefficient of output gap really seems to reflect the Fed's attempts to stabilize output.

### **3.4 Regimes of the Bundesbank**

It is rather difficult to give the estimation results for the policy rule of the Bundesbank a sensible interpretation. In many of the specifications, the parameter estimates are no longer significant and in addition they sometimes have wrong (negative) signs. This is especially the case for the coefficient of the inflation gap in the specifications with the interest rate smoothing term. The sensitivity of the estimation results on the presence of the lagged interest rates is also seen in the constant term. In the models without the lagged interest rate, the constant term clearly take higher values in regime two. With the lagged interest rate present, the results become contradictory. A closer scrutiny of the estimated coefficient values makes it, however, possible to somehow divide the sample period into two regimes. During regime two the coefficients for both the inflation and output gap tend to either get higher values than during the regime one or at least they get statistically significant values slightly more often. Starting with regime two, although the coefficients of the inflation gap get considerably higher values than the coefficients of the output gap, even the inflation gap coefficients remain below unity in every specification, thus violating the Taylor principle.

In the models with the lagged interest rate term, the coefficients are not even statistically significant in most cases. Moreover, the coefficient on the output seems to get lower values when the inflation is measured as expected instead of the actual inflation<sup>15</sup>. Thus, our results support the view that by reacting to changes in output gap, the Bundesbank may only have attempted to react to the information about the future inflation contained in the output gap. The coefficient estimates for the lagged interest rate of the Bundesbank in turn get values above 0.8. All in all, it is possible to characterize the regime two as the regime during which the Bundesbank has operated more aggressively in resisting inflation. Whether the Bundesbank has also been more concerned about stabilizing output during that regime, remains an open question.

### **3.5 Timing of the regimes**

Figures A.1 to A.12 in Appendix IIB show the filtered, smoothed and predicted probabilities for the Fed, while Figures B.1 to B.12 in Appendix II B show them for the Bundesbank. The classification of the monetary policy into different regimes makes sense only if the estimated timing of the regime changes reported by the figures, is robust enough with respect to model specification. As the figures suggest, this seems to be the case more for the Bundesbank than for the Fed. Thus, one of the main findings of the study appears to be that when the estimation results for the Fed and the Bundesbank are compared, the regime switches of the German monetary policy seem to be easier to track, but more difficult to interpret.

Starting with Fed, as is seen in the figures, during the sample period 1970 – 1998, the US economy fluctuated between the two regimes with both regimes having been in force for roughly the same length of time. The timing of the results is most robust during both the years beginning at the turn of the eighties and at the turn of the nineties. The models with interest rate smoothing suggest that the sample period begins driven by regime one, the Fed being more concerned about stabilizing output than inflation. Starting around 1979, there seems to have been a switch to regime two, which has lasted until around the mid-eighties. Because it is regime two with the higher estimate for the coefficient of the inflation gap, this result does not

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<sup>15</sup> During regime two, in models with inflation measured as realized inflation, the coefficient of output gap took a statistically significant value in three cases out of four. In the eight models where inflation was measured as expected inflation, the output gap was a significant explanatory variable only twice.

sound surprising: At the turn of the 1970's and 1980's, the Fed changed its operating procedure, which resulted in a sharp tightening of the monetary policy. The rest of the sample period then, beginning in the latter half of the eighties and ending at the end of the nineties, seems to be characterized by regime one again.

When we look at the models estimated without the interest rate smoothing term, our view of the timing of the regimes changes somewhat. The sample period seems to begin as driven by the regime one again, but then the regime turns to regime two at the middle of the 70's. The figures suggest that regime two seems to have lasted about ten years, ending in the latter half of the eighties. The sample period ends dominated by regime one, as in the case of the models with the lagged interest rate term.

For the Bundesbank, most of the time paths of the smoothed probabilities take roughly similar shapes with three to four clearly observable peaks for both regimes. In addition, for all the models, the timing of the regimes seems to be much the same at least for the first twelve years. The first half of the 1970's is difficult to assign to either of the two regimes, since the Bundesbank seems to have been wavering between the two regimes without any clear tendency to stay at either of the states for a longer period. The figures suggest, however, that at least the years around the first oil price shock beginning in 1973 are dominated by regime two. The same seems to be true around the mid-eighties and at the turn of the eighties and nineties. The subperiods dominated by the regime one, in turn, take place just after the mid seventies, around the mid eighties and at the end of the nineties.

### **3.6 Economic interpretation of the regimes**

As previously noted, the changes in the estimated parameter values of the policy rules do not need to have anything to do with changes in the deep parameters of the social welfare function of the central banks. Four different sources of interpretation for our results will be discussed instead<sup>16</sup>.

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<sup>16</sup> There is an implicit assumption throughout the paper that the Bundesbank really did conduct autonomous monetary policy during the sample period although the DEM was adjustable with other European currencies for quite a long period. The autonomy follows from the well-known fact that the Bundesbank acted as a leader among the central banks in the EMS area.

1. The values of the output gaps may provide at least partial explanation for the regime switches. It is possible that during periods with positive output gaps a central bank may perceive the costs of highly anti-inflationary monetary policy to be lower than during periods with an already negative output gap and vice versa. Thus, for the Fed, the occurrence of the two regimes is compared to the concurrent values of the output gap. For the Bundesbank this kind of comparison was however not possible because of some technical difficulties.<sup>17</sup>
2. The low estimates for the inflation gap coefficient especially during the regime one in the case of the Fed and during both regimes in the case of the Bundesbank may partly be due to the low variation in inflation during those periods. It is possible that the two central banks reacted only to relatively large changes in the rate of inflation during the sample period, but ignored small changes. If this really was the case, then the coefficient of the inflation gap gets a low estimate during the periods when the variation in inflation has been low.
3. The low value for the inflation gap coefficient may be a sign of a period of non-Wicksellian monetary policy. This explanation is closely related to the Taylor principle mentioned before.
4. The estimation results will also be discussed in light of the previous literature. Goodfriend (1995) and Judd and Rudebusch (1998) provide an interesting interpretation for the Fed's monetary policy since the late 1970's. Von Hagen (1995) and Clarida et al. (1998) in turn, discuss the monetary policy of the Bundesbank.

### *3.6.1. Does the state of the business cycle matter?*

Beginning with the first of the possible explanations, when the output is below its potential level, there is more room for a central bank to ease monetary policy when facing a widening output gap, because the easing is less likely to increase inflation. By contrast, if the output is

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<sup>17</sup> This argument is analogous to discussion by Fitoussi and Creel (2002, pp. 30-31), who consider the possibility that the prevailing low level of inflation and high level of unemployment may have resulted in inertia in the monetary policy of the ECB at the time it was set up.

above its potential, it is more difficult for the central bank to ease the monetary policy without a fear of increasing inflation even if it is facing a sharp temporary decline in output growth<sup>18</sup>.

Thus, it should be expected that in the case of the Fed, the output was below its potential level during regime one while regime two should be associated with the output above its natural level. The hypothesis is discussed using Figure III.1 in the Appendix III, which plots the series of our two estimates for the output gap of the US. As is seen, the US output seems to exceed its potential level during the years 1972-74, 1978-81, 1986-91, and 1996-, while during the rest of the time the output gap seems to get negative values. Thus, regime one (two) fairly well seems to be associated with periods with a negative (positive) output gap. The first half of the 1970's forms an exception, since for that period it is difficult to say anything about the link between the output gap and the regime switches. The identification of the policy regime during that time was rather sensitive on the model specification. During the latter half of the 1970's, however, the behaviour of the Fed was quite well in accordance with the explanation above. According to almost every graph, the Fed's policy seems to have been driven by regime one during that time, and the years 1974 – 1978 also seem to have been characterized by output above its potential level.

The anti-inflationary monetary policy at the turn of the 1970's and 1980's could also be understood in terms of the concurrent value of the output gap. At the end of the 1970's, output seems to have been above its potential and that period also corresponds to regime two. It has to be noted, however, that the output gap already turned negative at the beginning of the 1980's, probably just as a result of the sharp tightening of the monetary policy. Finally, even the dominance of regime one during the most of the 1990's fits in the above framework. Although real growth during the period was high, output remained below its potential level until 1996, which left room for relatively easy monetary policy without any need to worry about inflation.

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<sup>18</sup> Clarida and Gertler (1996) made a very similar exercise when they searched for an explanation for their low estimate of the Bundesbank's inflation gap coefficient. Instead of output gap, they examined the possible asymmetry of the monetary policy response to the value of the inflation gap. Clarida and Gertler indeed found that the Bundesbank's policy reacted more strongly to inflation when the inflation gap was positive. Our decision to examine the output gap rather than inflation gap is based on the fact that the difficulties to estimating the inflation gap appears even more problematic than estimating the output gap.

Unfortunately, in the case of the Bundesbank, comparing the timing of the regimes with the concurrent output gap provides a less fruitful means to interpret the results than with the US case. The differences between the Bundesbank's two regimes were small and neither of the two regimes could easily be classified as a strict "inflation nutter" regime. Moreover, as seen in Figure III.2 in Appendix III, the two measures of the output gap deviate from each other during the sample period. The OECD estimate of the output gap seems to "lead" the output gap measure based on the potential output estimate obtained by H-P filtering 1-2 years through the whole period. Of course, the possible inaccuracies in the output gap estimates limit also the reliability of the conclusions we made in the case of the Fed.

### *3.6.2 Do the central banks react only to large swings of inflation?*

The coefficient of the inflation gap got remarkably low estimates during regime one in the case of the Fed and during both of the regimes in the case of the Bundesbank<sup>19</sup>. Whether this finding could be explained by the low variation in inflation during those periods, was examined next. For both central banks, the sample period was divided into sub-periods that roughly correspond to the timing of the policy regimes. Next, the standard deviations of inflation in the US and in Germany were calculated separately for each subperiod. For the US, the periods are 1970:1 – 1979:4, 1980:1 – 1986:4 and 1987:1 – 1997:4 and they roughly correspond to the timing of our two estimated regimes.

The standard deviations were calculated for all four measures of inflation or inflation gap. It appeared that the volatility of inflation was at its lowest (at the level of 0.31 – 0.78) during the third of the periods, regardless of the way the inflation or inflation gap is measured. This period actually corresponds to regime one with the lower coefficients for the inflation gap. Moreover, with two measures for the inflation, volatility was at its lowest during the second of the periods that in turn corresponds to regime two with its higher coefficients for the inflation gap. On the other hand, with two out of four different measures of inflation, volatility was highest during the first of the periods, which also corresponds to regime one. Hence, the evidence is rather mixed for drawing clear conclusions about the role of the low variability of inflation (gap) in explaining the estimated low coefficient values for the regime one.

During the Bundesbank's both regimes, the coefficient estimates for both the inflation and the output gap get rather low values. Thus, for Germany, the volatilities were computed for both inflation and output (gaps) to ascertain, whether the low variability of the explanatory variables is the reason for the low coefficient estimates<sup>20</sup>. Standard deviations of the series were calculated for the whole estimation period and for five subperiods of 1970:1 – 1974:4, 1975:1, 1979:4, 1980:1 – 1983:4, 1984:1 – 1990:4, 1991:1 – 1997:4, roughly corresponding to the timing of the regimes. For the whole period, the standard deviations range from 0.9 to 1.9 for inflation and from 2.0 to 2.5 for the output gap. The two periods with more volatile inflation were those of 1975:1 – 1979:4 and 1991:1 – 1997:4. The volatilities of inflation and output seem not to have been lower in Germany than in the US during the sample period. Thus, the low volatility of the explanatory variables does not seem to provide a likely explanation for the low estimated values for the coefficient of the reaction function.

### *3.6.3 Monetary policy of the Fed and the Bundesbank in the Wicksellian framework*

The Wicksellian framework rests on the concept of a “natural rate of interest”<sup>21</sup>. The natural rate of interest is determined by the supply side factors of the economy, being independent of monetary policy. It can be defined as an equilibrium rate at which the total demand equals the natural rate of output. A deviation from the natural level of interest rate is then the ultimate cause for the increasing inflation and the deviations from the natural level of output. The Wicksellian analysis results in the conclusion that the monetary policy should be conducted according to the so-called Taylor principle, that is, the nominal interest rate should be adapted enough to also change the real rate of interest.

Woodford (2000) examines the stabilizing properties of several variants of the simple Taylor rule in the Wicksellian framework. He uses a simple macro model to derive the necessary and sufficient conditions for the price determinacy. Woodford found that in order to achieve price determinacy, the policy rule should respond to both deviations of output and inflation and to the variation of natural rate of interest. Basically, these conditions rely on the Taylor principle: At least in the long run, the central bank should react to inflation by increasing the nominal

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<sup>19</sup> Also in two specifications for the Fed with the lagged interest rate in the rule (specifications 11 and 12) the inflation gap got remarkably low values in both regimes.

<sup>20</sup> The low variability of the explanatory variables is the explanation for the low coefficient values if the central bank has been interested to stabilize only large deviations of inflation and output from their equilibrium values.

<sup>21</sup> See also Blinder (1999, Ch. 2.), who uses the closely related term “neutral” monetary policy.

interest rate by more than the increase in the inflation rate. A sufficient condition for the Taylor principle to hold is that the coefficient of the inflation gap exceeds unity. Woodford relaxes this assumption a little and suggests a set of necessary conditions for the price determinacy that also include the coefficient for the output gap and the deviations from the equilibrium real rate of interest.

Taylor (1998) and Clarida et al. (1999) provide discussion about the stabilizing properties of the Fed's monetary policy actions in context of the Taylor principle and the Wicksellian framework. Taylor found that the interest rate increases of the Fed in the face of increasing inflation during the 1960s and the 1970s were not aggressive enough to increase the real interest rate. Too easy a monetary policy then contributed to the high inflation of the 1960s and 1970s but beginning at the 1980s the Fed's policy against inflation turned more aggressive. Clarida et al. (1999) found support for Taylor's findings, when they discussed the values of the parameters of the monetary policy rule of the Fed in the Wicksellian framework. For the coefficient of expected inflation Clarida et al. yielded estimates significantly below one that the period preceding Volcker's appointment as the Fed chairman. Accordingly, the authors concluded that the high and volatile inflation from the late 1960's to the early 1980's may have been a result of monetary policy that did not follow the Taylor principle.

The estimation results of Clarida and Gertler (1996) and Clarida et al. (1998) cited previously, can also be discussed within the Wicksellian framework. According to the first of the studies, during the sample period 1974 :8 – 1993:09 the Bundesbank reacted to the widening inflation gap by also raising the real rate of interest, thus fulfilling the Taylor principle. The latter of the studies in turn suggests that the year 1979 divides the monetary policy of all three large central banks, the Fed, the Bundesbank and the bank of Japan, into two sub-periods so that only during the latter was their monetary policy in accordance with the Taylor principle.

In our study the Wicksellian framework was taken into account by examining whether the parameter values of the estimated policy rules fulfil Woodford's conditions for price determinacy. In the case of the Fed, the results were somewhat contradictory, since signs of Wicksellian policy were found only in the model specifications without the interest rate smoothing term. In some cases the confidence bands for the estimated parameter values also tended to imply borderline cases between Wicksellian and non-Wicksellian policy.

In the case of the Bundesbank, by contrast, the parameter values of all twelve models strongly and consistently suggest that the Bundesbank has followed non-Wicksellian monetary policy during both its regimes. Thus, our estimation results are in accordance with the conclusions of Clarida et al. (1998) when it comes to the period prior 1979. The results, however, contradict the results of Clarida et al. (1996).

#### *3.6.4 Results in light of previous studies*

It is possible also to try to interpret the estimation results by discussing them in light of some previous studies. Goodfriend (1995) explains the Fed's policy actions by "inflation scares". Inflation scares are defined as significant long-term interest rate rises without the preceding sharp tightening of monetary policy on the part of the Fed. When facing an inflation scare, the Fed is, however, obliged to act by raising its policy rate, regardless of the negative effects to the real activity, since the inflation scares tend to be self-fulfilling through the workers' and firms' wage and price decisions. Hence, Goodfriend's interpretation of the Fed's policy supports the view that the US monetary policy has been markedly forward-looking. Thus, when interpreting the estimation results of this study, we should at least put more emphasis on the estimation results obtained with the specifications based on expected rather than on realized inflation.

Judd and Rudebusch (1998) tried to find out whether the Fed's monetary policy changed when the Fed's chairman changed. In our study, particularly the policy rule specifications with the interest rate smoothing term seem to imply regime switches that are somewhat in line with changes in the Fed's chairman. Beginning with the chairmanships of Burns (1970:1 – 1978:2) and Greenspan (1987:3 – 1997:4), the estimation results suggest that the periods are driven by regime one with a weaker response from the Fed to the inflation gap. Similarly, according to Judd and Rudebusch' study, the coefficient for the inflation gap did not get a significant value during the Burns' chairmanship. Moreover, both in this study and in that by Judd and Rudebusch, the estimates for the coefficient of the output gap suggest that the Fed was concerned with stabilizing output during Burns' period. Further, our estimation results suggest that Volcker's period (1979:3 – 1987:2) is driven by regime two. Likewise, according to Judd and Rudebusch's characterization the Fed did not respond to the level of output gap during that time, although it seemed to have reacted to *changes* in it. On the other hand, the estimates

of the coefficients of the inflation gap are larger in our study compared with the estimate of about 0.5 by Judd and Rudebusch.

Von Hagen (1995) in turn, attempts to explain the Bundesbank's actions during the Bretton-Woods era. He suggests that the Bundesbank's goal was the targeting of inflation and monetary growth at the same time. According to von Hagen, the Bundesbank's primary goal has been to stabilize long-term inflation. Long-term inflation is measured as the trend-rate of change of the equilibrium price level, not the observed actual inflation or sudden discrete shifts in the price level. The equilibrium price level in turn is defined as the price level that clears the money market. Von Hagen highlights the importance of reputation building for the Bundesbank throughout the whole sample period. Because of this reputation-building motive, the Bundesbank has occasionally even targeted price level instead of inflation. According to von Hagen, the Bundesbank has adopted the price level target whenever the German economy has faced a rapid temporary shift in price level. The motivation for this was the fear that private agents would have difficulties in separating a temporary shift in the price level from increased inflation. This kind of misinterpretation would then have led to increased inflation expectations and hence to cost-push inflation. Thus, von Hagen's conclusions partly account for the relatively low explanatory power of the inflation gap in our estimations, if the Bundesbank really was targeting rather the equilibrium price level instead of actual inflation that we have focused.

Our estimated timing of regime switches also seems to be in line with the interpretations of von Hagen. According to him it is possible to identify three periods during the post Bretton Woods era with an initial upward jump in the equilibrium price level. The jumps were followed by the marked decline in prices that comes with a severe recession. The timing of these jumps and declines coincides quite accurately with the periods of regime two, when the Bundesbank seemed to be at least somewhat more concerned of stabilizing both inflation and output. The first jump took place after the first oil-price shock in 1974-5, the second after the second oil-price shock and the appreciation of the US dollar in 1980-2 and the last one after German reunification. On the other hand, our estimates of the transition probabilities between the regimes contradict von Hagen's interpretations. If the Bundesbank really had pursued a price level target, it would have been expected to almost certainly stay at that regime once it has been reached. My estimates for the probabilities of the shifts between the regimes, however, were considerably above zero.

#### 4. CONCLUSIONS

In this paper the monetary policy rules of the Federal Reserve and the Bundesbank were studied using Markov Regime switching models. Because of the well-known problems with the correct way to measure inflation and output gaps, several alternative data sets and specifications were used in the estimations. It was concluded, firstly, that during the post Bretton-Woods era, there seems to have been several sudden regime switches in the parameters of the reaction functions of both the Federal Reserve and the German Bundesbank. Secondly, the estimation results of the coefficients of the policy rule and the timing of the regimes turned out to be somewhat sensitive on the exact model specification concerning the way inflation and the output gap are measured and particularly on whether the specification contains an interest rate smoothing term or not. It was found that the regime switches of the German monetary policy are easier to track, but more difficult to interpret than the US regimes.

The sensitivity of the coefficient estimates to the model specification is broadly in line with some previous studies by e.g. Orphanides (1997), Kozicki (1999) and Cerra et al. (2000) who, using linear models, concluded that the Taylor rule estimates may be sensitive to the exact specification of the rule or on the way the inflation and output gaps are defined. As Kozicki (1999) points out, however, although the sensitivity of the Taylor rules on minor variations made to their assumptions limits their role as a tool for real-time monetary policy decisions, the rules can still be of valuable use. For instance, the Taylor-type rules can still serve as valuable components in forecasting models, since many of the real-world problems related to the rules disappear in the modelling frameworks, which already are extensively simplified.

Nevertheless, since the Markov switching models seem to fit the data relatively well, irrespective of the exact specification, the stability of the feedback rules of both Fed and Bundesbank during the sample period may well be called into question. The two regimes of the Federal Reserve were identified as a regime with the stronger response to the inflation and a regime in which the Fed was more interested in stabilizing output. The economic interpretation for the regimes was detected by comparing, for instance, the timing of the regimes with the concurrent value of the output gap during the sample period and by trying to find evidence about possible price indeterminacy in the parameter values of the policy rules. It was found that the Fed reacted to inflationary pressures more strongly during periods with

output above its potential. Some evidence was also found that our estimated regime changes to some extent go hand in hand with the changes in the holder of the Fed's chairmanship. The possible existence of price indeterminacy in turn remains an open question since the estimation results did not permit firm conclusions to be drawn about this question.

In the case of the German Bundesbank, it was not possible to make a clear distinction between the regimes to a regime with more emphasis put on resisting inflation and a regime with more emphasis put on stabilizing output. Instead, during the first of the regimes, the coefficient values for neither inflation nor output gap turned out to be statistically significant. The other regime in turn was characterized by statistically significant, but still rather low coefficient values for both the inflation and the output gap, at least in some model specifications. Because the output gap seemed to lose its explanatory power when inflation was measured by expected inflation, the higher estimate for the output gap coefficient may, however, only reflect the Bundesbank's reaction to the information content of the future inflation of the output gap, rather than real concern of stabilizing output. Hence, one of the two regimes may be considered a regime when the Bundesbank was more active in resisting inflation. The values for the inflation gap, however, remained low enough during both regimes to suggest price indeterminacy for the whole sample period, if the Wicksellian framework is valid.

Our results turned out to be at least partly in line with von Hagen's (1995) interpretation of the Bundesbank's monetary policy. That is, although the Bundesbank has mainly targeted long-run inflation instead of monetary aggregates, it has occasionally adopted temporary price level targeting when facing sudden discrete shifts in the actual price level. The estimated timing of regime two coincides fairly well with the periods of price level targeting proposed by von Hagen. Some further understanding of the empirical findings was also found by comparing the timing of the regimes with the institutional changes during the sample period.

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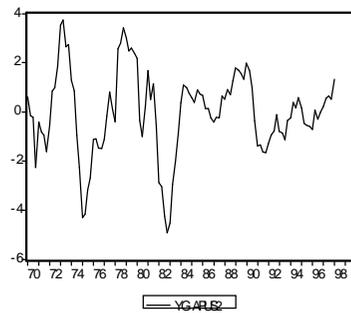
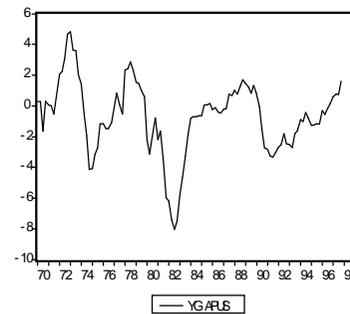
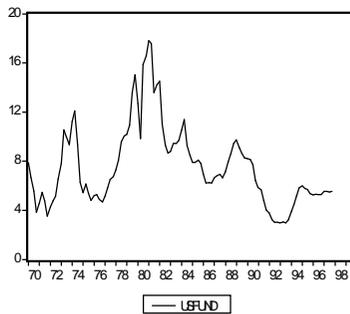
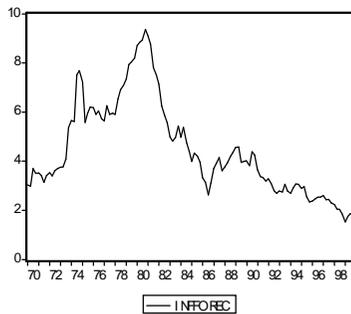
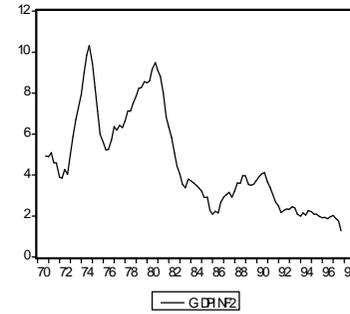
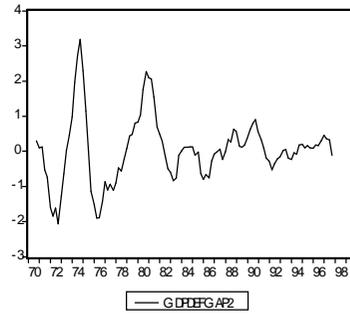
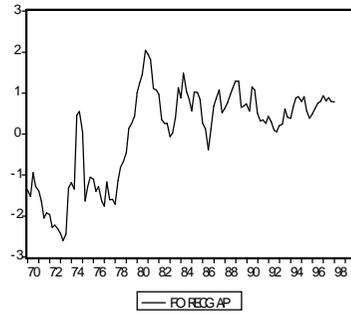
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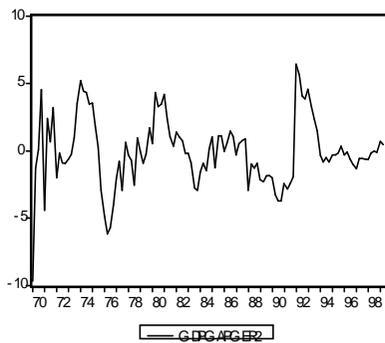
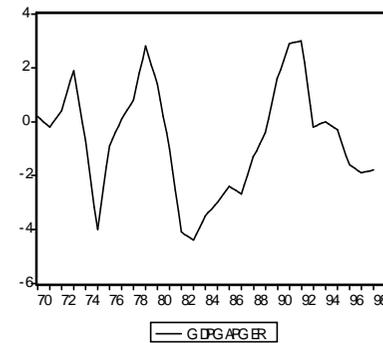
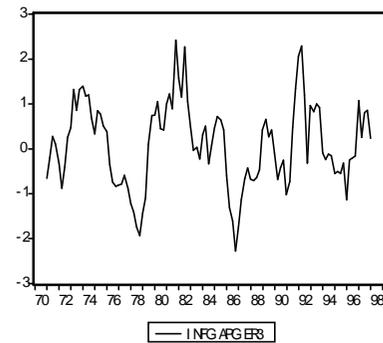
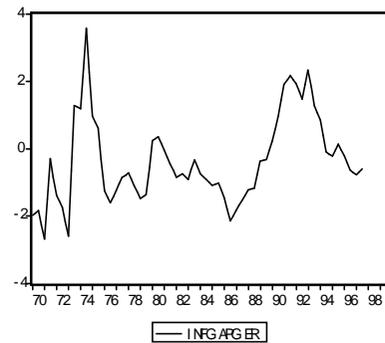
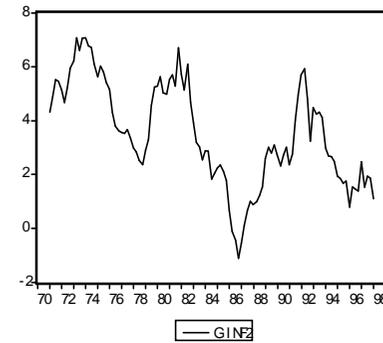
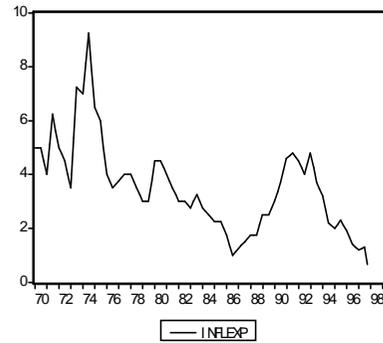
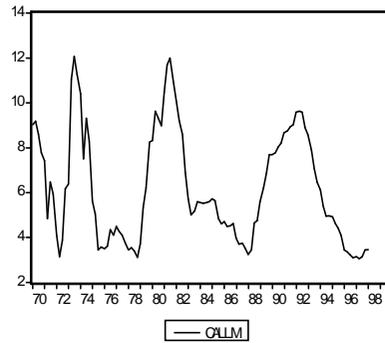
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## APPENDIX IA: Line graphs of the US data



The series are: usfund = federal funds' rate, inforec = inflation forecast, foregap = inflation gap calculated from the forecast, gdpinf2 = realized inflation, gdpdefgap2 = inflation gap calculated from the realized inflation, ygapus = output gap estimate of OECD, ygapus2 = output gap calculated using potential output estimate based on HP-filtering.

## APPENDIX IB: Line graphs of the German data



Callm = call money, inflexp = expected inflation, infgapper = inflation gap calculated from the expected inflation, ginf2 = realized inflation, infgapper3 = inflation gap calculated from realized inflation, gdpgapper = output gap estimate of the OECD, gdpgapper2 = output gap calculated from the potential output estimate based on HP-filtering.

## APPENDIX II A – The filtered, smoothed and predicted probabilities for the regimes for the Federal Reserve

Figure A.1.

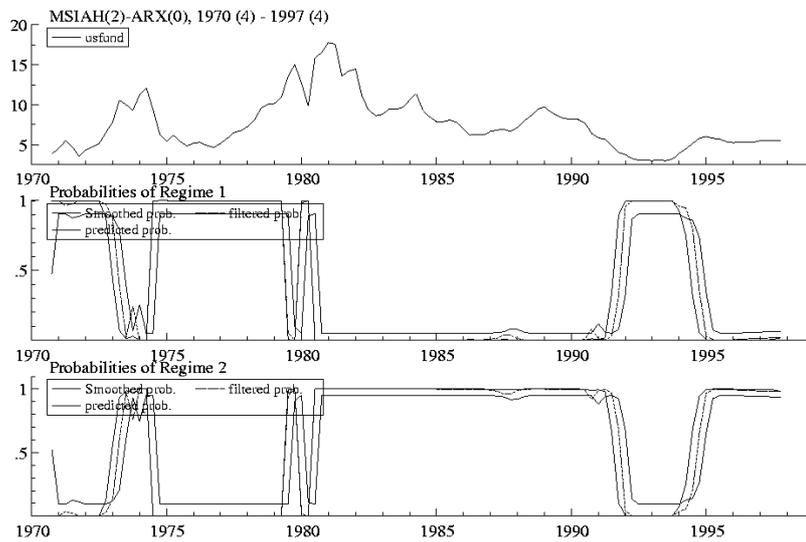


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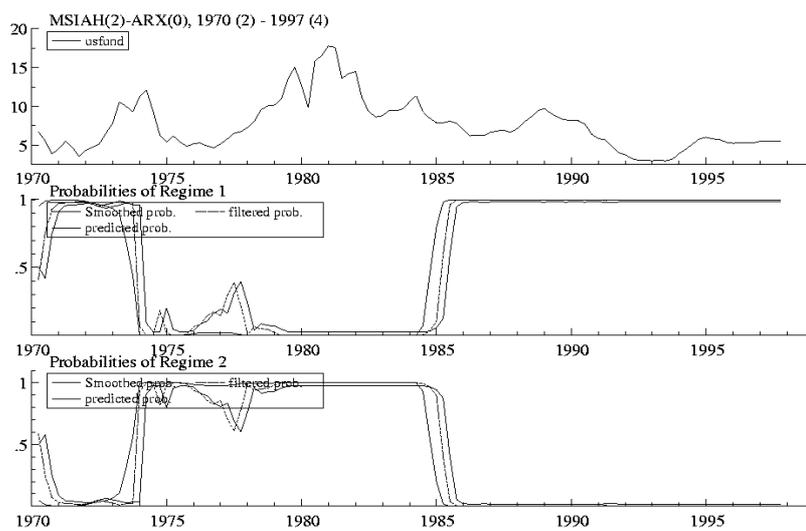


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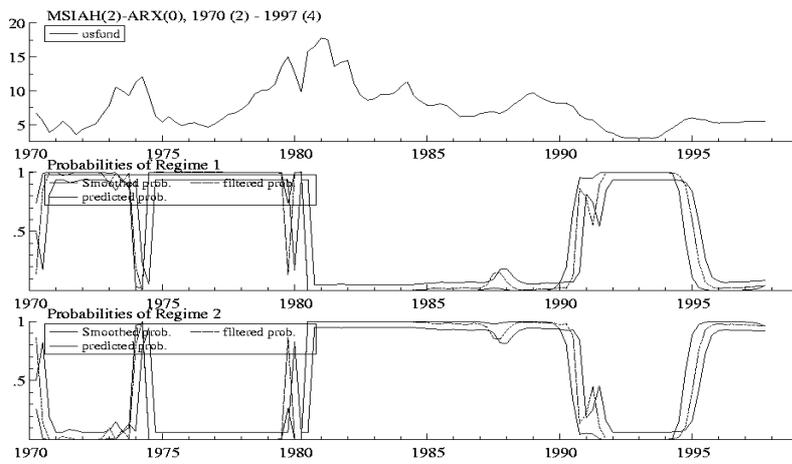


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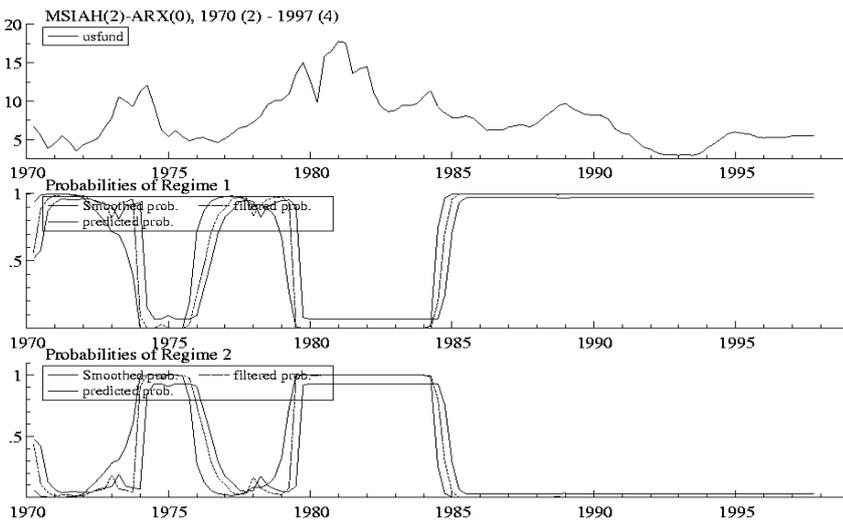


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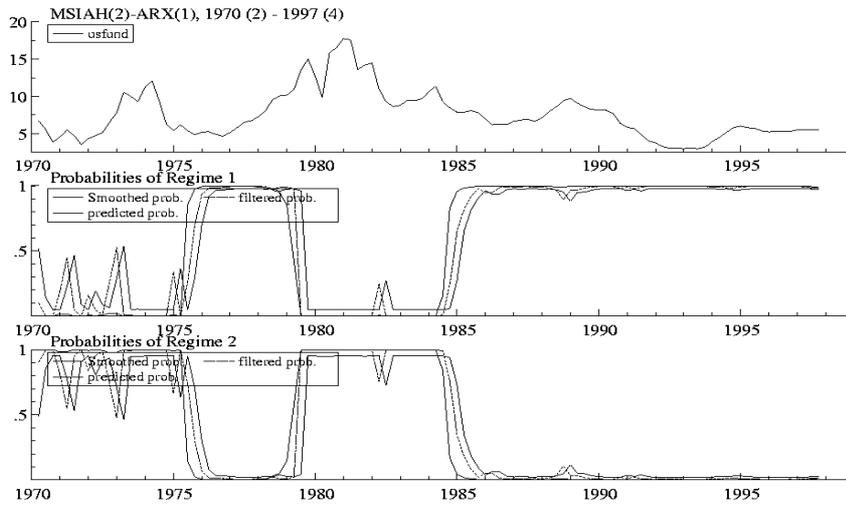


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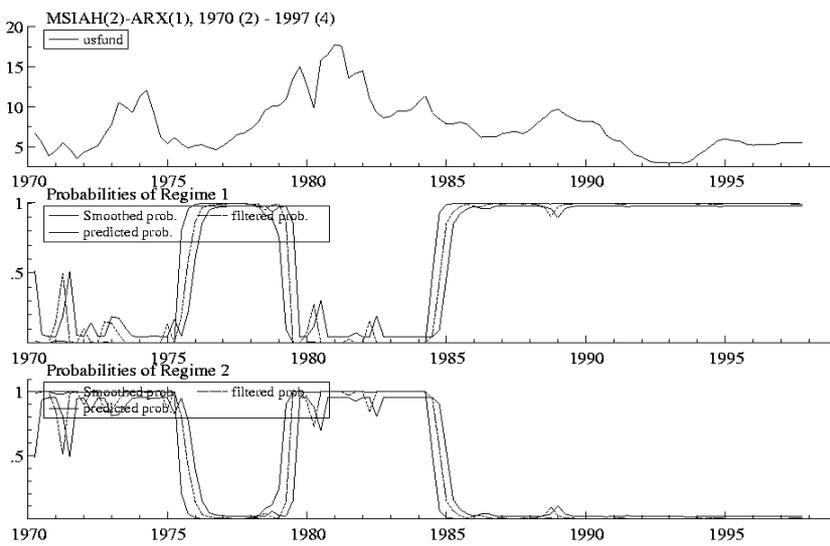


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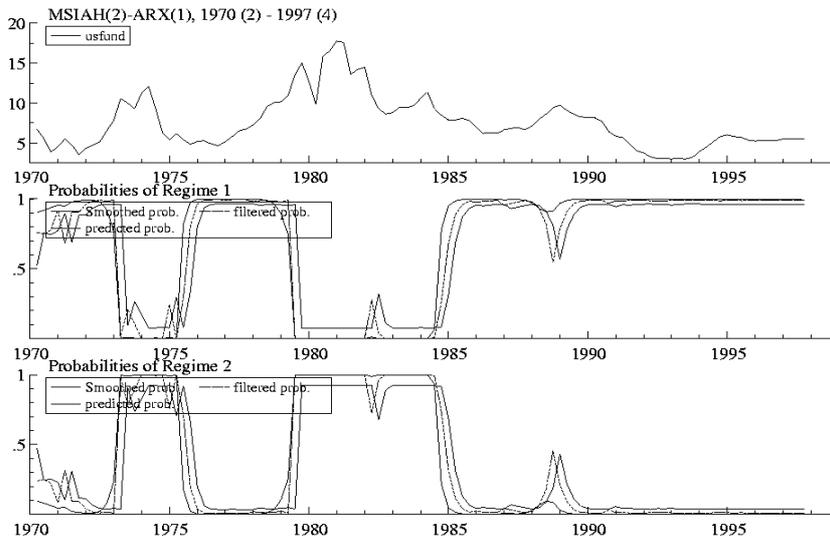


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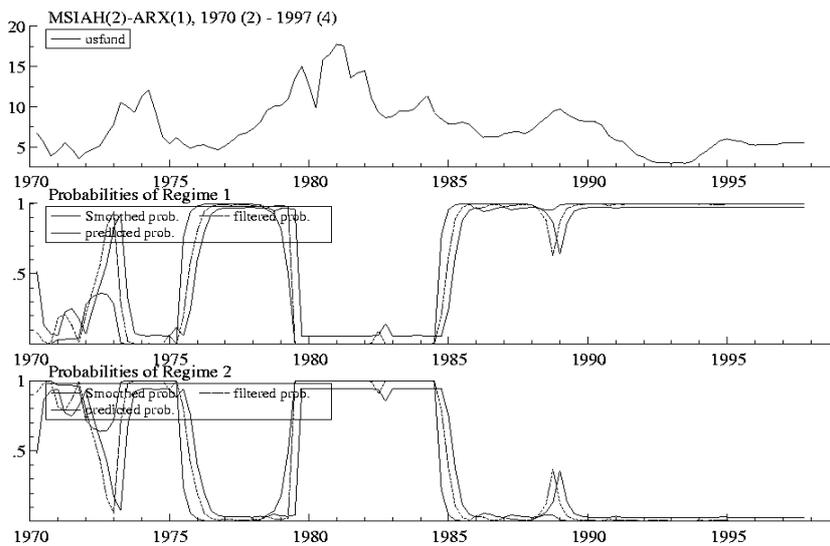


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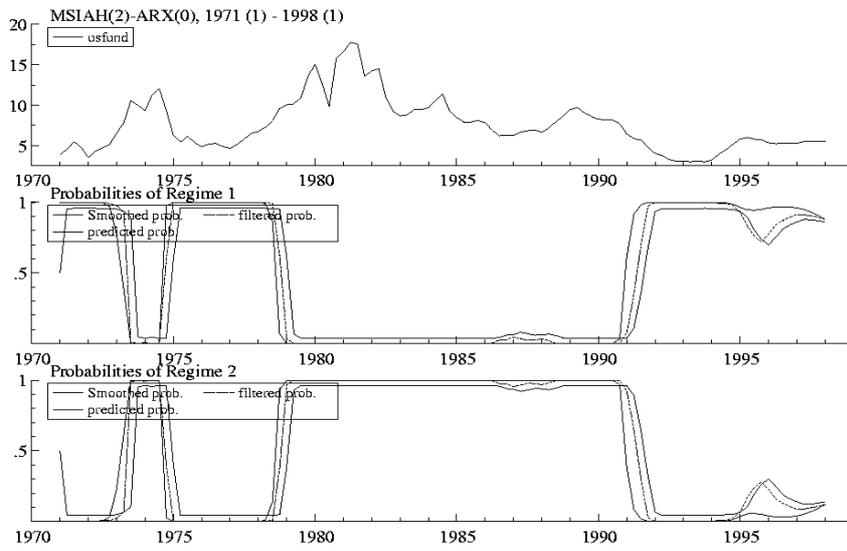


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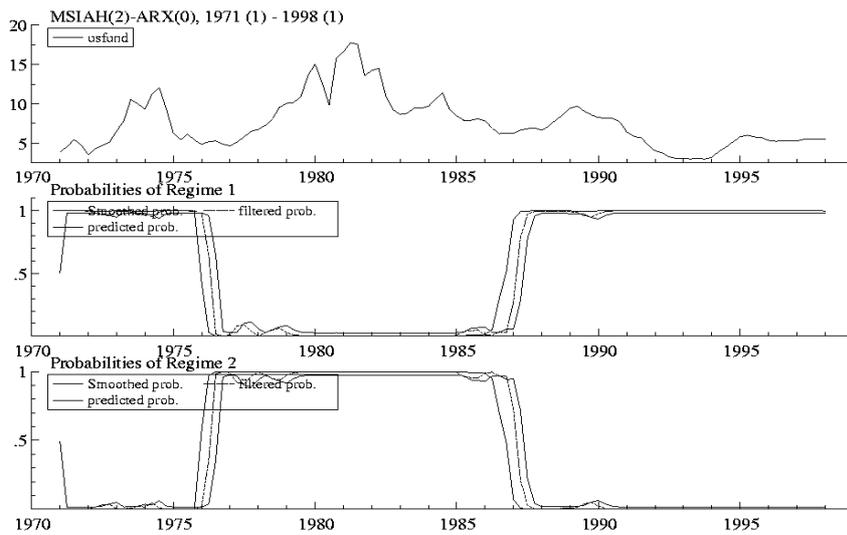


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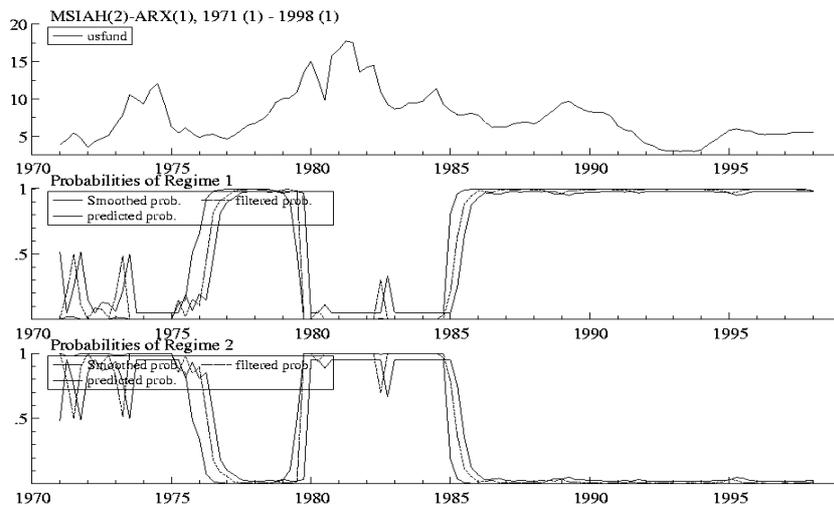
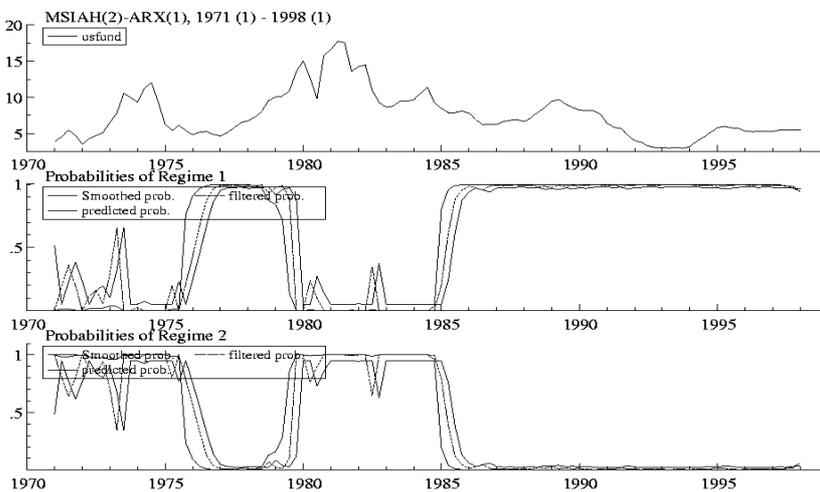


Figure A12.



The numbering of the figures corresponds with the numbering of the models in the Table 2.1.

## APPENDIX II B – The filtered, smoothed and predicted probabilities for the regimes for the German Bundesbank

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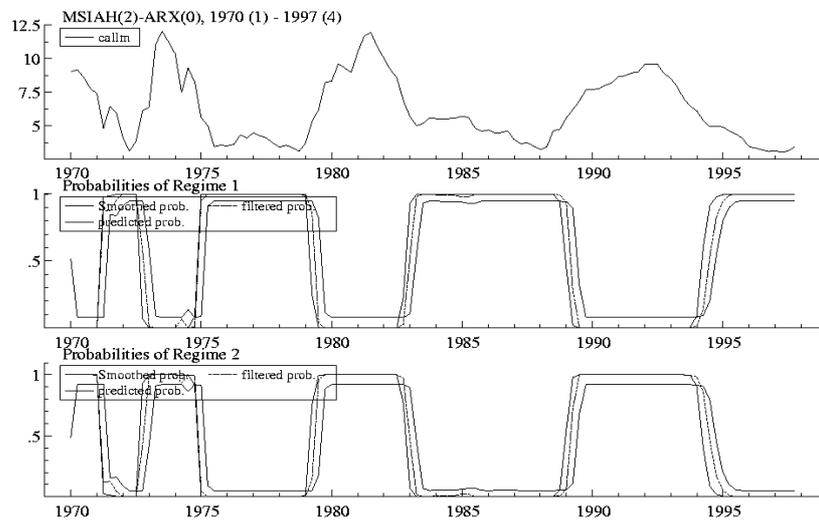


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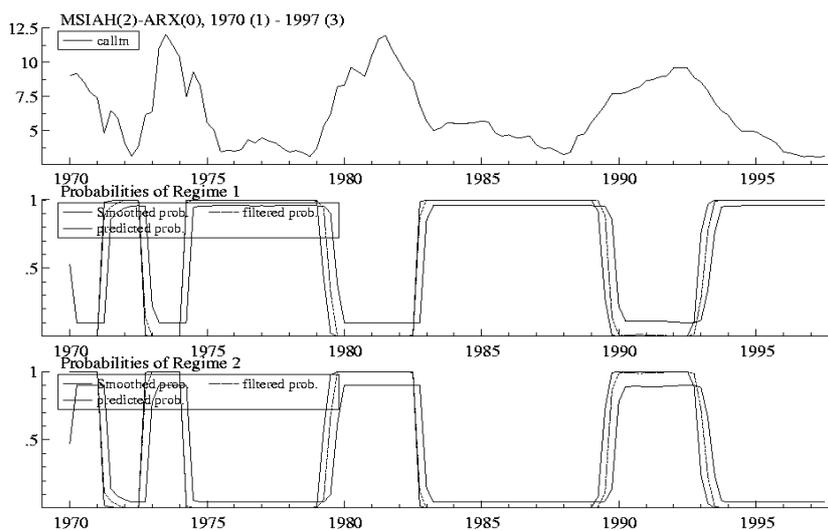


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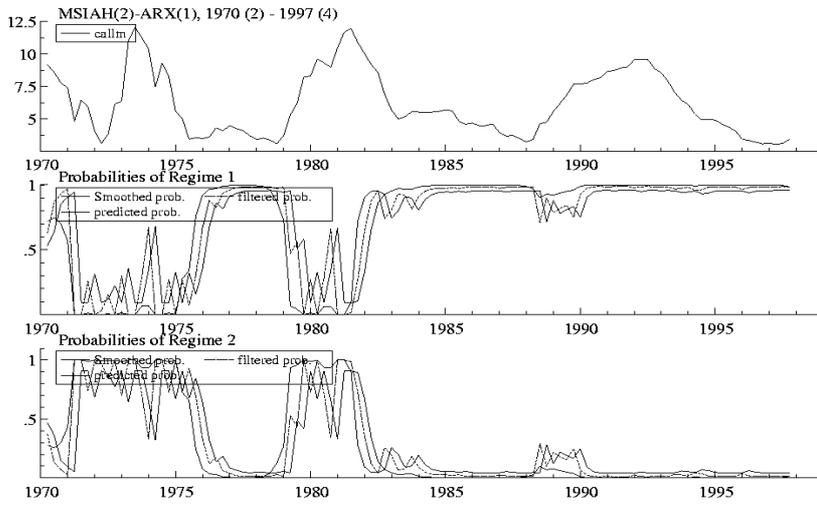


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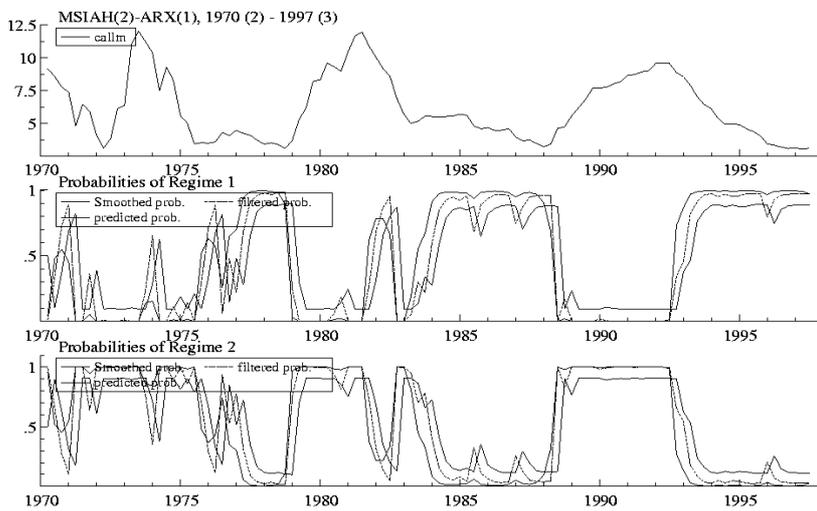


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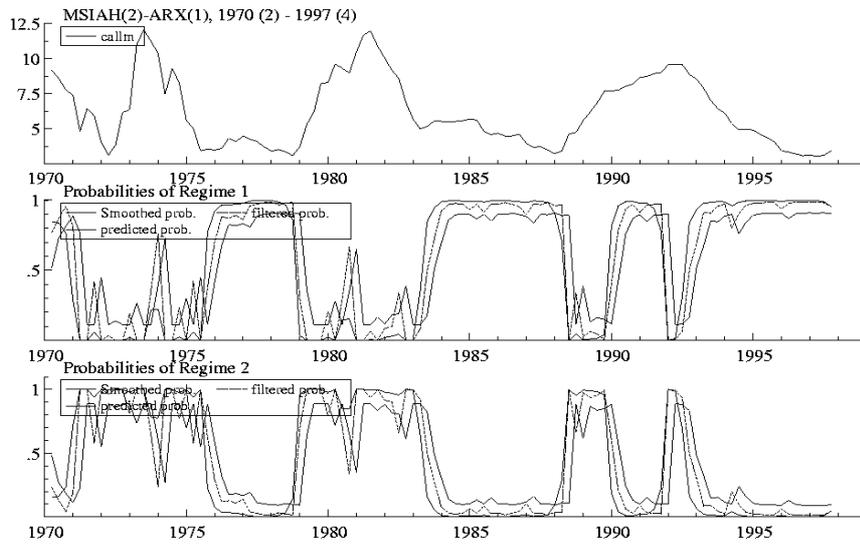


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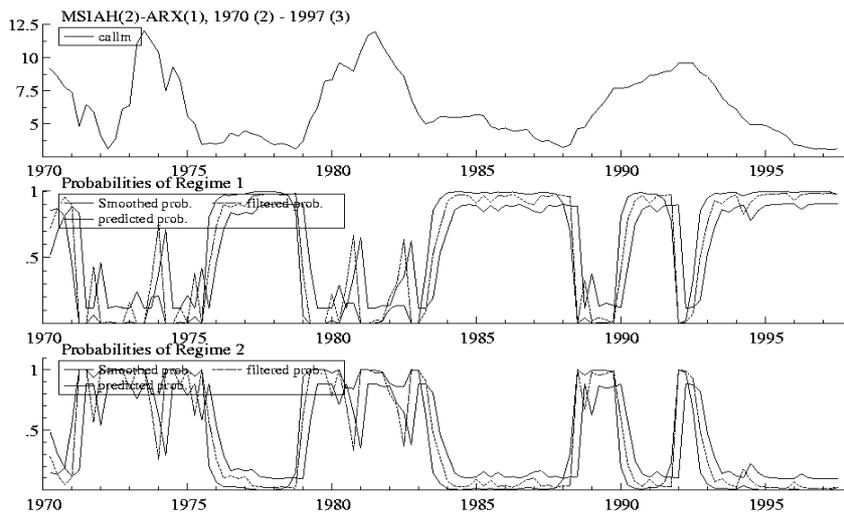


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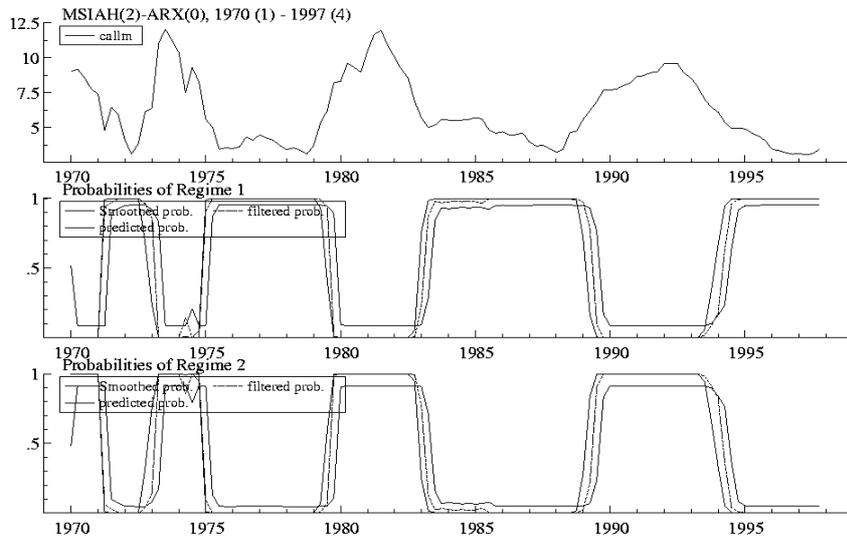


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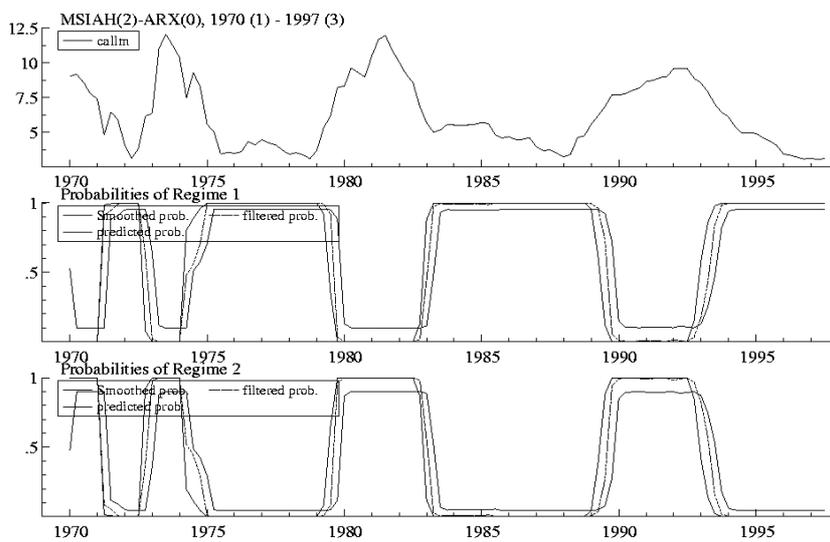


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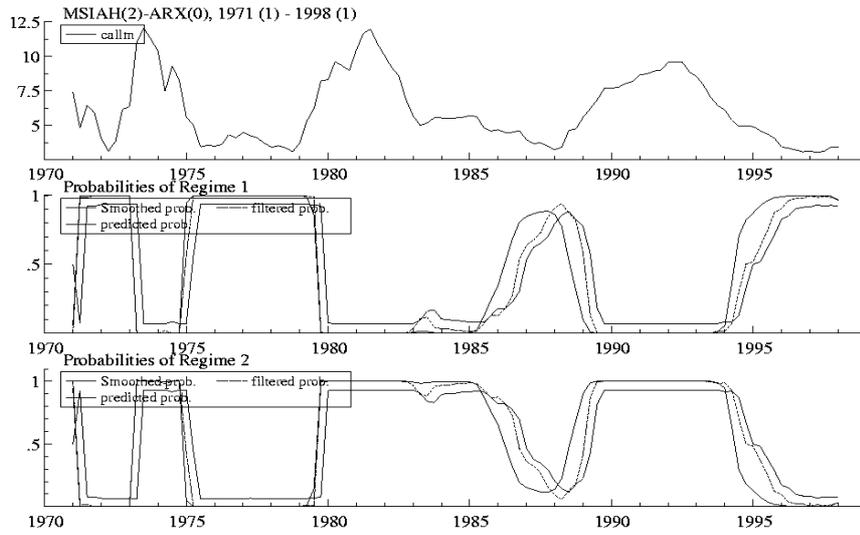


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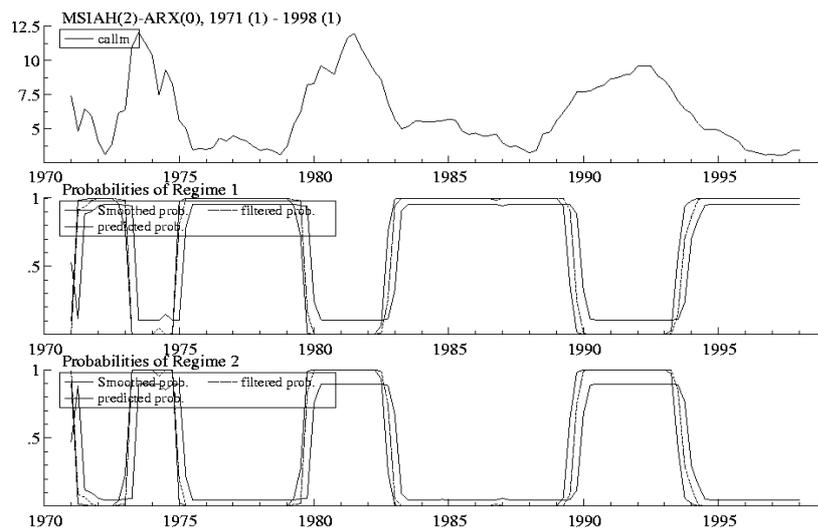


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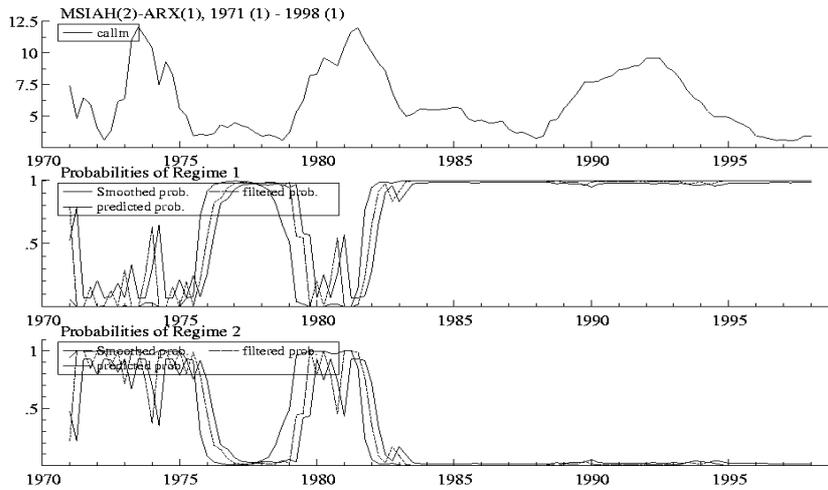
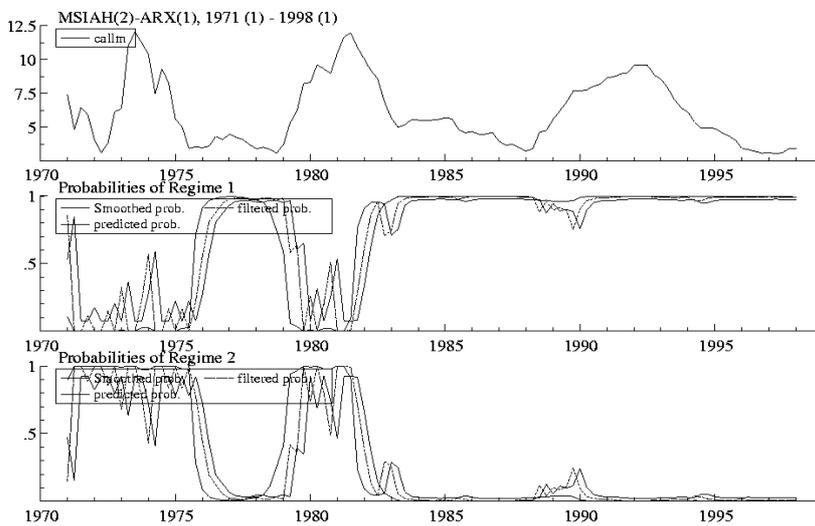


Figure B.12.



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APPENDIX III

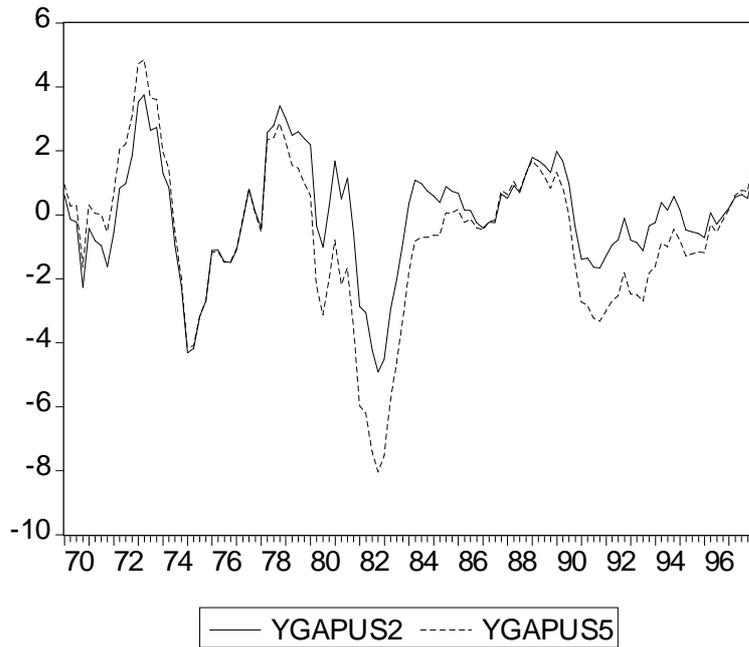


Figure III.1. The output gap of the US measured in two different ways. YGAPUS2 = output gap based on the potential output obtained by HP-filtering the output series. YGAPUS5 = output gap estimated by the Congressional Budget Office of the US.

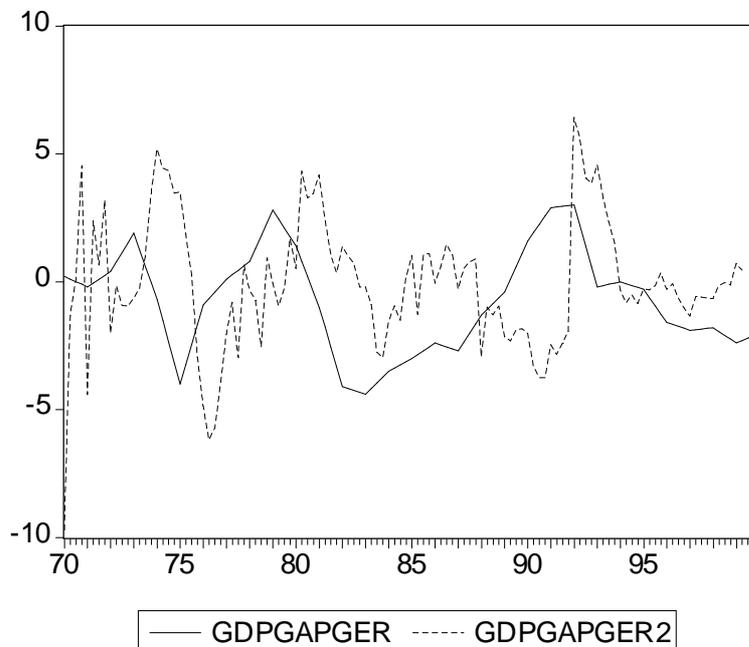


Figure III.2. The output gap of Germany measured in two different ways. GDPGAPGER = output gap estimated by the OECD and provided by the OECD Economic Outlook database, GDPGAPGER2 = output gap based on the potential output obtained by HP-filtering the output series.

## CHAPTER 4

### **SHOULD THE ECB ADOPT AN EXPLICIT EXCHANGE RATE TARGET?**

#### **ABSTRACT**

This paper uses a structural, quantitative macro model to investigate, whether the ECB should introduce the stabilization of the real exchange rate of the euro as one of the goals of its monetary policy. The problem is considered from the perspectives of both the whole monetary union and a single member state with a national economy more open than the union economy on average. According to the results, the member state would benefit from exchange rate stabilizing more than the rest of the union. It appears, however, that the asymmetries of the external shocks facing the economies may be a more important factor behind the greater volatility of the inflation and output of the member state than the structural differences.

**KEY WORDS:** Euro area, monetary policy rules, optimal currency areas.

JEL Classification: E32, E52, E58, F42

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## 1. INTRODUCTION

Since the adoption of the euro, economists have been discussing whether the stabilization of the real exchange rate of the euro should be one of the goals of the ECB's monetary policy. The opponents to exchange rate interventions stress that the primary goal of the ECB is to pursue price stability, not to target the exchange rate of the euro. On the other hand, if the fluctuations of the euro eventually pass through to consumer prices, this will make it more difficult to reach the inflation target.

The problem of whether the ECB should pay attention to stabilizing the exchange rate of the euro is also a part of the discussion whether the euro area can be considered as an optimal currency area. Because of the asymmetries in both the monetary transmission mechanisms and in the business cycle pattern between the member states, the same monetary policy does not necessarily suit all member states. For example, there are considerable differences in the degree of openness of the member states, measured as the share of foreign trade with countries outside the union. Moreover, the exogenous shocks to aggregate demand and productivity do not hit the single member economies symmetrically. Still the ECB has to target only the union wide averages of these variables.

In short, the research problem of this study is to investigate with a structural, quantitative macro model, whether the ECB should include the real exchange rate as a variable in its reaction function. The problem is considered both from the perspective of the whole monetary union and from that of a single member state with a national economy differing from the averages of the whole union both in its degree of openness and with regard to its business cycle pattern. Another goal of the study is to examine whether the union's one-size-fits-all monetary policy can create significant welfare losses because of increased deviations of inflation and output in some of the EMU member states.

The research method of the study is to specify a quantitative, calibrated macromodel that is consistent with both economic theory and data. The macro model is a small "New Keynesian" model consisting of a simple monetary policy rule and equations

covering the essential features of both a large monetary union and a small member state of the union. After the model has been solved, it is simulated under different assumptions concerning the weight that is placed on stabilizing the exchange rate in the central bank's policy rule equation of the model. Whether increasing this weight improves or impairs the macroeconomic performance of either the union as a whole or its small member state, is then discussed by calculating the unconditional variances of the inflation and output from the simulated series.

The importance of exchange rate shocks for the economic stability of the EMU area depends on its openness against the rest of the world. Peersman and Smets (1998), for instance, argue in favour of considering the euro area as a closed economy like the US and Japan, since the ratio of exports to the euro area-wide GDP is only about 14%. On the other hand, some researchers have argued that the relatively low degree of openness of the euro area does not necessarily imply an insignificant role for the exchange rate. Mayes and Virén (1998), for instance, estimate monetary condition indexes for groups of EMS countries. The results suggest that the significance of the exchange rate channel for the transmission of monetary policy to both inflation and real variables may be much larger in the euro area than could be concluded from the volume of its foreign trade. The authors conclude that the transmission mechanism of the exchange rate changes is not based solely on foreign trade but is a more complicated process. The tentative results of Ranki (2001) also suggest that the degree of pass-through may be much larger than would be expected in light of the openness of the euro area.

Previous theoretical analyses on including a direct exchange rate target in the monetary policy rule are provided by Ball (1998), Taylor (1999) and Svensson (1998)<sup>1</sup>. Each of the studies approach the problem from slightly different viewpoint but a common feature of all these studies is that the central bank policy rule is assumed to be of the form

$$(1.1.) \quad i_t = \alpha\pi_t + \beta y_t + \lambda_0 e_t + \lambda_1 e_{t-1},$$

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<sup>1</sup> For a discussion of these papers, see also Taylor (2001).

where  $\pi_t$  =inflation,  $y_t$  = output,  $e_t$  = real exchange rate and  $\alpha$ ,  $\beta$ ,  $\lambda_0$  and  $\lambda_1$  are parameters.

Ball uses a small macromodel to argue that in an open economy the central bank should take the exchange rate into account in its policy by including the monetary condition index (MCI), that is, a weighted average of the interest rate and the exchange rate, into its reaction function. For the parameter  $\lambda_0$  Ball's study implied an optimal value of  $-0.37$  and for  $\lambda_1$  a value of  $0.17$ . The alternative policy rule considered in Ball's study for comparison, pure inflation targeting, would instead create large fluctuations in exchange rate and output.

Taylor (1999) in turn, simulates ECB interest rate rules in a dynamic stochastic multicountry model for seven large countries. In the study the euro area was modelled by assuming fixed exchange rates between Germany, France and Italy and a single short term interest rate. When the performance of the original Taylor rule was compared with that of a rule that also contained the nominal euro/USD exchange rate as an argument, with  $\lambda_0 = -0.25$  and  $\lambda_1 = 0.15$ , neither of the rules strictly dominated the other. Instead, for some countries (France and Italy) the policy rule with the exchange rate target led to better performance, while for Germany, this policy rule implied poorer performance.

Svensson (1998) compared several variants of inflation targeting in an open economy setting. When a policy rule of Equation (1.1) was considered, Svensson assumed values  $\lambda_0 = -0.45$  and  $\lambda_1 = 0.45$ . Analysing the optimal monetary policy responses to many different shocks the author concluded that flexible CPI targeting stands out as successful in limiting the variability of CPI inflation, output gap and real exchange rate.

In light of the three studies referred to above, the exchange rate should not play a very important role in the monetary policy rules of even open economies. Adopting an exchange rate target implied only small reductions in the volatilities of inflation and output, although some of the models assumed rather large values for  $\lambda_0$  and  $\lambda_1$ . In

Svensson's study, including the exchange rate in the policy rule actually seemed to imply a slight increase in the volatility of output<sup>2</sup>.

The viewpoint of a single small member state on the optimal policy rule of a monetary union is actually part of the discussion of the optimal currency areas (henceforth, OCA). Whether the euro area can be considered an optimal currency area or not is discussed in Bayoumi and Eichengreen (1992) and Dornbusch et al. (1998). Bayoumi and Eichengreen discuss the symmetry of the structural shocks in the EC area by estimating a set of structural VAR models to the 11 EC countries to identify the demand and supply shocks hitting these economies. The authors conclude that only the core countries of the EC experienced shocks with roughly the same magnitude and cohesion as the US regions. Particularly the supply shocks hitting the EC periphery tend to be both larger and less correlated with the shocks hitting the neighbouring countries. Thus, the results suggested that operating a monetary union may be more difficult in the euro area than in the US.

Dornbusch et al. (1998) provide a survey of the symmetry of the monetary transmission mechanism in the EMU area. The authors conclude that, due to the differences in the financial systems, the wage-price processes and also in the degree of openness of the EMU countries, the monetary processes differ widely among the member states. Because of the already ongoing restructuring of the financial processes and the adaptation of the labour markets of the member states to the changing environment, the transmission mechanisms in the member states are however, likely to converge.<sup>3</sup>

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<sup>2</sup> The intuition behind this result is based on the indirect effect of the exchange rate on the interest rate that was built into the models by assuming rational expectations and some inertia.

<sup>3</sup> Schelkle (2001) provides an alternative standpoint for the whole OCA literature. If the exchange rates no more reflect only economic fundamentals, but are more or less driven by (rational or irrational) bubbles, the exchange rate adjustment no longer provides a shelter from economic shocks. Accordingly, the presence of asymmetric shocks is no more an acceptable argument against monetary unification, and eliminating the exchange rate instability becomes rather a benefit than a cost.

## 2. THEORETICAL MODEL

### 2.1. Structure of the model

From the methodological point of view, the study at hand represents an approach that Taylor (2001, p. 263) calls “new normative macroeconomic research”. This approach includes building a macroeconomic model containing a monetary policy rule, solving the model numerically, examining the stochastic behaviour of the model variables and choosing the monetary policy rule with the most satisfactory performance. Further, as the macroeconomic model of this study assumes nominal rigidities, it is an example of what Clarida et al. (1999) call “New Keynesian models”. It is typical for the New Keynesian models that they closely resemble the traditional ISLM models, while they still are derived from the behaviour of optimising agents<sup>4</sup>. As McCallum and Nelson (1997) have demonstrated, the models correspond to a linear reduced form of fully-optimising general equilibrium model. A typical New Keynesian model consists of a Taylor type monetary policy rule, an IS-curve type relation and equation(s) describing the supply side of the economy. The model may also include an LM curve equation and in an open economy setting the model is often supplemented by an uncovered interest parity condition for determining the exchange rate.

Our model is built from a single country macro model by Batini and Haldane (1998) to cover two economies, that is, the monetary union as a whole and a single member state. (For convenience, the single member state is henceforth referred to as simply “member state”). More formally, the model is a linear difference equation system of ten equations, so that Equations (2.1) – (2.6) below characterize the whole monetary union, while Equations (2.7) – (2.10) describe solely the economy of the member state. The equations characterizing the whole union follow Batini’s and Haldane’s model very closely, whereas the rest of the equations describing the small member state form the “new” part of the model. Note that there is only one-way feedback between the member state and the union: The member state takes the interest rates as given and a relatively large share of its foreign trade is assumed to consist of intra-

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<sup>4</sup> Recent surveys of these “New Keynesian” models are provided by Clarida et al. (1999) and Taylor (2001).

union trade. The member state, however, is assumed to be so small relative to the union that the union's variables are unaffected by the performance of the economy of the single country.

The model implies stickiness to consumer prices, and hence some persistence to consumer price inflation. In addition, the model is forward-looking in nature and the expectations are assumed to be rational. The forward-looking features of the model appear in many forms. Firstly, in the policy rule the central bank reacts to anticipated inflation. Secondly, the IS equation may be interpreted as a linearised Euler equation, where the present consumption is affected by the expected marginal utility from the consumption of the next period. Thirdly, in the uncovered interest rate parity equation the nominal exchange rate adjusts according to the expected future paths of the domestic and foreign short-term interest rates. Finally, in the wage contracting equation the workers set their wage demand partly according to the expected wage level of the future wage contracts.

## The macro model

### The monetary union

$$(2.1) \quad r_t = \gamma r_{t-1} + (1-\gamma)r_t^* + \theta_1 [E_t \pi_{t+1} - \pi^*] + \theta_2 (y_t - y_t^*) + \theta_3 (q_t - q_t^*)$$

$$(2.2) \quad y_t - y_t^* = \alpha_1 y_{t-1} + \alpha_2 E_t (y_{t+1}) + \alpha_3 [r_t] + \alpha_4 (q_t) + \varepsilon_{yt}$$

$$(2.3) \quad e_t = E_t (e_{t+1}) - i_t + i_t^f + \varepsilon_{et}$$

$$(2.4) \quad p_t^d = 1/2 [w_t + w_{t-1}]$$

$$(2.5) \quad w_t = \chi_0 [E_t (w_{t+1})] + (1-\chi_0) [w_{t-1}] + \chi_1 (y_t - y_t^*) + \varepsilon_{wt}$$

$$(2.6) \quad p_t^c = \phi p_t^d + (1-\phi) e_{t-1}$$

### The small country

$$(2.7) \quad y_t^m - y_t^{m*} = \beta_1 y_{t-1}^m + \beta_2 E_t (y_{t+1}^m) + \beta_3 [r_t^m] + \beta_4 (q_t^m) + \beta_5 (y_t) + \varepsilon_{yt}^m$$

$$(2.8) \quad p_t^{md} = 1/2 [w_t^m + w_{t-1}^m]$$

$$(2.9) \quad w_t^m = \psi_0 [E_t (w_{t+1}^m)] + (1-\psi_0) [w_{t-1}^m] + \psi_1 (y_t^m - y_t^{m*}) + \varepsilon_{wt}^m$$

$$(2.10) \quad p_t^{mc} = \kappa p_t^{md} + \vartheta p_t^d + (1-\kappa-\vartheta) e_{t-1}$$

All variables, except interest rates, are in logarithms. Inflation variables of both the union and the single country,  $\pi_t$  and  $\pi_t^m$ , are defined as consumer price inflation. That is,  $\pi_t \equiv p_t^c - p_{t-1}^c$  and  $\pi_t^m \equiv p_t^{mc} - p_{t-1}^{mc}$ , where  $p_t^c$  and  $p_t^{mc}$  are the price levels of the consumption goods of the union and the member state. The nominal exchange rate ( $e_t$ ) is defined as the domestic price of foreign currency. Accordingly, the real exchange rates of the union and the member state are defined as  $q_t = e_t + p_t^{cf} - p_t^c$

and  $q_t^m = e_t + p_t^{cf} - p_t^{mc}$  where  $p_t^{cf}$  is the price level of the consumption goods outside the union that is normalized to zero.<sup>5</sup>

Equation (2.1) represents *the ECB's monetary policy rule*. It is assumed that while the ECB's policy instrument is actually the nominal interest rate,  $i_t$ , it tries to adjust the *ex-ante real rate of interest* ( $r_t \equiv i_t - E_t \pi_{t+1}$ ) of the whole union<sup>6</sup> through its forecast of the future inflation<sup>7</sup>. The policy rule is a variant of the Taylor rule so that the ECB is assumed to respond to deviations of the expected inflation and output from their desired levels, that is,  $E_t \pi_{t+1} - \pi^*$  and  $y_t - y_t^*$ . The Taylor rule type policy rule with inflation and output gaps as central bank's objectives may also be motivated theoretically, as Woodford (1999) shows<sup>8</sup>. The desired levels of the output  $y_t^*$ , are implicitly assumed to be the natural rate of output so that there is no Barro-Gordon bias built into the model. In addition to the inflation and output gaps, the ECB is assumed to react to deviations of the real exchange rate from its target ( $q_t - q^*$ )<sup>9</sup>.

The right hand side of the policy rule equation also includes the lagged real interest rate, which reflects the central bank's urge to smooth its interest rate changes<sup>10</sup>. Such an interest rate smoothing element has become a mainstream assumption in the literature and it can be motivated for instance by central banks' attempt to stabilize financial markets. Alternatively, the sluggishness in the interest rate changes can also be interpreted as reflecting central banks' caution in the face of the uncertain information on which the central banks have to build their decisions.

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<sup>5</sup> The variables of the single member state are distinguished from the union variables by superscript m.

<sup>6</sup> Accordingly, the real interest rate of the single member state is given by  $r_t^m \equiv i_t - E_t^m \pi_{t+1}$ .

<sup>7</sup> According to the deterministic analysis, the results were not sensitive on whether the variable in the left hand side of the equation is the nominal or the real interest rate.

<sup>8</sup> With a simple optimising model Woodford shows that it is possible to motivate a quadratic loss function with inflation and output gap as arguments as a second-order Taylor-series approximation to the expected utility of the economy's representative household. Some of the assumptions of Woodford's model, regarding eg the definition of the output gap, are somewhat special so that some minor qualifications would actually be needed to justify the stabilization goals of the Taylor rule using Woodford's model. For instance, the natural rate of output should be defined as an equilibrium level that is obtained under perfectly flexible prices, and which varies as a response to the shocks the economy is facing.

<sup>9</sup> The exchange rate could be defined e.g. as the trade-weighted exchange rate or the exchange rate between the Euro and the USD.

<sup>10</sup> See e.g. Kozicki (1999), p. 8.

Equation (2.2) represents *the IS curve* of the economy, relating the deviation of the real output,  $y_t$  from its potential level  $y_t^*$ , to the ex ante real interest rate and the real exchange rate as well as to the lagged and lead term of the output ( $\alpha_3, \alpha_4 > 0$ ). The right hand side of the equation contains both a lagged and a lead term of output. This is a novel feature compared to the traditional specification of the IS curve with the current output in the right hand side instead. The lead term is motivated by McCallum's and Nelson's (1997) work that shows the similarities between the ISLM models and a fully optimising general equilibrium model. The lead term of the output becomes understandable when the IS equation is thought to represent a linearised version of the Euler equation relating the expected marginal utilities of the current consumption and the consumption in the following period. The lagged output is more an *ad hoc* increment to the model that tries to capture the sluggishness of the output, created by adjustment costs. The error term  $\varepsilon_{yt}$  finally, captures the union wide exogenous demand shocks of the model.

Equation (2.3) is an *uncovered interest parity condition*. This parity condition does not contain any explicit foreign exchange risk premium, although any noise in the foreign exchange rate market, like the shocks to the exchange risk premium, is included in the error term  $\varepsilon_{et}$ . The implicit assumption in our model is that the equilibrium exchange rate  $e^*$  remains constant over time. Equation (2.4) is the *mark-up equation* according to which domestic output prices are a constant mark-up over the average of the nominal wage rate of the current and the preceding period. Here the mark-up is standardized as zero.

Equation (2.5) is *the nominal wage-contracting equation*. The consumption wage today is a weighted average of the nominal wages of the previous period and the expected wages during the next period. The crucial assumptions of this equation are that wage contracts last for two periods and a given cohort of workers is interested in nominal wages relative to the nominal wages of the other cohorts of the labour force. The output gap term on the right hand side of (2.5) captures the tightness of the labour market and the error term  $\varepsilon_{wt}$  stands for the union wide supply shocks. The specification differs from that of Batini's and Haldane's study, in which the wage

setting was modelled with real wage contracting. The nominal wage specification was chosen here because it implied more plausible impulse responses. In addition, although nominal contracting admittedly implies less inflation persistence to the model than real wage contracting, our specification may also be considered empirically justified by the results of Coenen and Wieland (2000). The study compared the empirical fit of a nominal wage-contracting model and three different versions of the relative real wage contracting model using aggregated European data. According to the results, both the nominal and the real wage version of the models fit the data fairly well, although the best fit was obtained with a real wage specification, which again also implied more persistence in the inflation process.

Equation (2.6) defines the **consumption price index** of the monetary union as a weighted average of the prices of domestic goods and imported foreign goods. The correct formulation of (2.6) is crucial for the results, since it is the most important determinant of the pass-through of the nominal exchange rates. The role of the exchange rate in the transmission process of the monetary policy as a whole is actually based on two channels. At first, the changes in the real exchange rates are transmitted indirectly, as the change in net exports affects the output gap, which in turn partly determines inflation. The impact through Equation (2.6) is the direct effect: A rise in the prices of imported goods raises the consumer prices, but the extent to which the consumer prices are affected, ultimately depends on the competitive structure of the goods markets. Note that now (2.6) implies full but not immediate pass-through of the exchange rate into consumption prices, since the exchange rate emerges in the equation only with lag. The theoretical background for the specifications with less than full or other than immediate pass through is primarily based on the recent pricing to market literature<sup>11</sup>.

The basic structure of Equations (2.7) – (2.10) is largely similar to the corresponding equations characterizing the whole union. Equations (2.8) and (2.9) are completely analogous to their union-wide counterparts. In the IS equation (2.7) that determines the output demand of the member state, there is now an additional explanatory variable  $y_t$  reflecting the dependence of the output demand of the member state from

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<sup>11</sup> See e.g. Goldberg and Knetter (1997).

the intra-union trade. Accordingly, in Equation (2.10) the consumption prices of the member state are defined as a weighted average of production prices of goods produced in the home country, inside the monetary union and outside the union. The model does not contain an LM equation characterizing the equilibrium in the money market. In fact, the money supply is totally omitted from the model.<sup>12</sup> As McCallum (1999, pp. 9 – 11) argues, leaving an LM relation out of the model is justified only if at least two assumptions are fulfilled. At first, the central bank has to conduct the monetary policy only with interest rate changes, paying no attention at all to the monetary aggregates<sup>13</sup>. Secondly, the monetary aggregates are not allowed to appear in the other behavioural equations of the model. In the case of the IS relation this would mean that the transaction-cost function, which describes the way that money facilitates transactions, must be separable in money and income.

## 2.2. Solving the model

When solving the model, it is assumed that all the behavioural relationships above represent deviations from equilibrium. Hence, the (log) natural rates of output of both the union and the member state, the (log) price level of the goods produced outside the union, the interest rate outside the union, the implicit mark-ups in (2.5) and (2.9) and foreign interest rate premium in (2.3) are normalized to zero.

The model was solved by the method proposed and software provided by Uhlig (1999). Uhlig's method is based on solving the recursive equilibrium law of motion with the method of undetermined coefficients<sup>14</sup>. In this method, the model variables are divided into three subgroups:  $\mathbf{x}_t$ ,  $\mathbf{y}_t$  and  $\mathbf{z}_t$ . Now  $\mathbf{x}_t$  is a vector of endogenous state variables of size  $m \times 1$ , which is identified as the set of variables that is given at date  $t-1$ .  $\mathbf{y}_t$  is a  $n \times 1$  sized vector of the other endogenous variables, while  $\mathbf{z}_t$  is a

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<sup>12</sup> Batini's and Haldane's model contained an LM equation but the equation was found to be largely redundant as the changes in money supply were assumed to be accommodated by money demand at any given level of interest rates

<sup>13</sup> One objection to the choice of dropping the money supply from the model could be that controlling broad money is, *de jure*, the second of the two "pillars" used to achieve the ECB's price stability objective.

<sup>14</sup> The brief description of the method presented here is based on Uhlig (1999), pp. 35 – 45.

$k \times 1$  vector of exogenous stochastic processes that hit the economy. The equilibrium relationships between these variables can be characterized as follows:

$$(2.11) \mathbf{0} = \mathbf{A}\mathbf{x}_t + \mathbf{B}\mathbf{x}_{t-1} + \mathbf{C}\mathbf{y}_t + \mathbf{D}\mathbf{z}_t$$

$$(2.12) \mathbf{0} = \mathbf{E}_t[\mathbf{F}\mathbf{x}_{t+1} + \mathbf{G}\mathbf{x}_t + \mathbf{H}\mathbf{x}_{t-1} + \mathbf{J}\mathbf{y}_{t+1} + \mathbf{K}\mathbf{y}_t + \mathbf{L}\mathbf{z}_{t+1} + \mathbf{M}\mathbf{z}_t]$$

$$(2.13) \mathbf{z}_{t+1} = \mathbf{N}\mathbf{z}_t + \boldsymbol{\varepsilon}_{t+1}; \mathbf{E}_t[\boldsymbol{\varepsilon}_{t+1}] = \mathbf{0},$$

where  $\mathbf{A}, \mathbf{B}, \mathbf{C}, \mathbf{D}, \mathbf{F}, \mathbf{G}, \mathbf{H}, \mathbf{J}, \mathbf{K}, \mathbf{L}, \mathbf{M}$  and  $\mathbf{N}$  are coefficient matrices of appropriate size. The matrices have to obey the following restrictions: Firstly,  $\mathbf{C}$  is of size  $l \times n, l \geq n$  and of rank  $n$ . Secondly,  $\mathbf{F}$  is of size  $(m+n-l) \times n$ , and thirdly,  $\mathbf{N}$  has only stable eigenvalues.

The matrix equation (2.11.) describes the deterministic equations of the model, whereas (2.12) is built of the expectational equations. Eq. (2.13) in turn, describes the behaviour of the stochastic processes of the economy as AR(1) –process. The ultimate aim of solving the model is to find the recursive equilibrium law of motion, which takes the form

$$(2.14) \mathbf{x}_t = \mathbf{P}\mathbf{x}_{t-1} + \mathbf{Q}\mathbf{z}_t$$

$$(2.15) \mathbf{y}_t = \mathbf{R}\mathbf{x}_{t-1} + \mathbf{S}\mathbf{z}_t$$

Here the vector of the endogenous state variables  $\mathbf{x}_t$  consists of  $[r_t, y_t, e_t, w_t, p_t^c, i_t, r_t^m, y_t^m, w_t^m, p_t^{mc}]$ , while the vector of other endogenous variables  $\mathbf{y}_t$  reads as  $[\pi_t, p_t^d, q_t, \pi_t^m, p_t^{md}]$ . The vector of exogenous stochastic processes of the model is  $\mathbf{z}_t = [\varepsilon_{yt}, \varepsilon_{et}, \varepsilon_{wt}, \varepsilon_{yt}^m, \varepsilon_{wt}^m]$ . The matrices  $\mathbf{P}, \mathbf{Q}, \mathbf{R}$  and  $\mathbf{S}$  are such that the equilibrium described by these rules is stable. The values for the elements of the matrices  $\mathbf{P}, \mathbf{Q}, \mathbf{R}, \mathbf{S}$  and  $\mathbf{Z}$  were found using the software package written for

MATLAB by Uhlig (1999). After the equilibrium law of motion has been solved, the unconditional variances of the inflation and output variables implied by the model can be calculated either by simulations (see the APPENDIX I, or analytically, as Uhlig (1999) shows.

### **2.3. Calibrating and assessing the plausibility of the model**

The parameter values for our model are partly based on the studies by Peersman and Smeds (1999), Ball (1997) and Batini and Haldane (1999). The parameter values of Equations (2.7) – (2.10) that determine the openness of the small member state are selected so that the member state could be considered as representing Finland, for instance. Where a direct empirical estimate of a parameter value was not available, the plausibility of the impulse responses was used as a criterion to choose between the different values. The robustness of the results on small changes to the baseline parameterization will be discussed later in the study.

The coefficient of inflation in the central bank reaction function ( $\theta_1$ ) is set equal to 0.5. Note that because it is the real interest rate in the right hand side of the policy rule, this coefficient value does not contradict the well-known Taylor principle<sup>15</sup>. The Taylor principle states that the inflation coefficient in the Taylor rule type central bank reaction function should exceed unity or otherwise the monetary policy becomes destabilizing.<sup>16</sup> The coefficient for the output gap ( $\theta_2$ ), in turn, is set equal to 1. The relatively high value for the coefficient value of the output gap is roughly in line with the findings of Peersman and Smeds (1999) and Ball (1997). According to these studies, the efficient monetary policy rule should put greater weight on output gap than the weight of 0.5 that was used in the Taylor's original specification<sup>17</sup>. The

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<sup>15</sup> Rearranging the terms of Equation (2.1.) would in fact reveal that it is equivalent to a policy rule for the nominal interest rate with  $\theta_1 = 1.5$ .

<sup>16</sup> For a discussion on this theoretical result. see Taylor (1999), Clarida et al. (1999) and Woodford (1999 and 2000). On the other hand, Benhabib et al. (2001) calls into question the stability of the Taylor rule even in the case when the inflation coefficient exceeds unity

<sup>17</sup> On the other hand, Taylor (1999) compares the performance of alternative monetary policy rule specifications with the US model using a number of different macro models finding that the rules with more weight put on stabilizing output do not outperform the benchmark rule with a coefficient of 1.5 to inflation and 0.5 to output. Moreover, the policy rules with the lagged interest rate do not seem to

interest rate smoothing parameter ( $\gamma$ ) is set equal to 0.6, which suggests a rather strong interest rate smoothing motive. This again follows Peersman and Smets (1999) and their estimates for the coefficients of the efficient rule. In the stochastic analyses, the coefficient for the real exchange rate ( $\theta_3$ ) will get a number of different values, but for the deterministic simulations is set to 0.25.

The parameters  $\alpha_1$  and  $\alpha_2$  of the IS equation of the union, as well as the corresponding parameters  $\beta_1$  and  $\beta_2$  of the IS equation of the member state, are set equal to 0.8 and 0.2, following the example of Batini and Haldane (1998). Hence, the agents are assumed to be mostly backward-looking. The parameters  $\alpha_3$  and  $\beta_3$  respectively, describing the elasticity of total demand to real interest rate, both get values of -0.6. The parameters  $\alpha_4$ , and  $\beta_4$ , in turn, measuring how the demand reacts to changes in the real exchange rate, get values 0.2 and 0.3. The difference between the values  $\alpha_4$  and  $\beta_4$  reflects the assumption that, compared to the union as a whole, a greater share of the aggregate demand in the member state consists of exports outside the union. The parameter values are in line with the values adopted in Ball (1998), which are based on estimates for small to medium-sized open economies, such as Canada or Australia. These parameter values, however, also sound plausible for EMU area since they correspond to the consensus view, according to which the monetary condition index (MCI) that measures the relative sensitivity of output to changes in the interest rates and exchange rate for EMU takes a value of about 3<sup>18</sup>.

The parameter  $\beta_5$  measuring the elasticity of the member state aggregate demand to changes in the demand in the union area is set equal to 0.2. This number roughly corresponds to the share with which exports from the union area contribute to the aggregate demand of Finland. The value of  $\beta_5$  implies that the goods markets of the single country and the rest of the union are only moderately connected to each other. Therefore, our model economy does not look like an optimal currency area, at least when it comes to the integration of the goods market.

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dominate the benchmark rule, although the interest rate smoothing seems to work better in the models with than without rational expectations.

<sup>18</sup> See e.g. Ball (1998) p. 5 or Mayes and Virén (1998).

The labour markets also are modelled similarly in the union area and the member state. Unfortunately, no empirical studies about the European labour market were available that would have directly provided the parameter values for the contracting equation. These values had therefore to be set more or less arbitrarily. Luckily, the chosen parameter values seemed to provide plausible dynamic responses to the shocks to the economy. In both wage contracting equations of the model (Equations. 2.5 and 2.9), the parameters  $\chi_0$  and  $\psi_0$  were set at 0.5, which implies equal weights for backward and forward lookingness. (For comparison, in Batini and Haldane (1998)  $\chi_0$  was set to 0.2.) The parameters  $\chi_1$  and  $\psi_1$  measuring the output sensitivity of nominal wages are set at 0.1.

The most important asymmetry between the union and the small member state comes with Equations (2.6) and (2.10), which determine the consumer prices as weighted averages of the prices of both domestic and imported goods. For the whole union, the weighting parameter  $\phi$  is set at 0.9 so that  $(1-\phi)$ , reflecting the share of trade to outside the union, gets a value of 0.1. For the small member state the parameter describing the weight of the domestically produced goods ( $\kappa$ ) gets a value of 0.5, while the parameter  $\vartheta$  that captures the cost effects of the imports from inside the union is set at 0.2. Hence, it is assumed that 30 % of consumption of the member state consists of goods produced outside the union. For the union as a whole, the corresponding figure is 10 %, so the single member state considered indeed is assumed to be more open than the union on average.

When the model was solved, it turned out to be dynamically stable so that the variables returned quickly to their long-run equilibrium values after the shocks. On the other hand, the matrix  $\mathbf{P}$  of the recursive equilibrium law of motion appeared to contain a unit root. The presence of unit roots implies that the consumer and producer prices, the nominal exchange rate and nominal wages converge to new equilibrium levels instead of the old steady states after a temporary shock.

The overall plausibility of the model was examined by deterministic analysis, which included calculating and analysing the impulse responses to some exogenous shocks. The impulse responses were calculated by setting  $\mathbf{x}_0 = \mathbf{0}$ ,  $\mathbf{y}_0 = \mathbf{0}$ ,  $\mathbf{z}_0 = \mathbf{0}$  and  $\varepsilon_t = 0$

for  $t \geq 2$ . Using the recursive law of motion, the values for  $\mathbf{z}_t$  and then  $\mathbf{x}_t$  and  $\mathbf{y}_t$  are calculated recursively using the values  $\mathbf{x}_{t-1}$ ,  $\mathbf{y}_{t-1}$ ,  $\mathbf{z}_{t-1}$  and  $\varepsilon_t$  for  $t = 1, \dots, T$ . The magnitude of the shock was assumed to be one percentage point.

The shocks examined included an IS shock and a real wage shock for both the monetary union and the member state, as well as a monetary policy shock and an exchange rate shock facing symmetrically both the union and the member state. The general conclusion was that the dynamic patterns of the impulse responses corresponded fairly well with what should be expected in light of previous theoretical and empirical research. All the deterministic analyses were carried out with the same basic parameterisation of the model presented above. A detailed discussion on the results of the deterministic analysis is provided below for the monetary policy shock and the wage shock facing the whole union area and the demand shock facing only the member state.

### Interest rate shock

#### *The effects in the union*

The contractionary monetary policy shock is defined as a temporary one percentage point increase in the real interest rate for a period of one quarter. Thereafter, the policy rule determines path of the real rate. From the point of view of the whole union area, in particular, the effects of a monetary policy shock are very short-lived, as is seen in the Figures 1 – 3 of Appendix II. The union variables reach their steady states in two years, and the member state variables four years after the shock. The effects of the shock are also modest in size, since none of the impulses exceeds 0.6 % in magnitude in absolute values.

After the shock both the ex ante real and the nominal interest rate seem to move largely hand in hand. Both interest rate variables rise right after the shock, (nearly 0.5 % at its maximum), and then visit temporarily below the baseline as the central bank temporarily reacts to the decreased output, appreciated currency and decline in inflation, by lowering the interest rates. Finally, the interest rates return to their base levels after about seven quarters. As expected, the nominal exchange rate reacts with

a permanent appreciation. The real exchange rate appreciates on impact, depreciates then temporarily and converges then to the old steady state in about six quarters. The output reacts to the shock by declining some 0.4 %, but the effect is temporary, as the output has converged to very near the old steady state in only one year<sup>19</sup>. Inflation declines slightly, about 0.15 %, but reaches its old level in six quarters. Accordingly, the rest of the nominal variables, namely the nominal wages, the nominal producer and consumption prices also converge to their new steady states in approximately six quarters.

#### *The effects in the member state*

As expected, the influence of the monetary policy shock is somewhat more persistent in the member state than in the monetary union as a whole, as the central bank does not directly target the member state variables when it is setting its policy stance. This notion also applies to the other shocks examined. It is seen in Figures 4 – 5 of Appendix II that it takes 10 – 12 quarters for the member state GDP, inflation and real interest rate to settle down to their steady state levels after the initial monetary policy shock. On the other hand, the shape and magnitude of the responses of these member state variables closely resemble those of the union variables. The responses of the member state price variables and nominal wages are hump shaped with minimum values little below those of the respective union variables. The new steady states are reached in about four years.

#### The wage shock

##### *The union*

The shock to the contracting equation of the union can be interpreted as a supply shock. Like the aggregate demand shock, the wage shock is also considered asymmetric so that it does not hit the member state at all. This kind of asymmetric productivity shock could be a consequence e.g. of inflationary wage settlements made in the union area. As is seen in the Figure 6 in Appendix II, the time path of the union

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<sup>19</sup> In fact, according to the common view, monetary policy should affect with a lag of several quarters and the pattern of the response should be hump shaped. For a review of empirical research of real effects of monetary policy shocks, see e.g. Walsh (1998), Ch. 1.

nominal wages reaches its new steady state level very soon, in about two quarters. To begin with, the wage shock results in a rapid but temporary, increase in inflation of about one percentage point, which lasts about two quarters. The increase in inflation sharply depreciates the nominal exchange rate immediately, although the real exchange rate depreciates only modestly, some 0.1 percentage point, for a period of about one year.

The increase in union inflation causes the central bank to tighten the monetary policy, which, because of the increase in inflation, is seen only as a slight increase in the real interest rate. The net effect of the depreciation of the real exchange rate and the increase in the real interest rate is a temporary 0.2 percentage point decline in the union output. The output, however, converges to the original level in about one year. The consumer and producer prices show very different responses on the impact of the shock. The consumer prices increase sharply due to the depreciated currency, whereas the producer prices remain virtually unaffected.

#### *The member state*

The accelerated union inflation is also transmitted to the inflation of the member state, both through the depreciated nominal exchange rate and the increased prices of the imports from the union area. After about one year, on the other hand, the inflation turns into a period of slight deflation in the member state, lasting some two-years. The time path of inflation is directly reflected in both the real interest rate and exchange rate of the member state. As is seen in the figure, an initial sharp decrease in the real interest rate is followed by a modest but rather persistent increase, before the return to the original level. The real exchange rate of the member state has not been drawn into the figure but comparing the graphs of the nominal exchange rate and the member state producer prices, it is easily concluded that at first it depreciates, then temporarily appreciates, after which it regains its original level. The net effect is a positive peak of about 1.2 % in the member state output, lasting for almost two years. The inflation rate and the real interest rate also reach their original levels about at the same time. The prices and the nominal wages rise and stabilize into a new permanent level after about four years.

## Total demand and wage shocks in the member state

The shocks facing the member state do not have any effects in the union area, because of the small size of the member state relative to the union. Qualitatively, the mechanism of the transmission of the shocks is otherwise the same as the transmission mechanism of the shocks hitting the whole union, except that now the central bank does not try to stabilize the effects of the shocks. In Figures 11 – 14 in Appendix II, two features of the impulse responses are noteworthy. At first, both the total demand and the wage shock seem to have relatively strong and long lasting effects. Secondly, the prices and nominal wages stabilize to their initial levels after the shocks, whereas after the union wide shocks these nominal variables converged to new steady state levels. This, of course, is possible if and only if the inflationary (deflationary) periods after the shocks are always offset by deflationary (inflationary) periods.

### **3. STOCHASTIC ANALYSIS**

#### **3.1. Calculation of the exogenous shocks**

The stochastic simulations require estimates of the covariance matrix and autocorrelation structure of the structural shocks hitting both the member state and the rest of the union. Five different shocks are considered. The shocks include a demand shock and a labour-market shock that hit the member state, a demand shock and a labour-market shock that hit the rest of the union (but not the member state) and an exchange rate shock<sup>20</sup>.

Batini and Haldane (1998) propose three ways to estimate a covariance matrix of structural shocks. One way would be to estimate the structural shocks and their covariance structure from a VAR model. The VAR models have rich dynamic

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<sup>20</sup> A more detailed description of the procedure used for the stochastic simulation is provided in Appendix I.

structure but the approach suffers from difficulties in imposing the correct set of identifying restrictions on the model. The opposite strategy would be to estimate the IS equations, the wage contracting equations and the interest rate parity equation of the model and measure the structural shocks as residuals of these equations. Because of the inadequate dynamic structure of the equations, however, the estimated residuals would not represent pure structural shocks but instead some linear combinations of the shocks and model specification errors. The handling of the expectational variables could also be problematic.

Batini and Haldane (1998) avoided these problems by choosing the third way in the middle of the two extreme approaches. They calculated the covariance matrix and the autocorrelations of the structural shocks from the residuals of a large structural forecasting model. Here the example of Batini and Haldane is followed by measuring the structural shocks by the forecast errors taken from the NIGEM model used by the Research Institute of the Finnish Economy. The series for the demand and labour market shocks of the member state are forecast errors of the equations describing the goods and labour markets of Finland. The series of the demand and labour market shocks of the rest of the union are created by aggregating the forecast errors from the corresponding equations of five large EMU countries (Germany, France, Spain, Italy, Netherlands) to single European shocks. The exchange rate shocks are drawn from the forecasting equations for the nominal exchange rate between ECU/USD. The period from which the forecasting errors are calculated is 1984:1 – 2001:1.

The covariance matrix is presented in Table 3.1 below. It can be seen that the member state (Finland) is hit by considerably larger shocks than the rest of the union. The variance of the supply shocks is roughly eight times larger and the variance of the demand shocks still four times larger than the corresponding union wide shocks. The demand and supply shocks, however, are still relatively small when compared to the size of the exchange rate shocks with their estimated variance of 23.7 %. The considerable volatility of the ECU/USD rate is well-known fact, while the large difference in the size of the supply and demand shocks between the member state and the rest of the union is a more surprising finding. Although Bayoumi and Eichengreen (1992) also found considerable asymmetries between the supply shocks of the core and periphery countries of the EC, the shocks hitting the periphery were only two

times larger than the shocks of the core countries. A partial explanation for the large variance of the Finnish shocks is provided by the years of the severe depression in Finland during the sample period. The more specialized production structure of Finland also provides an intuitively appealing explanation for the larger shocks its economy faces.

The signs of the off-diagonal elements of the covariance matrix reveal that the shocks to the labour market and aggregate demand are positively correlated between the whole union and the member state. The covariances between the union labour market and the member state total demand and, respectively, union total demand and the member state labour market, are in turn negative.

The autocorrelation structure of the shocks was examined by modelling the series as AR(1) models. The highest coefficient for the AR(1) term – approximately 0.5 in both cases- was found for the shocks to union aggregate demand and union wages. The exogenous shocks to the aggregate demand and wages in the member state showed less persistence with the AR(1) coefficients of 0.12 and 0.35. The rate of autocorrelation of the exchange rate shock is rather low, since the value of AR (1) coefficient takes a value of 0.24.

**Table 3.1. The covariance matrix of the structural shocks facing the union and the member state.**

$\mathcal{E}_{et}$	$\mathcal{E}_{et}$	$\mathcal{E}_{yt}$	$\mathcal{E}_{wt}$	$\mathcal{E}_{yt}^m$	$\mathcal{E}_{wt}^m$
$\mathcal{E}_{et}$	23.7	0.321	-0.746	-0.235	-1.40
$\mathcal{E}_{yt}$	0.321	0.578	-0.109	0.267	-0.45
$\mathcal{E}_{wt}$	-0.746	-0.109	0.322	-0.0862	0.46
$\mathcal{E}_{yt}^m$	-0.235	0.267	-0.0862	2.56	-0.46
$\mathcal{E}_{wt}^m$	-1.4	-0.45	0.465	-0.463	2.66

$\mathcal{E}_{et}$ ,  $\mathcal{E}_{yt}$ ,  $\mathcal{E}_{wt}$ ,  $\mathcal{E}_{yt}^m$  and  $\mathcal{E}_{wt}^m$  denote to the exchange rate shock, then aggregate demand shock facing the union, the supply shock facing the union, the aggregate demand shock facing the member state and the supply shock facing the member state, respectively.

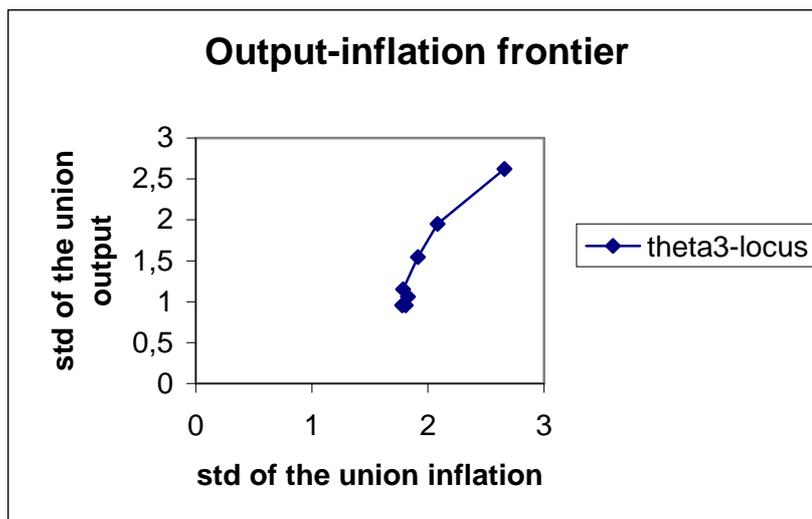
### 3.2. Simulations

The simulations were carried out by calculating 200 artificial series of 100 periods (quarters). In all the simulations the variability of the inflation and output is measured as standard deviations and all the simulations were made for Hodrick-Prescott filtered series to remove the effects of possible seasonality to the results. The performance of the different rules in the simulations was compared by the performance frontiers. A performance frontier means a locus of points in the space with the variability of the output and inflation as its axes. A performance frontier is drawn by changing the values of one (or two) parameters of the model, while holding the rest of the variables constant. Although we do not apply any explicit social welfare function to rank the outcomes of the different policies, it is evident that when moving south and west in the figures the welfare is improved, while when moving to north and east the welfare is deteriorated.

#### 3.2.1. The Union

The stochastic analysis is started by looking at the effects of changing the values of the exchange rate coefficient of the policy rule ( $\theta_3$ ) on the stability of the union area. In the performance frontier of Figure 3.1 the parameter  $\theta_3$  gets values of 0, 0.1, 0.25,

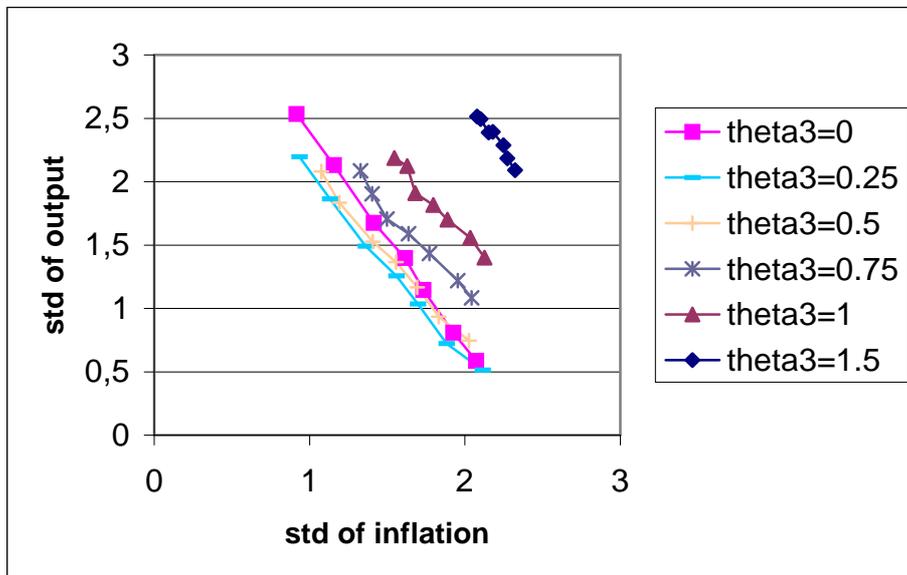
0.5, 0.75, 1, 1.5, while the rest of the parameters remain unchanged. There is a cluster of points in the other lower end of the frontier, showing that if  $\theta_3$  is given fairly modest values in the range of 0.1 to 0.5, the monetary policy results in superior performance for both inflation and output stabilization. At this level of  $\theta_3$  the standard deviation of output stands at about 1% and the standard deviation of inflation at about 1.8%. Note that when  $\theta_3$  gets a value of 0, neither the volatility of inflation nor output get its lowest values. On the other hand, if  $\theta_3$  exceeds 0.5 the volatilities of both inflation and output start to increase hand in hand so that with  $\theta_3=1.5$ , the standard deviations of both inflation and output exceed 2.5%. Thus, our results suggest that from the point of view of the whole union, the ECB to put moderate weight between 0.1 and 0.5 on targeting the exchange rate. With this policy the volatility of both the inflation and output takes its lowest value. The volatility of output however, is reduced more than that of inflation.



**Figure 3.1.** The performance frontier of the monetary union

The interaction of  $\theta_3$  with the other two parameters in the policy rule,  $\theta_1$  and  $\theta_2$ , in turn, is discussed with the Figure 3.2. As the policymaker can freely choose the values of  $\theta_1$  and  $\theta_2$ , it can also control the effects of an exchange rate change on inflation and output indirectly. Because the inflation in the reaction function is defined in consumer prices, the inflationary (deflationary) pressures induced by depreciation (appreciation) of the euro might be possible to offset simply by more aggressive

inflation targeting. Of course, there is a danger that the price stability would then be attained at the cost of larger output instability. The performance frontiers in Figure 4.2 are drawn assuming that when sliding along a frontier, the parameter pair  $(\theta_1, \theta_2)$  is given values (1.8, 0.2), (1.5, 0.5), (1.2, 0.8), (1, 1), (0.8, 1.2), (0.5, 1.5), (0.2, 1.8). Thus, when moving along a frontier, the weight placed on the inflation in the policy rule is decreased and the weight placed on the output gap increased. The different frontiers in turn correspond to different values given to the parameter  $\theta_3$ . These values are 0, 0.25, 0.5, 0.75 and 1. The figure shows that the optimal value of  $\theta_3$  lies somewhere between 0.25 and 0.5, regardless of the values of the parameter pair  $(\theta_1, \theta_2)$ .



**Figure 3.2.** The performance frontiers of the union, when the values of  $\theta_1$  and  $\theta_2$  are changed.

The Figures C.1 – C.6. in Appendix III are used to discuss, whether or not the optimal response to exchange rate is sensitive to the exact model specification. Each performance frontier in the figures is drawn by holding  $\theta_3$  constant and changing some of the other parameter values, one at a time. Overall, this sensitivity analysis suggests that the conclusions we drew about optimal exchange rate policy are not very sensitive to small changes in the parameterization of the model.

Figures C.1, C.2 and C.3 depict a set of performance frontiers calculated by varying the parameter values that characterize the openness of the union economy and the speed of the pass-through of the exchange rate to import prices. Figure C.1 depicts five inflation-output frontiers. Each frontier is drawn assuming that parameter  $\theta_3$  gets some of the values of 0, 0.25, 0.5, 0.75 or 1, while when moving along the frontiers the speed of pass-through of the exchange rate to import prices varies from an immediate pass-through to a pass-through lasting two quarters. The points on the extreme left represent the case of the lengthiest pass-through while the points at the extreme right end of the lines correspond to immediate pass-through. In terms of output stabilization the frontier corresponding to  $\theta_3 = 0.25$  slightly dominates the other policies. The variability of the inflation, on the other hand, seems not to be affected by the value of  $\theta_3$ . The highest volatility for the output is clearly obtained when  $\theta_3$  gets its highest values of 0.75 or 1. Interestingly, it is difficult to say which of the values of  $\theta_3 = 0$  and  $\theta_3 = 0.5$  results in a better performance.

Figure C.2 tells the sensitivity of the results on the share of foreign prices of the consumption prices of the union, which depends on the value of parameter  $\phi$ . When sliding along the frontiers,  $\phi$  gets values from 1 (totally closed economy) to 0.6 (fairly open economy). There seem to be only negligible differences between the performance implied by the best two policies of  $\theta_3 = 0$  and  $\theta_3 = 0.25$ , both in terms of inflation and output volatility. When the weight placed on stabilizing the exchange rate is increased beyond 0.25, however, the volatility of the output starts to increase again. The extent of the indirect price effect of the exchange rate changes depends on the parameter  $\alpha_4$ . Each of the frontiers of the Figure C.3 is drawn by giving  $\alpha_4$  values of 0.2, 0.4 or 0.6, and holding  $\theta_3$  unchanged. The frontiers corresponding to  $\alpha_4=0$  were totally omitted from Figure C.3, because  $\alpha_4=0$  implied instabilities in the simulations when combined with some values for  $\theta_3$ . The optimal monetary policy now incorporates giving  $\theta_3$  a value between 0.25 and 0.5. A closer look at Figure C.3 reveals however, that the standard deviation of inflation implied by the frontiers varies in a very narrow range between 1.75 and 1.9, while more significant differences are related to the variability of the output.

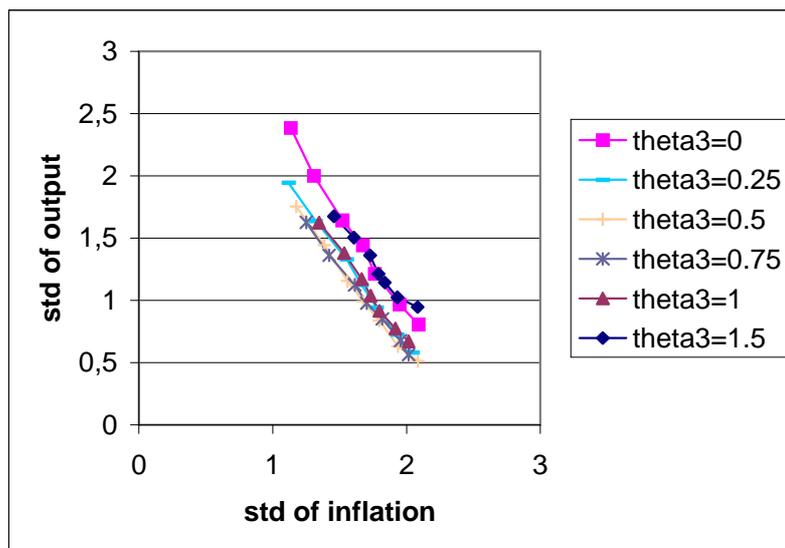
The sensitivity of the result can also be discussed in light of the assumptions made about the rate of forward-lookingness of the union economy. It depends on the values of parameters  $\alpha_1$  and  $\alpha_{12}$ , which measure the forward-lookingness of the goods markets and  $\chi_0$ , which captures the forward-lookingness of the wage-price process. Figure C.4, which plots the performance frontiers for  $\alpha_1$  shows that the output seems to reach its lowest standard deviation with  $\theta_3$  in a range of 0 to 0.5. The points of the frontiers corresponding to these values of  $\theta_3$  are clustered very close to each other so that it does not seem to make a difference which the exact value for  $\theta_3$  is in that range. When the value of  $\theta_3$  is increased beyond 0.5, the volatility of output starts to increase. The volatility of inflation still seems to be fairly unaffected by the values of  $\alpha_1$  and  $\theta_3$ , remaining at the level of about 2 %, regardless of the values of these parameters. The shape of the frontiers also reveals that in the more forward looking goods (that is, with relatively small  $\alpha_1$  and large  $\alpha_2$ ) market the volatility of output is lower regardless of the value of  $\theta_3$ .

Figure C.5 shows the performance frontiers when  $\chi_0$  is given values 0, 0.25 and 0.5<sup>21</sup> holding  $\theta_3$  constant. The excessively backward looking wage-price process with  $\chi_0=0$  corresponds to the left ends of the frontiers, whereas the baseline case of  $\chi_0=0.5$  corresponds to the right ends of the frontiers. The volatility of inflation seems to be sensitive on the forward-lookingness of the job markets so that the fully backward looking wage-price process results in considerably higher volatility of inflation than the moderately backward looking process (0.7 % vs. 2 %). The result can be explained by the important role of the contracting process in the determination of the prices in our model. When it comes to the optimal monetary policy, the frontiers of  $\theta_3 = 0$  and  $\theta_3 = 0.25$  again imply superior performance for output stability. For the inflation stability the value of  $\theta_3$  does not seem to make a difference.

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<sup>21</sup> If  $\chi_0$  gets a value above 0.5, the model did no more have a sensible solution.

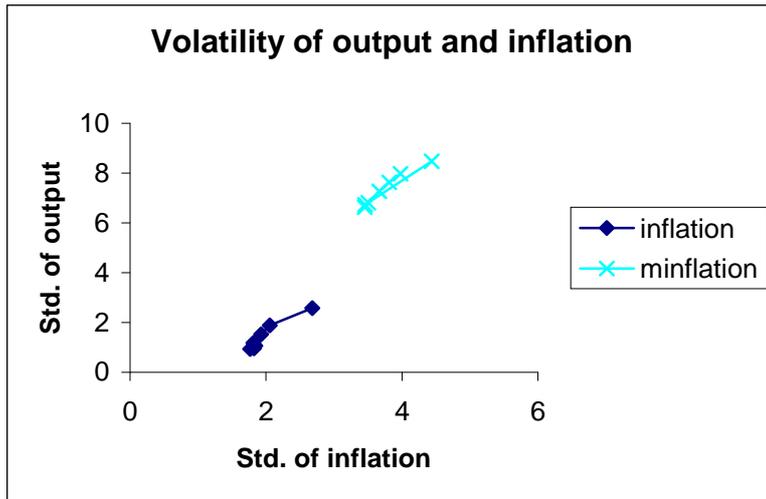
Figure 3.3 below finally sums up our discussion about the sensitivity of the results to the parameter values of the model. Figure is drawn assuming that the union is both more open with  $\phi = 0.8$ ,  $\alpha_4 = 0.4$  and more forward looking with  $\alpha_1 = 0.2$ . From the point of view of the union economy, the optimal value for  $\theta_3$  lies now somewhere between 0.25 and 1. Thus, for a more open economy than the euro area, our model would suggest more weight put on stabilising the exchange rate. The extreme policies of either  $\theta_3=0$  or  $\theta_3=1.5$  clearly result in inferior outcomes, however.



**Figure 3.3** The performance frontiers of the union when several parameters affecting its openness are changed at a time.

### 3.2.2 The member state

Figure 3.4 below plots the performance frontiers of both the union and the member state in the same figure. It is seen that the frontier of the member state is located relatively far to the north-east from the frontier of the whole union. Hence, although the structural differences between the member state and the rest of the union, after all, are rather small in the baseline parameterisation, the volatility of both inflation and output of the member state seem to be significantly larger than those of the union on average. The relatively poor performance of the member economy is related particularly to the volatility of its output. It lies between 6 % and 9 %, while the volatility of the member state inflation levels between 2 % and 3 %.

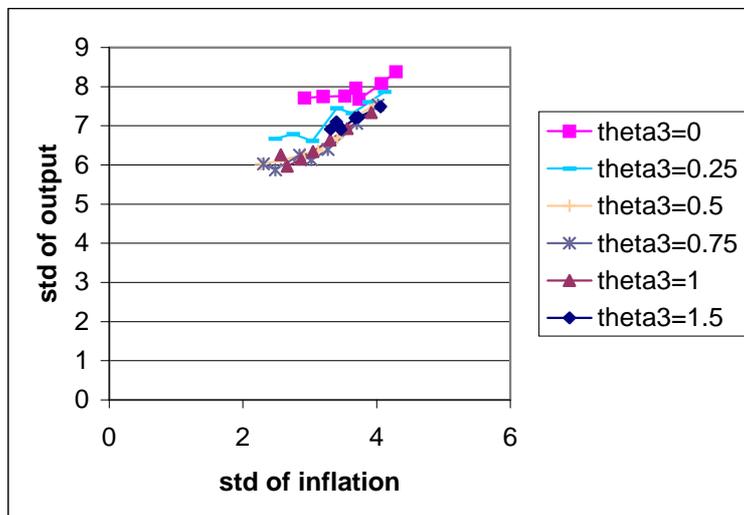


**Figure 3.4.** The performance frontiers of the member state and the rest of the union.

According to Figure 3.4, the ECB seems to have only limited possibilities to improve the performance of the economy of the member state by adopting a direct exchange rate target. From the point of view of the member state, the optimal value for the coefficient of the exchange rate ( $\theta_3$ ) lies somewhere between 0.75 and 1. This value for  $\theta_3$  would reduce the output variability of the member state approximately 1.5 percentage points and the inflation variability a half of a percentage point compared to the case of no direct exchange rate target at all. Increasing  $\theta_3$  beyond 1.0, however, becomes destabilizing, also from the point of view of the member state, as the volatility of both its inflation and output start to increase.

Figure 3.5 below is analogous to Figure 3.2. It illustrates how the relation between the central bank's exchange rate target (the value of  $\theta_3$ ) and the performance of the member state economy depends on the weights that the central bank sets on stabilising the inflation and output gaps (on the values of  $\theta_1$  and  $\theta_2$ ). Note that putting more weight on stabilizing inflation should now not be a substitute for targeting the exchange rate since the central bank targets the inflation and output of the whole union, not that of the member state. Putting more weight on exchange rate stabilization now makes both the output and inflation of the member state less volatile, whatever values  $\theta_1$  and  $\theta_2$  take. The distance between the best (corresponding to  $\theta_3 = 1$ ) and the worst ( $\theta_3 = 0$ ) performance frontier reveals that according to our model, the ECB could reduce the output volatility of the member

state roughly two percentage points and that of inflation roughly one percentage point by adopting the optimal weight to the direct exchange rate target. The volatility of output, in particular, remains, however, still far above that of the union as a whole.



**Figure 3.5** The performance frontiers of the member state when  $\theta_1$  and  $\theta_2$  are varied.

Why is then the macroeconomic performance of the member state relatively insensitive to the exchange rate policy? One explanation could be provided by the asymmetry in the shocks that hit the union and the member state. Since the differences in the parameter values between the union and the member state were relatively small, the differences in the performances of the two economies seem also to be caused by the differences in the business cycle pattern between the member state and the rest of the union. According to the estimated covariance matrix of the structural shocks, the shocks to the goods and labour markets of the single country seem to have considerably larger variance than the shocks facing the rest of the union. The issue of the asymmetric shocks is returned to later, when the sensitivity of the results on the covariance matrix of the shocks is examined.

The sensitivity of the results to changes in the parameter values describing the member state is discussed with Figures C.6 – C.11. The effects of varying the parameters determining the openness of the economy of the member state is first discussed with Figures C.6 – C.8. These figures tell us whether the weight that the central bank puts on stabilizing the exchange rate becomes more important to the

member state as it becomes more open against the world outside the union. The openness is measured as the share of goods ( $\kappa$ ) in its consumption bundle that the member state imports from outside the union, the sensitivity of the export demand of the member state on the exchange rate of the euro ( $\beta_4$ ), and the speed of the pass-through of the exchange rate to consumption prices in the member state. Figure C.9, in turn, illustrates the sensitivity of the results to the degree of integration of the goods market between the member state and the rest of the union. The degree of integration is measured by value of  $\beta_5$  that determines how sensitive the aggregate demand of the member economy is to the output of the union.

Overall, our qualitative conclusions about the ECB's optimal exchange rate policy, from the point of view of the member state, do not seem to be sensitive regarding small changes in the parameter values that describe the openness of the member economy in our model. The volatility of both the inflation and output are at their lowest level when  $\theta_3$  gets a value of 0.75 or 0.5, whereas putting zero weight on the exchange rate, for example, clearly implies less favourable outcome. Quantitatively, too, the results remain roughly unchanged for all the alternative parameter values considered. If the central bank would pursue optimal exchange rate policy from the point of view of the member state, that would lead to a two percentage point decrease in the standard deviation of output and roughly one percentage point in that of inflation.

Parameter  $\beta_5$  determines how deeply the goods markets of the member state are integrated with the goods markets of the rest of the union. The sensitivity of the performance of the member state economy to changes in  $\beta_5$  is shown in Figure C.9. It is seen that neither the volatility of inflation nor the output of the member state can be significantly reduced by integrating the goods markets closer together. All the points of the frontiers are concentrated close together. This finding is against the basic result of the literature on optimal currency areas, according to which integrating the goods markets of the countries of a currency area closer together effectively protects them from the problems of asymmetric economic shocks. Our previous conclusions concerning the optimal monetary policy however still remain valid. By adopting a

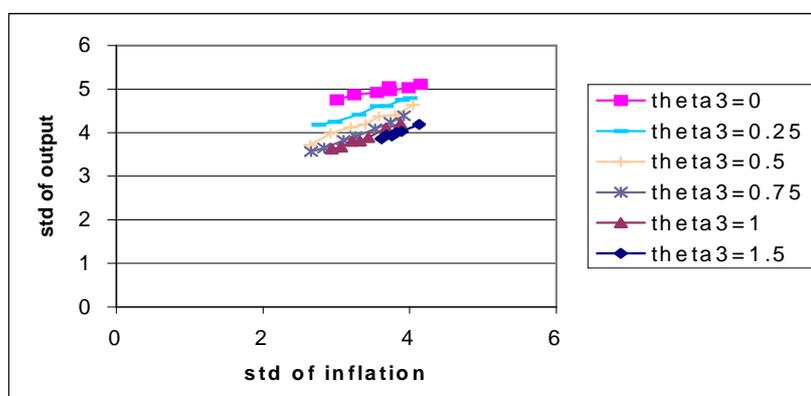
relatively active exchange rate policy with  $\theta_3$  set as 0.5 or 0.75 the ECB can reduce the standard deviation of member state inflation from around 4% to about 3% and the standard deviation of output from the level of 8% to the level of 6 %.

Figures C.10 and C.11 show the robustness of the results to the assumptions about the degree of forward-lookingness of the goods and labour markets of the member state. Figure C.10 at first shows that irrespective of the rate of forward lookingness of the goods market (values for  $\beta_1$  and  $\beta_2$ ), active exchange rate policy reduces the volatility of inflation and output. Moreover, it can be seen that the points in the frontiers that correspond to markedly forward looking goods market in the member state (relatively low values of  $\beta_1$  and high values for  $\beta_2$ ) are much closer to each other than the points that correspond to markedly backward-looking goods market. Thus, if the goods markets of the member state are significantly backward looking, the exchange rate policy seems to matter more to the performance of its economy.

Although the optimal value of  $\theta_3$  does not seem to depend on the rate of forward-lookingness of the goods market of the member state, the rate of forward lookingness in itself seems to affect to the volatility of the inflation and output of the member state. In simulations with  $\alpha_1 = 0.8$  and  $\psi_0 = 0.5$  the standard deviation of inflation took values around 3 % - 4 % and that of output between 6 % and 8%, irrespective of the parameter values describing either the monetary policy or the openness of the economy. When either the goods markets or the labour markets were assumed to be more forward-looking, the volatility of both inflation and output, however, decreased sharply. When either  $\alpha_1 = 0$  or  $\psi_0 = 1$ , the standard deviation of inflation was reduced near 2 % and the standard deviation of output near the level of 4 %.

Figure C.11 then confirms the robustness of our previous results to the assumptions made on the forward-lookingness of the labour markets. The worst outcomes again seem to result from the policy with no exchange rate target at all, while the best performance seems to be achieved with  $\theta_3$  set either to 0.5 or 0.75. In the simulations the value of  $\psi_0$  ranged only between 0.5 and 1, because at values below 0.5 the system exploded.

Figure 3.6 below sums up the discussions about the sensitivity of the results on the member state parameter values. The performance frontiers are now drawn with three parameter values differing from the baseline specification. The member state is now assumed to be both more open so that  $\beta_4 = 0.5$  and  $\kappa = 0.3$ . The goods markets are assumed to be markedly forward-looking so that  $\beta_1 = 0.2$ . As can be seen in Figure 3.6, the value of  $\theta_3$  mostly affects the volatility of output while it is unclear which policy guarantees the least volatile inflation. Note, however, that the best performance again seems to be achieved with fairly moderate policy with  $\theta_3$  set equal to 0.75 or 1.

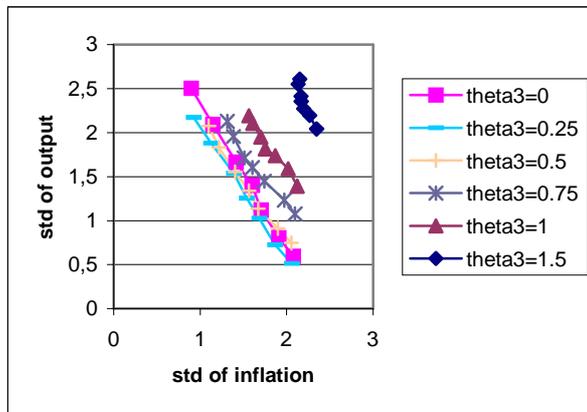


**Figure 3.6** The frontiers of the member state when several parameters describing its economy are changed.

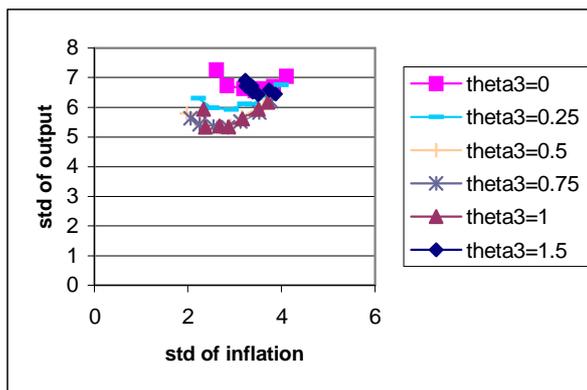
### 3.2.3. Role of the time series properties of the shocks

So far the robustness of the results has been examined only with respect to the parameter values of the model. The sensitivity of the results on the time series properties of the estimated structural shocks used in the simulations is discussed with Figures 3.7 to 3.10 below, which are analogous to Figures 3.2 and 3.5 so that when sliding along a frontier,  $\theta_1$  and  $\theta_2$  get different values while  $\theta_3$  remains the same. The structural shocks, however, now have different covariance matrices than the shocks in the baseline model. In Figures 3.7 and 3.8 the variances of the output and labour market shocks of the member state have been assumed to be smaller than in the baseline model. Figures 3.9 and 3.10 in turn are drawn assuming that all the variances

of the shocks are of equal size and strongly contemporaneously positively correlated with each other.



**Figure 3.7** The performance frontiers of the union when the variance of the member state shocks are assumed to be smaller than in the baseline case.

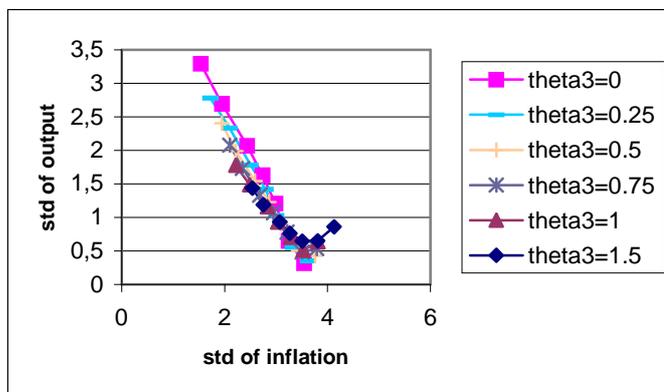


**Figure 3.8** The performance frontiers of the member state when the variance of the member state shocks are assumed to be smaller than in the baseline cases.

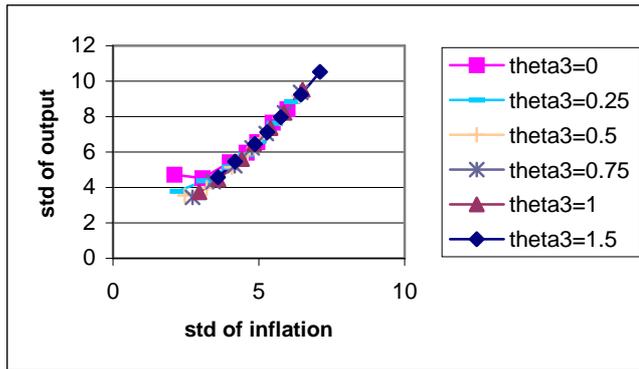
Comparing Figures 3.7 and 3.8 with Figures 3.2 and 3.5 shows that the performance of the member state is somewhat sensitive to the variance of the structural shocks its economy faces. If the variances of the aggregate demand and the labour market shocks of the member state is reduced to 1.1 and 0.9 percentage points respectively, the standard deviation of the member state output decreases to the level of five percentage points, while the standard deviation of its inflation remains at the previous levels around 2 - 3 percentage points. The previous conclusions about the central bank's optimal response to the exchange rate changes also remain unchanged. From the point of view of the member state the optimal monetary policy still would include a value between 0.5 – 1 put on  $\theta_3$ , while from the point of view of the union economy

the value of  $\theta_3$  should lie somewhere at the level of 0 – 0.5. It is expected that the results for the union remain unchanged, since the central bank does not react to shocks in the markets of the small member state.

According to Figures 3.9 and 3.10, on the other hand, when the shocks become highly correlated with each other, the value of  $\theta_3$  loses its significance. It is seen in Figure 3.10 that all the six performance frontiers of the member economy are of almost equal shape. The performance frontiers of the union in Figure 3.10 also look much alike. From Figure 3.10 it can also be seen that when the shocks are highly correlated, it is possible to still reduce the volatility of output of the member state. The left ends of the performance frontiers (corresponding to values around 1.5 for the inflation coefficient  $\theta_1$  and very low values of the output gap coefficient  $\theta_2$ ) imply that the standard deviation for member state output can be reduced to somewhere near the level of 3 %. On the other hand, if the parameters of the reaction function are not near their optimal levels, the model implies rather high volatilities for the output and inflation of the member state.



**Figure 3.9** The performance frontiers of the union when the structural shocks between the member state and the union are strongly correlated.



**Figure 3.10** The performance frontiers of the member state, when the structural shocks between the member state and the union are highly correlated.

#### 4. CONCLUSIONS

Using a small calibrated macromodel, this study has examined whether it would be optimal for the European Central Bank to adopt an explicit target for the real exchange rate of the euro. From the point of view of a single member state, the problem is a part of the ongoing discussion whether the EMU can be considered as an optimal currency area. Thus, the question has been discussed not only from the viewpoint of the performance of the union economy as a whole, but also from the viewpoint of a single small member state. The parameters describing the economy of the small country are assumed to differ from the union-wide averages in two ways. First, the economy is more open towards the world outside the union, and secondly, the exogenous shocks that hit the member state economy differ from the shocks hitting the rest of the union.

The results suggest that from the point of view of the union economy as a whole, the central bank should put at most moderate weight on the direct exchange rate target, which is in line with the previous studies by Ball (1998), Taylor (1999) and Svensson (1998). The relatively more open small member state considered would benefit somewhat from the active exchange rate policy. Thus, the study suggests that losing monetary independence may be somewhat costly for a small, relatively open EMU member state. It does not seem possible, however, to reduce the volatility of the inflation and output of the member state to the same level as the whole union with only active exchange rate policy. In addition, the considerable volatility of the

member state output seemed to result more from the size and the symmetry of the structural shocks that hit its economy than from its greater degree of openness.

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## APPENDIX I

### The calculation of the unconditional variances of inflation and output

The conditional moments were calculated from simulated series. The simulation horizon of each series was 100 periods and the simulation was repeated  $x$  times, so that totally  $100x$  sets of solution values was available for the calculation of the unconditional moments.

Denote the estimated covariance matrix of the structural shocks by  $m \times m$  matrix  $\hat{\Sigma}$ , computed as  $(1/T)\hat{Z}\hat{Z}'$ , where  $\hat{Z}$  is the  $m \times T$  matrix of the estimated values of the exogenous structural shocks. If the  $z$  shocks are IID distributed, the set of shocks used in the stochastic simulation can be obtained from a simple transformation of  $\hat{\Sigma}$ . To generate the shocks, the matrix  $\hat{\Sigma}$  is decomposed into two triangular matrices that, when calculated together, yield the original matrix  $\hat{\Sigma}$ . If the rank condition holds ( $T > m$ ), there exists a unique such decomposition,  $\hat{\Sigma} = \mathbf{P}\mathbf{P}'$  such that  $\mathbf{P}$  is lower triangular and  $\mathbf{P}'$  is upper triangular.

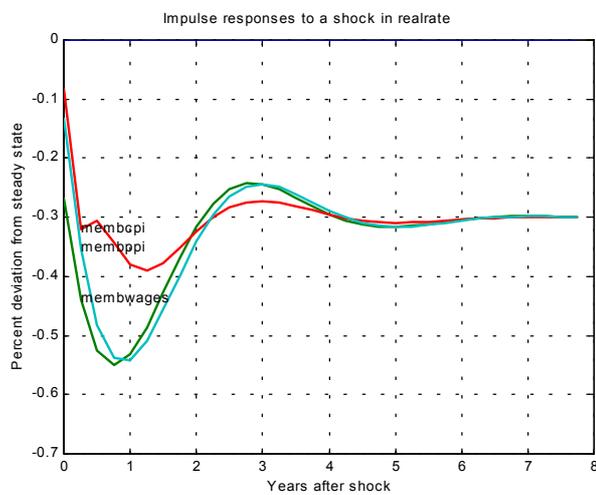
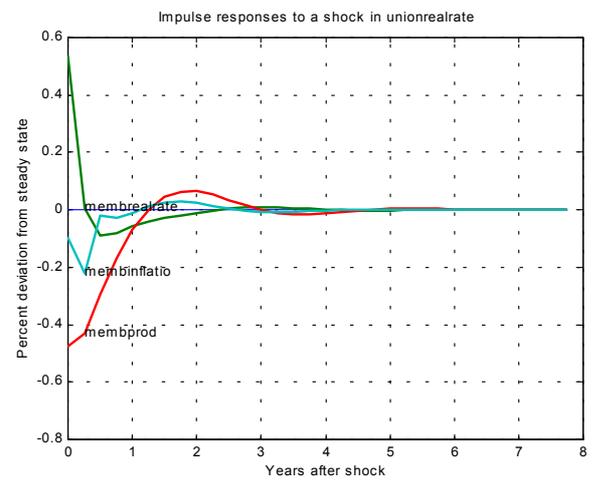
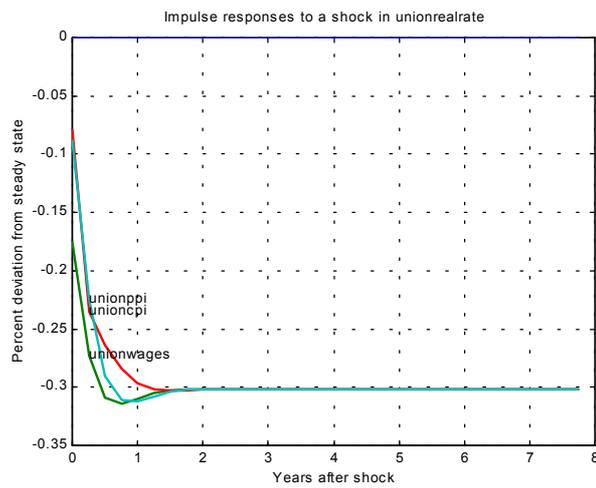
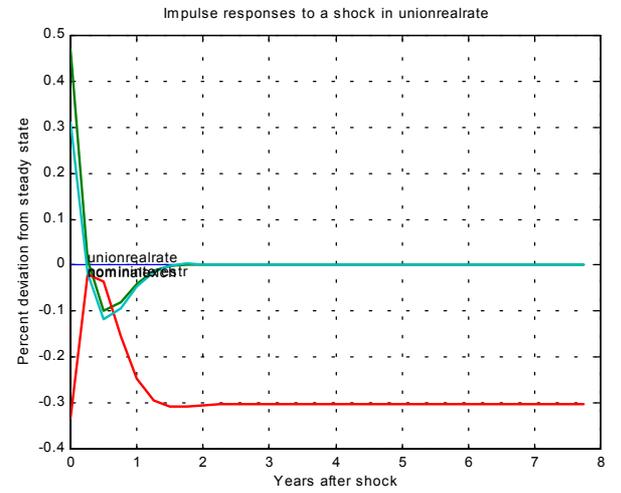
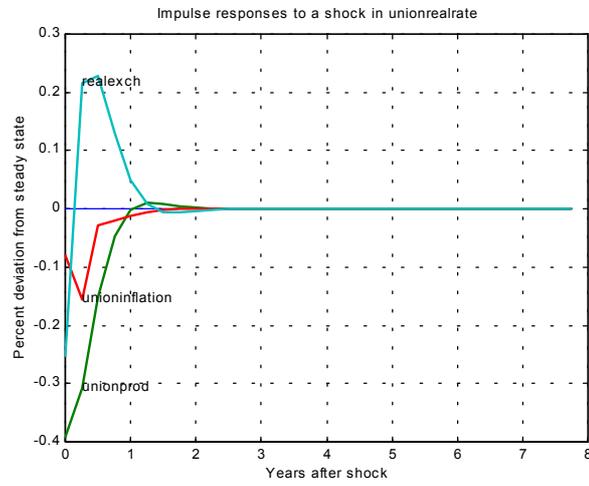
The initial ( $t=0$ ) values for the exogenous shocks  $z$  were calculated by first drawing  $m$  values from a standard normal distribution. Let's denote the vector of these values by  $\mathbf{e}_1$ . These white noise disturbances were then turned into structural shocks by  $\mathbf{z}_1^* = \mathbf{P}\mathbf{e}_1$ . Using the values  $\mathbf{z}_1^*$  and the equations of the recursive law of motion, it is then possible to calculate values of  $\mathbf{x}_1$  and  $\mathbf{y}_1$ . Another draw from a normal distribution is then made for calculating values for  $\mathbf{z}_2^*$ ,  $\mathbf{x}_2$  and  $\mathbf{y}_2$ . The process is then repeated until  $N$  values are obtained.

Assuming that the historical residuals are independently and identically distributed implies that in the equation all elements in the matrix  $\mathbf{N}$  equal to zero. In case that the historical residuals are autocorrelated, the residuals have to be "whiten" before calculating the covariance matrix. Suppose, for example, the first order autocorrelation  $\mathbf{z}_t = \mathbf{N}\mathbf{z}_{t-1} + \mathbf{v}_t$ ,  $\mathbf{v}_t \approx \mathbf{N}(\mathbf{0}, \Sigma_v)$ .  $\hat{\Sigma}_v = \mathbf{P}^*\mathbf{P}^{*}$ . Now the value for  $\mathbf{z}_1^*$  is obtained from  $\mathbf{z}_1^* = \mathbf{P}^*\mathbf{e}_1$ , where  $\mathbf{P}^*$  is obtained from the Choleski factorization  $\hat{\Sigma}_v = \mathbf{P}^*\mathbf{P}^{*}$ . The value for  $\mathbf{z}_2^*$  is then calculated from  $\mathbf{z}_2^* = \mathbf{N}\mathbf{z}_1^* + \mathbf{P}^*\mathbf{e}_2$ .

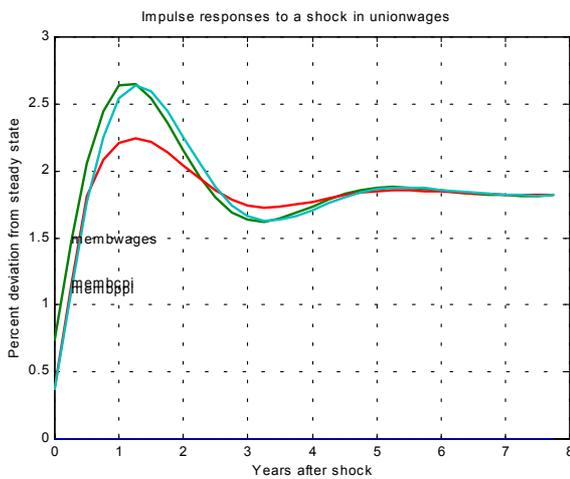
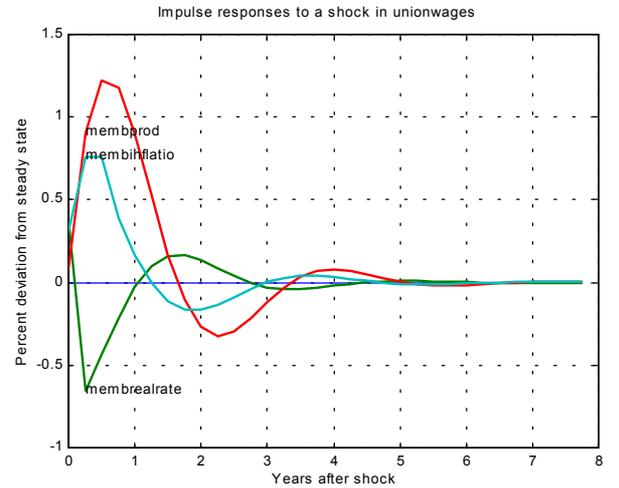
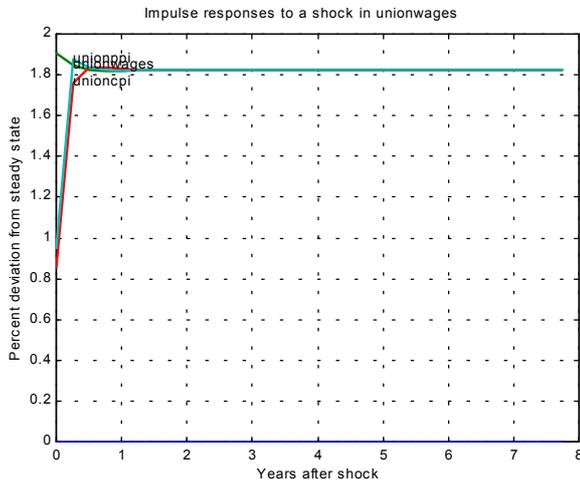
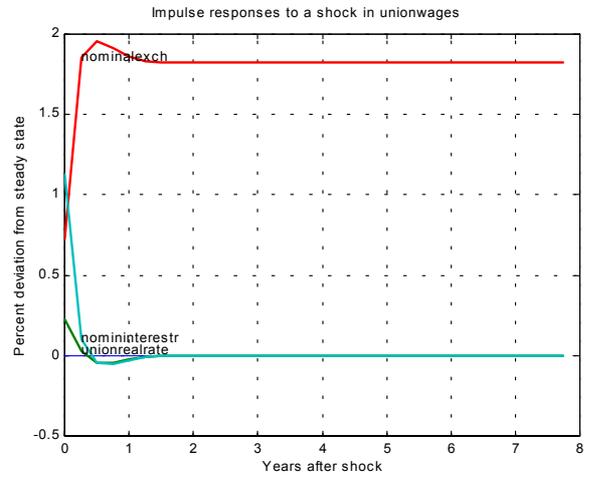
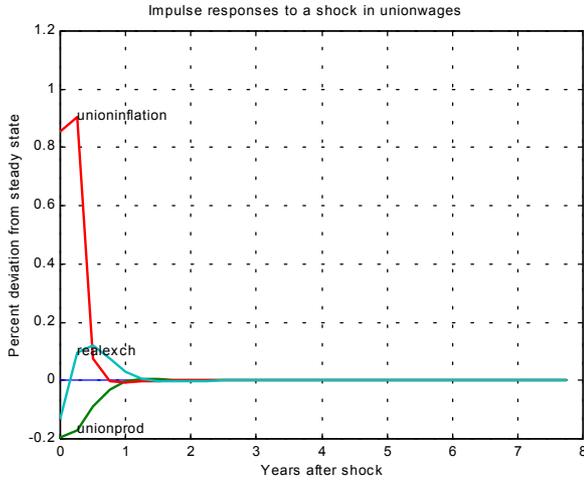
## APPENDIX II

### The impulse responses of deterministic analysis

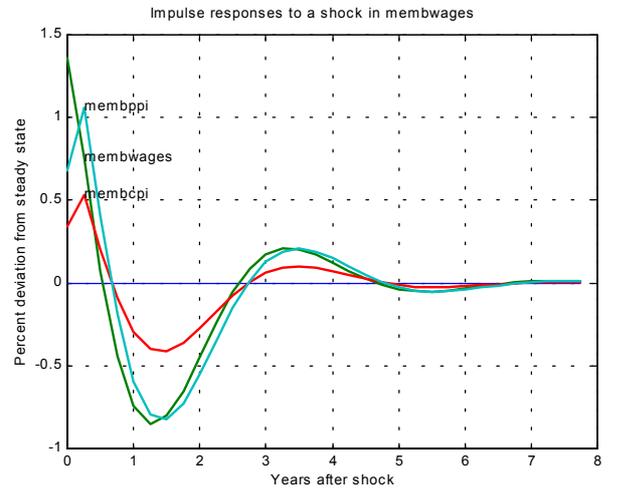
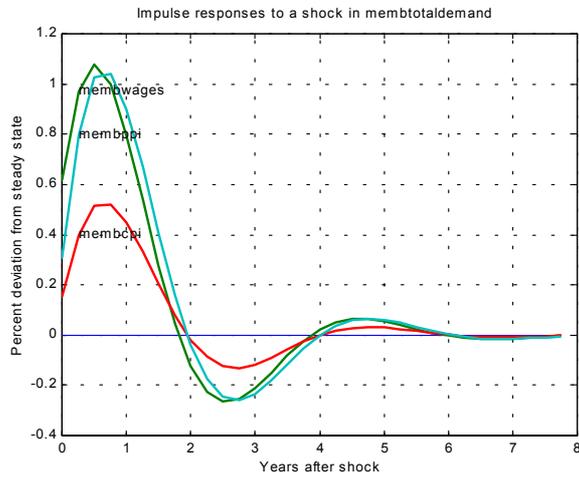
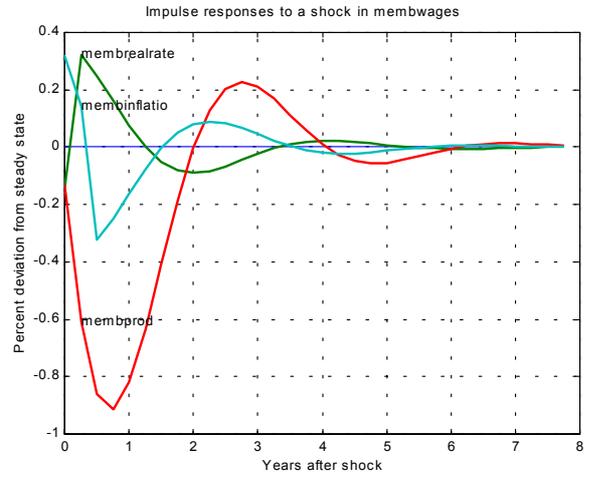
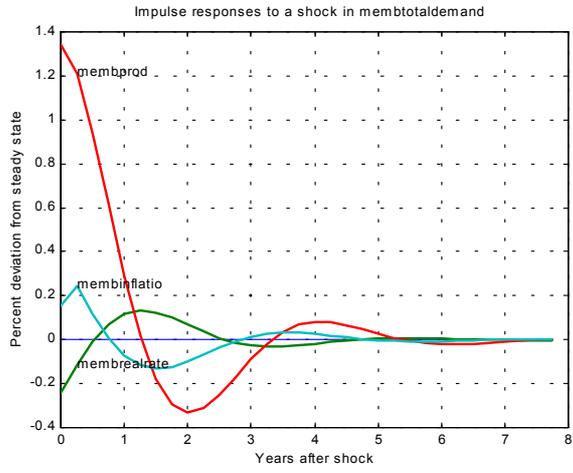
#### Interest rate shock



# Wage shock



## Demand and wage shock in the member country



### APPENDIX III The performance frontiers

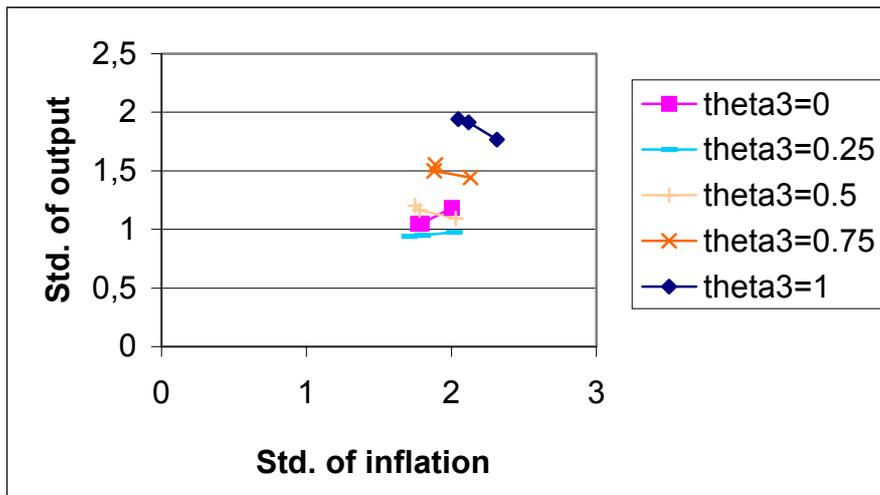


Figure C.1. The effects of changing the speed of pass-through in the union area.

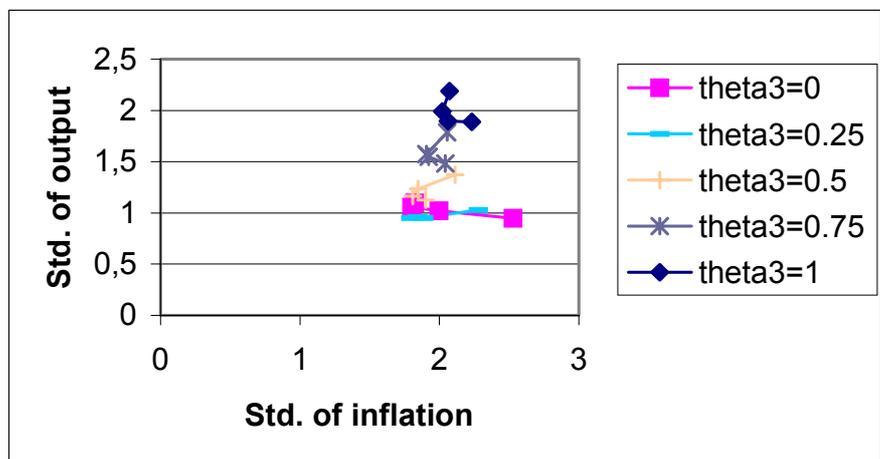


Figure C.2. The effects of changing the weight of import prices ( $\phi$ ) in the union consumption basket.

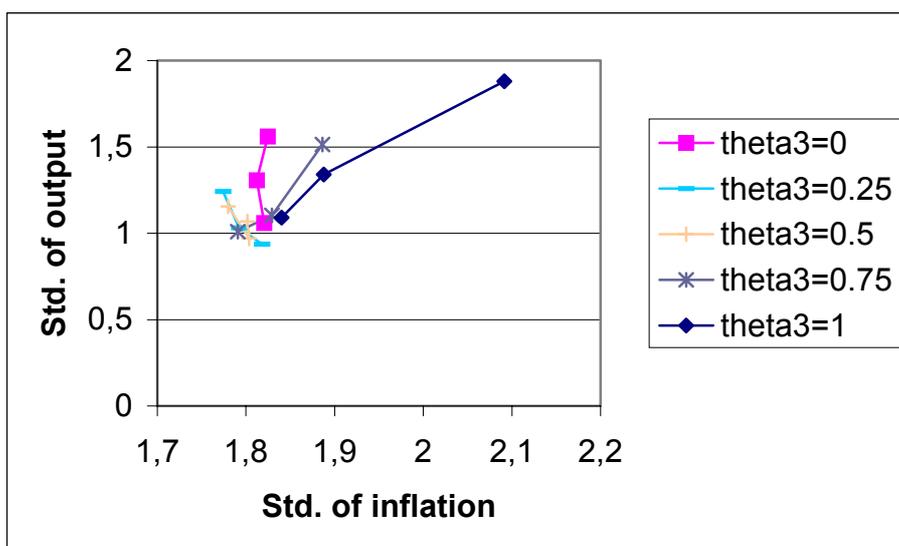


Figure C.3. The effects of changing the value of  $\alpha_4$ .

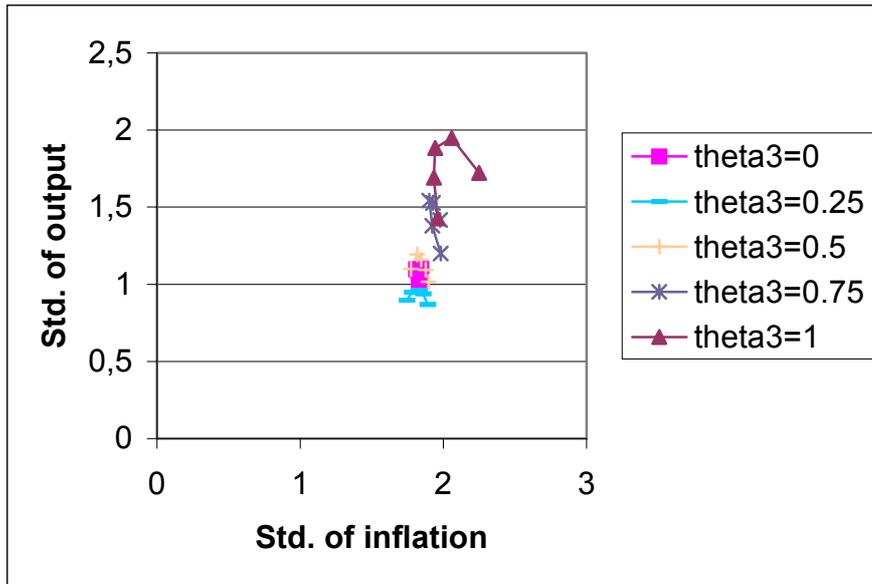


Figure C.4. The significance of the rate of forward lookingness of the goods market of the union (the value of  $\alpha_1$ ).

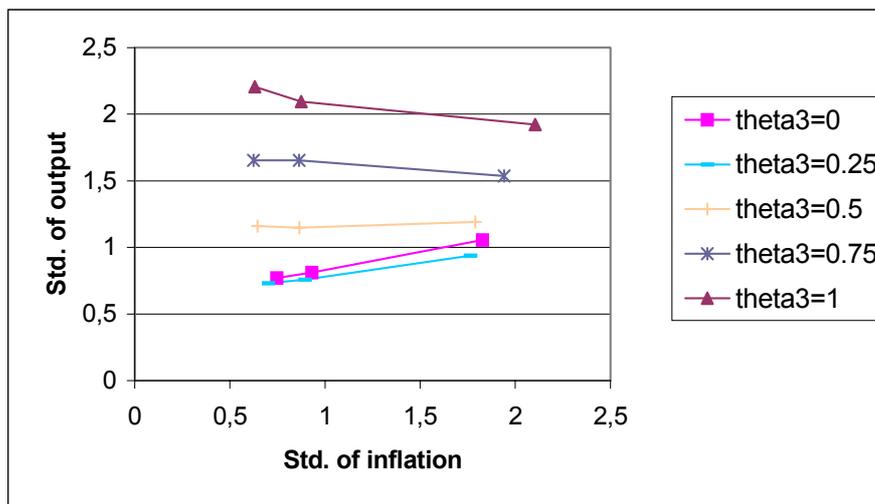


Figure C.5. The effects of the rate of forward lookingness of the labor markets of the union (the value of  $\chi_0$ ).

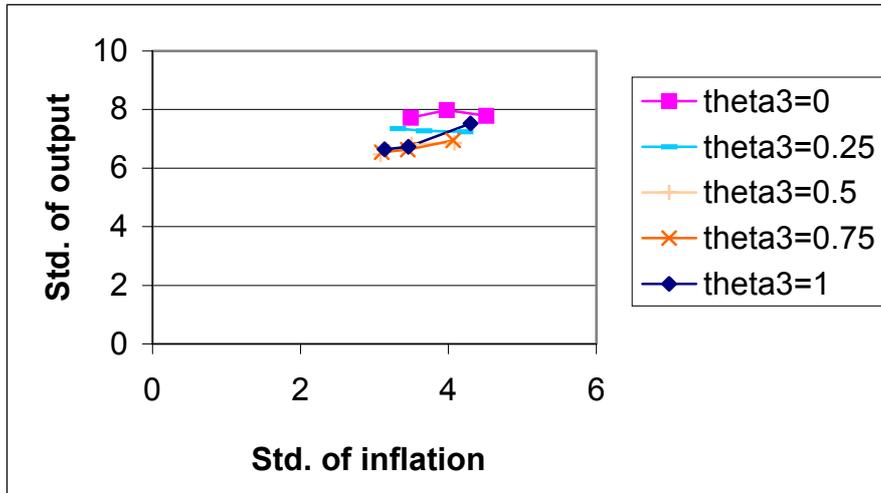


Figure C.6. The effects of changing the speed of pass-through in the member country.

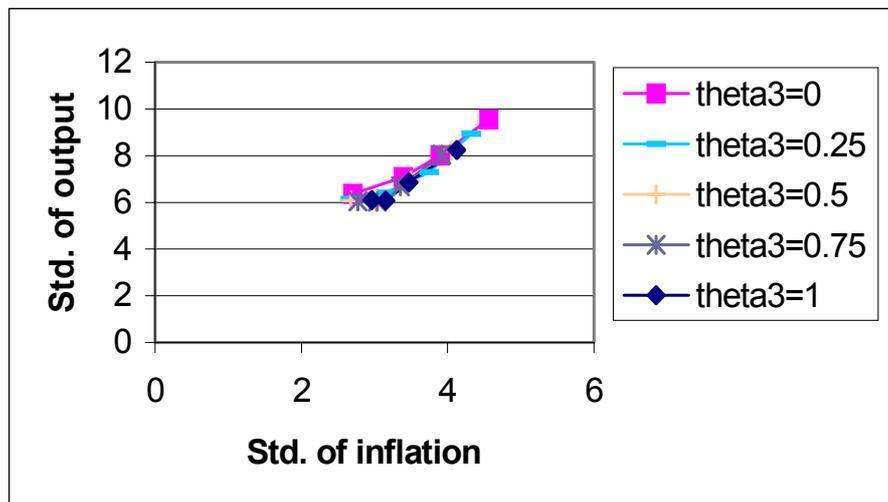


Figure C.7. The effects of changing the weight of import prices ( $\phi$ ) in the consumption basket of the member country.

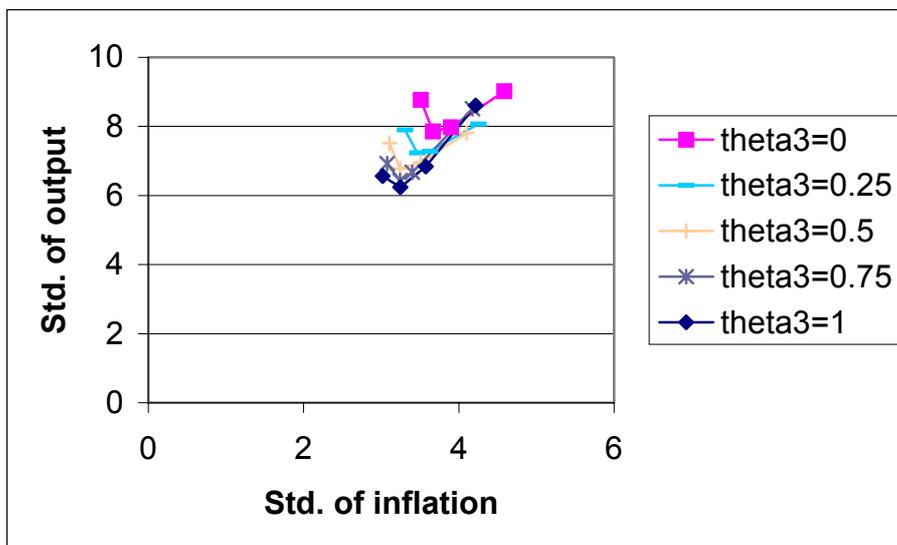


Figure C.8. The effects of changing the value of  $\beta_4$ .

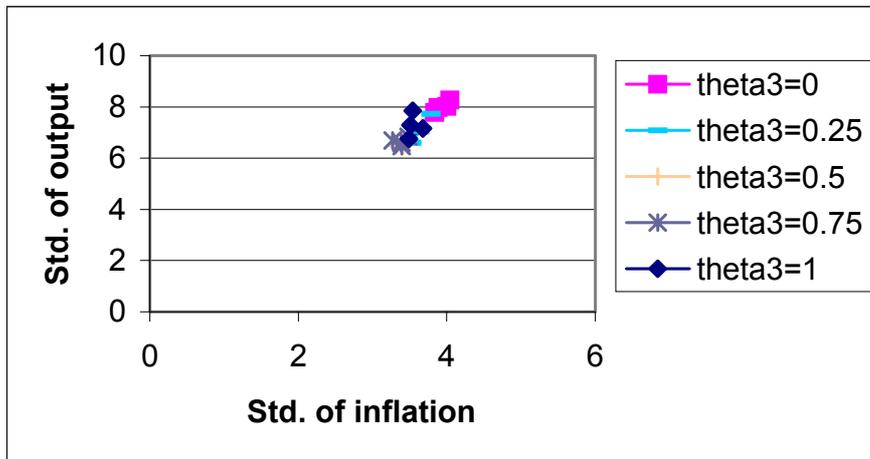


Figure C.9. The effects of changing the value of  $\beta_5$ .

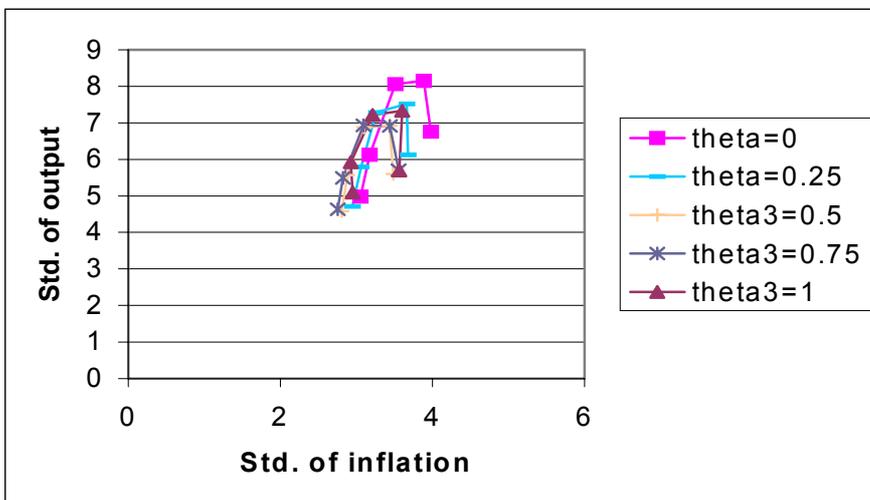


Figure C.10. The significance of the rate of forward lookingness of the goods market of the member country (the value of  $\beta_1$ ).

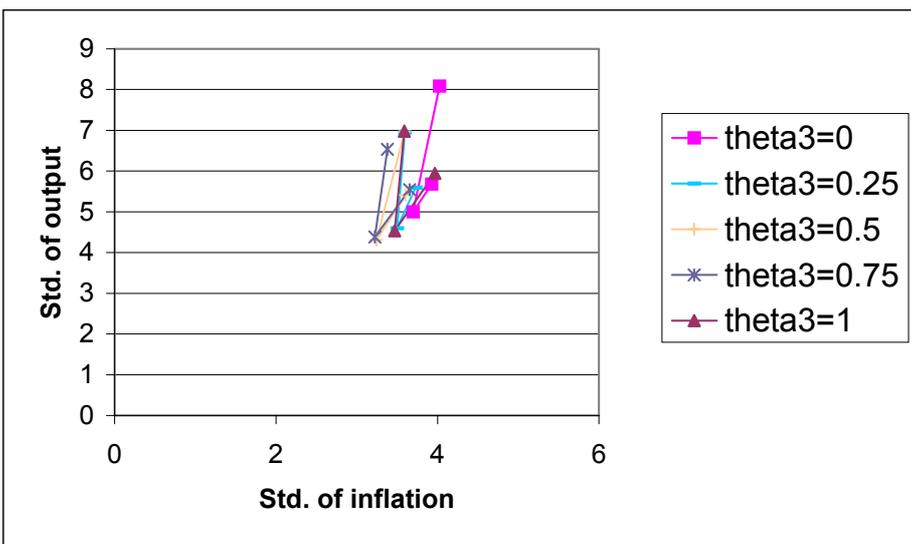


Figure C.11. The effects of the rate of forward lookingness of the labor markets of the member country (the value of  $\psi_0$ ).

## CHAPTER 5

### **THE INFORMATION CONTENT OF THE DIVISIA MONEY IN FORECASTING INFLATION IN THE EURO AREA**

#### **Abstract**

By means of a simulated out-of-sample forecasting exercise, the paper investigates whether the synthetic Divisia M3 monetary aggregate outperforms its simple sum M3 counterpart in forecasting euro area inflation dynamics. In addition to the growth rates of the nominal money stocks, the performance of the real money gap and monetary overhang series calculated for both sort of monies are also discussed. According to the results, some of the Divisia M3 money based monetary indicators seem to contain more information about the change of the future inflation than their counterparts based on the simple sum M3 money, while none of the simple sum M3 based indicator outperformed its Divisia money counterpart. Interestingly, and in contrast to some previous findings obtained with the simple sum M3 data, the growth rate of the Divisia money yielded the best forecasts, also outperforming the real money gap and monetary overhang measures calculated for the Divisia M3 money.

**KEY WORDS:** Divisia monetary aggregate, P-Star, money demand, liquidity

JEL Classification: E31, E41, E47, E52

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## 1. INTRODUCTION

In the long run, inflation is always and everywhere a monetary phenomenon. This traditional view is clearly reflected in the ECB's two-pillar strategy. While the first of the ECB's pillars refers to a broadly based assessment of the risks to price stability in the Euro area, the second pillar establishes a prominent role for the growth rate of nominal M3 money as an information variable about future inflation. There are, however, some theoretical problems related to the ECB's focus on only traditional monetary aggregates such as M1, M2 and M3. The traditional monetary aggregates are built simply by summing up their component assets, without explicitly paying attention to the different degree of liquidity of the components. This is equivalent to assuming that the component assets are perfect substitutes for each other and thus, the simple sum aggregates become upward biased estimates of the degree of liquidity of the economy.

A promising solution to this aggregation problem is provided by the Divisia monetary aggregates, monetary quantity index numbers based upon both the index number theory and the economic aggregation theory. The Divisia aggregates are computed as weighted averages of their components so that the weights are derived from economic theory with optimizing agents. The weight of a given asset is associated with the opportunity costs of holding that asset, which measures the liquidity of the asset. Intuitively, the Divisia monetary aggregates then measure the flow of liquidity services in the economy.

The research problem of this study is then to examine, whether the Divisia M3 monetary aggregate calculated for the euro-area contains more information on the future euro-area inflation than the traditional M3 money. If this really is the case, the Divisia monetary aggregates might provide a useful indicator variable for the ECB to be used instead / along with the traditional aggregates for forecasting inflation. Instead of only comparing the relative forecasting performance of the nominal growth rates of the two monies, also the forecasting performance of a set of monetary indicators measuring the excess liquidity in the economy (the real money gap and the monetary overhang) are examined. As an econometric method I use simulated out-of-sample forecasting that has recently been used to similar purposes by Stock and Watson (1999) and Altimari (2001).

Looking at the previous literature on the relation between money and inflation in the economy, according to the quantity theory of money, there should exist a one-to-one relationship between money and inflation in the long run. When looking at the previous empirical studies on the subject, mainly focused on the information content of the traditional monetary aggregates, the relation between money and inflation in horizons relevant for monetary policy-making is debatable, however. De Grauwe and Polan (2001), for example, examine empirically the validity of the basic propositions of the quantity theory of money and conclude that even the long-run relation between inflation and the growth rate of money breaks down for low inflation countries.

Moreover, the prominent role of the growth rate of M3 money given in the ECB's monetary policy is strongly criticized in Svensson (2000), mainly because of its lack of predictive power for inflation<sup>1</sup>. On the other hand, Altamari (2001), Gerlach and Svensson (2001) and Trecroci and Vega (2000) study whether the real money gap, the measure for the abundance of real money in the economy derived from the so-called P-star model, contains additional information in predicting the Euro area inflation. All these studies confirm that measures derived from the P-star model really have predictive value for CPI inflation, although Altamari's results do not support giving a strong role particularly to the real money gap. Svensson (2000) also refers to the possible information content of the monetary indicators derived from the P-star model, emphasizing the important distinction between the *level of real* money focused in the P-star model and the *growth rate of nominal* money that the ECB actually targets.<sup>2</sup> King (2002), Nelson (2002) and Meltzer (2001), in turn discuss the possibility that the real money balances may play a role in the transmission process of monetary policy that is independent of short term interest rates.

The information content of the Divisia money in predicting inflation in the euro area, in turn, is discussed in Stracca (2001) and Reimers (2002). Both studies suggest that the Divisia money actually has additional predictive power for the euro area inflation. Stracca examines the predictive power of the growth rate of real Divisia money in forecasting future inflation and output with linear models. Stracca both estimates an equation for the demand of Divisia

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<sup>1</sup> Moreover, it may make the ECB's policy less transparent if the significance of the reference value of M3 growth for ECB's policy is highlighted in rhetoric, while at the same time the ECB in practice ignores even persistent deviations of M3 growth from the reference value (see e.g. Allsopp, 2001).

<sup>2</sup> On the other hand, Svensson criticizes the P-star model for a lack of solid microfoundations and its dependence on the unreliable estimates of both real money and output gaps.

money in the euro area and builds an unrestricted VAR model with changes in the real Divisia money as one of the variables. From the impulse responses of the VAR model, Stracca concludes that the changes in real Divisia money carry some information about the future inflation and output that is not contained in the stock of M3 money.

Reimers (2002) in turn, examines the properties of several alternative series for the euro area Divisia money, based on slightly differing methods used to aggregate the national monetary series to a single euro-area wide aggregate. Reimers examines the information content of both the growth rate of the Divisia money and a Divisia money based P-star measure for predicting inflation of the euro area. The results remained somewhat mixed, depending e.g. on the exact aggregation method used and on whether the inflation was defined as a GDP deflator or HICP inflation. Reimers, however, concludes that it is possible to estimate a stable and reasonable looking money demand equation for the Divisia money in the Euro area. Further, both the in-sample and the out-of-sample forecasting exercises showed that both the Divisia money and the traditional M3 money have a connection with both inflation and output gap in the euro area.

Dorsey (2000) examined the relative information content of the Divisia and the simple sum aggregates in predicting inflation with the US and German data, using a simple artificial neural network (ANN) model. Dorsey concludes that the Divisia money consistently dominates its simple sum counterparts in explaining inflation. The ANN model was, in addition, found to be fairly stable in the sense that the out-of-sample forecasts did not deteriorate rapidly when the forecast horizon was extended.

## 2. DIVISIA MONEY

### 2.1. Theoretical background of the Divisia money

The definition of the Divisia monetary aggregate starts from the standard optimization problem of a representative consumer with money in the utility function<sup>3</sup> so that the utility function of a consumer can be written as

$$u = u(\mathbf{c}, \mathbf{x}),$$

where  $\mathbf{c}$  is a vector of the consumption goods (possibly including leisure) and  $\mathbf{x}$  is a vector of the quantities of the different monetary assets. Suppose that the utility of a consumer is separable in money so that the consumer's sub-utility from monetary services can be represented by economy's transaction technology over monetary assets denoted by function  $Q(\mathbf{x})$ , which is homogenous of degree one. Now the consumer's choice over the quantities of the monetary assets is reduced to maximizing  $Q(\mathbf{x})$  w.r.t the components of  $\mathbf{x}$  under a budget constraint  $\mathbf{p}'\mathbf{x} = m$ , where  $p_i$ 's stand for the user costs of the corresponding assets.<sup>4</sup> Taking the first order conditions, after some manipulation, results in a formula for the growth rate of the Divisia money:

$$(2.1) \quad d \log Q(\mathbf{x}) = \sum_{i=1}^n w_i d \log x_i,$$

where  $x_i(t)$ 's denote the components of the Divisia aggregate and  $w_i$ 's stand for the expenditure weights, obtained from the formula:

$$w_i(t) = p_i(t)x_i(t) / \sum_{i=1}^n p_i(t)x_i(t),$$

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<sup>3</sup> The derivation of the Divisia money here follows Barnett (2000).

<sup>4</sup> Here we implicitly assume that the consumers either are risk neutral or that the consumers face no risk regarding the utility they derive from the monetary services. Naturally, it would be possible to introduce uncertainty into the model so that the consumers maximise expected utility over the monetary services, that is,  $E_t(Q(\mathbf{x}_t))$ .

in which the user cost  $p_i$  is defined as the differences between the own yield of the asset  $i$  and the yield of a pure investment asset. The pure investment asset here means an asset that provides investment services, but no liquidity services at all. Rewriting Equation (2.1) as an explicit differential equation yields:

$$(2.2) \frac{d \log Q(\mathbf{x}(t))}{dt} = \sum_{i=1}^n w_i(t) \frac{d \log x_i(t)}{dt}.$$

The level of the Divisia money is obtained by solving Equation (2.2). w.r.t  $Q(t)$ :

$$(2.3) Q(t) = \exp \int_{\tau=0}^t \left[ \sum_{i=1}^n w_i(\tau) \frac{d \log x_i(\tau)}{d\tau} \right] d\tau$$

It can be seen in Equation (2.1) that the user cost  $p_i$  of holding an asset  $i$  is not the weight of the level of the asset  $i$  in the Divisia monetary aggregate. Instead,  $p_i$  should be interpreted as the contribution of the yield of the asset  $i$  as far as the changes of  $p_i$  induce changes in the components  $x_i$  of the Divisia index.

## 2.2. Building the synthetic aggregates

When examining the properties of the Divisia money in the context of the whole euro area we face an additional problem of how to aggregate the national monetary data into a single European Divisia monetary index number<sup>5</sup>. One way to construct the time series for the Divisia money in the euro area would be to assume one representative agent for the whole area, in which case the Divisia money for the Euro area would be computed as

$$(2.4) \Delta \ln Q_t = \sum_{i=1}^k \sum_{j=1}^n w_{ijt} \Delta \ln x_{ijt}, \text{ where}$$

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<sup>5</sup> Our discussion about the aggregation problems in constructing an euro area wide Divisia money is based on Stracca (2001) and Reimers (2002).

$w_{ij}$  denotes the expenditure weights of the component assets  $x_{ij}$ ,  $k$  is the number of the member countries and  $n$  is the number of the component monetary assets in the Divisia aggregate. Another possibility would be to first build the aggregates separately for each of the eleven member countries. The aggregate of the Divisia money in the euro area would then be obtained as a weighted average of the stocks of the Divisia moneys in the member countries. Formally, writing Formula (2.1) for the growth rate of Divisia money in discrete form, the formula for the optimal aggregation method for the Euro area Divisia money ( $Q_t$ ) is:

$$(2.5) \Delta \ln Q_t = \sum_{j=1}^k \rho^j \Delta \ln Q_t^j = \sum_{j=1}^k \rho^j \sum_{i=1}^n w_i^j \Delta \ln x_i^j,$$

where  $\rho^j$  denotes the weights put on the Divisia money stocks of the different member countries so that  $\sum \rho^j = 1$ .<sup>6</sup>

Because sufficiently long time series for the user costs for every component asset were not available for each euro area country, it was impossible to calculate all the expenditure weights  $w_i^j$ . Thus calculating Divisia money series separately for each member state was not feasible. Stracca (2001) solved the problem of calculating a union wide Divisia money aggregate by approximating the true value of the area-wide Divisia money stock by the *synthetic* Divisia money. It is defined by Formula (2.6) below.

$$(2.6) \Delta \ln Q_t = \sum_{i=1}^n \left( \sum_{j=1}^k \rho^j w_i^j \right) \sum_{j=1}^k \rho^j \Delta \ln x_i^j,$$

where  $k$  is the number of such member countries, for which the user costs of a given monetary asset  $i$  was available. The expression in the brackets tells now the average expenditure weight of the monetary asset  $i$ , based on the user cost from only such countries for which the data was available. The expression  $\sum_{j=1}^k \rho^j \Delta \ln x_i^j$  gives the average change of the holdings of the asset  $i$  in the euro area. The contribution of the asset  $i$  to Euro area wide Divisia money is then obtained by multiplying the average degree of liquidity by the average holdings of the asset.

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<sup>6</sup> Note that both formulas (2.4) and (2.5) assume fixed exchange rates between the EURO 11 countries for the whole sample period.

Obviously, the synthetic Divisia money is based on assumptions of one representative agent and fixed exchange rates. Finally, note that for calculating the *level* of the Divisia money, one has to choose an arbitrary initial value for the period  $t=0$ . In this study the initial value was set at 100.

The price dual of the Divisia money ( $DUAL_t$ ) is the opportunity cost variable for the whole aggregate. If the total transaction costs in period  $t$  are defined as  $TC_t = \sum_{i=1}^n (R_t - r_{it})x_{it} = Q_t DUAL_t$ , (where  $r_i$  is the user cost (level) for component  $i$  and  $R_i$  is the yield of a pure investment asset, defined earlier), then the level of the price dual is obtained from

$$(2.7) DUAL_t = \left( \sum_{i=1}^n (R_t - r_{it})x_{it} \right) / Q_t.^7$$

### 3. METHODOLOGY

#### 3.1. Monetary indicators

As already noted, in addition to the forecasting performance of the growth rate of the nominal Divisia money, we also examine the forecasting performance of the real money gap and the monetary overhang. The definitions of these two measures for the deviations of the liquidity of the economy from its desired long-run level are based on the long-run demand for the real money stock. Thus, the monetary overhang corresponds simply to the residuals of the long-run money demand equation. Theoretical foundations of the real money gap in turn are found from the so-called P-star model. It is a model that explains the inflation dynamics of the economy to be driven by a kind of error correction mechanism that reacts to the deviations of price level

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<sup>7</sup> The log change of the price dual is calculated as  $\Delta \ln(DUAL) = \sum w_i \Delta \ln u_i$ , where  $w_i$ 's are the expenditure weights defined earlier and  $u_i = \frac{R - r_i}{1 + R}$ , where  $R$  is again the return of the pure investment asset and  $r_i$  is the own yield a given component asset.

$p_t$  from its long-run equilibrium level  $p_t^*$  (a price gap).<sup>8</sup> P-star model suggests that in addition to the price gap, inflation is a function of the inflation of the previous period or the expected inflation of the next period. That is, the model can be defined either in backward looking or forward looking form. Sometimes the change in the equilibrium price level  $\Delta p_t^*$  itself is also used as one of the explanatory variables. More formally, the (forward looking) equation determining the time path of inflation reads as follows:

$$(3.1) \quad \pi_t = (1 - \lambda)E_t\pi_{t+1} + \lambda\Delta p_t^* - \alpha_p(p_t - p_t^*) + \varepsilon_{t+1}, \text{ where } \alpha_p > 0.$$

It can be seen that the P-star model closely resembles the Phillips curve equation, with the exception that now the output gap is replaced with the “price gap”. The equilibrium level for the price level ( $p_t^*$ ) that is the key concept of the model, is based on the quantity theory of money. Equation (3.2) below defines  $p_t^*$  as the price level that prevails with a given stock of nominal money, when output is at its potential level  $y_t^*$  and velocity is at its long-run equilibrium  $v_t^*$ .

$$(3.2) \quad p_t^* = m_t - y_t^* + v_t^*$$

At the same time, the equilibrium price level  $p_t^*$  defines the long-run equilibrium for the real money balances ( $\hat{m}_t^*$ ).

$$\hat{m}_t^* = m_t - p_t^* = y_t^* - v_t^*$$

For practical applications like ours, an estimate for the long-run equilibrium real money balances can be constructed by using the parameters of the long-run money demand equation.

$$(3.3) \quad \hat{m}_t^* = m_t - p_t^* = k_y y_t^* - k_i i_t^*,$$

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<sup>8</sup> The P-star model has sometimes been erroneously referred as also providing the theoretical justification for the money growth pillar in the ECB’s strategy, also in its current form (for discussion, see e.g. Svensson 1999 and Seitz and Tödter 2001).

where  $k_y$  refers to the income elasticity and  $k_i$  to the interest rate elasticity of the money demand.  $i_t^*$  refers to the equilibrium level of the opportunity cost and  $y_t^*$  to the potential level of output. The *real money gap* now measures the deviation of the real money stock ( $\hat{m}_t$ ) from its long-run equilibrium ( $\hat{m}_t^*$ ). It is defined as the negative of the price gap, as becomes evident from Equation (3.4) below.

$$(3.4) \quad \hat{m}_t - \hat{m}_t^* \equiv -(p_t - p_t^*) = \hat{m}_t - (\kappa_y y_t^* + \kappa_i i_t^*).$$

The equilibrium level for the opportunity cost of holding money ( $i_t^*$  in the Eq. 3.4), which is represented by the price dual in the case of the Divisia money and the interest rate variable in the case of the simple sum M3, were measured as a sample average over the estimation period.

The *monetary overhang*  $m_t^{ov}$  at period t, in turn, tells the difference between the current real money stock and the long-run demand for real money, evaluated at the current level of output and opportunity cost for money holdings. From Equation (3.5.) it becomes evident that the monetary overhang is defined simply as the residual term of the money demand equation.

$$(3.5) \quad m_t^{ov} = m_t - p_t - (k_y y_t - k_i i_t)$$

Intuitively, the real money gap can be used as a summary statistic of the monetary developments in the economy. It incorporates the information that deviations of the economy from its potential output and equilibrium price level have on the demand for money. The monetary overhang in turn tells more about the additional information in monetary developments, since it is unaffected by changes in the long-run levels of variables like the potential output or the equilibrium price level.<sup>9</sup> The conceptual difference between these two variables becomes clear if we do the following decomposition:

$$(3.6) \quad (\hat{m}_t - \hat{m}_t^*) - m_t^{ov} = \hat{m}_t^{ov} - k_y (y_t^* - y_t) - k_i (i_t^* - i_t)$$

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<sup>9</sup> Masuch et al. (2001 ), pp. 138 – 139.

Thus, the real money gap is a sum of the monetary overhang and the effect that the output gap and the deviation of the interest rate from its equilibrium level have on the money demand.

### 3.2. Econometric methodology

The assessment of the forecasting performance of our monetary indicators is based on simulated out-of-sample forecasting. Recent examples of applying this methodology for evaluating the properties of leading indicator candidates for inflation are Stock and Watson (1999) and Altimari (2001), the methodology of which is in fact also closely followed in the paper at hand. Stock and Watson examined the relative forecasting performance of the generalized Phillips curve, based on a number of different measures for real aggregate activity, while Altimari studied the leading indicator properties of some (simple sum M3) monetary variables for the euro area inflation.

Basically, our simulated out-of-sample forecasting is based on Equations (3.7) below.

$$(3.7) \pi_{t+h}^h - \pi_t = \phi + \mu(L)\Delta\pi_t + \beta(L)x_t + \varepsilon_{t+h}$$

$$(3.8) \pi_{t+h}^h - \pi_t = \phi + \mu(L)\Delta\pi_t + \beta(L)\Delta x_t + \varepsilon_{t+h}$$

where  $\pi_t$  = inflation between periods  $t$  and  $t-1$ ,  $\pi_{t+h}^h$  = the inflation  $h$  periods ahead,  $x_t$  refers to the variable whose forecasting performance is examined,  $\phi$  = a constant and  $\varepsilon_t$  = an error term.  $\gamma(L)$  and  $\beta(L)$  are polynomials in the lag operator. The forecasting horizon  $h$  will vary from 1 to 12 quarters.

Equations (3.7) and (3.8) are forecasting equations for the change of the euro area inflation, in which the change of inflation is explained by its own history, along with some given explanatory variable. The specifications for the forecasting equation differ from the baseline specification used in Stracca (2001), which assumed both inflation and the explanatory variables either as I(0) variables or I(1) variables that are cointegrated. Accordingly, in Stracca's baseline specification it was the inflation rate itself that was explained. In contrast, specification (3.7) is implicitly based on an assumption of inflation as a non-stationary

variable, while the indicator variables are  $I(0)$ . Specification (3.8) in turn, assumes both the inflation and the indicator variables as  $I(1)$  variables that are not cointegrated. Specification (3.7) is used to test the forecasting performance of the series of the growth rate of money, the monetary overhang and the real money gap based on the potential output estimate from HP-filtering. Specification (3.8) in turn is used for the series of the real money gap based on potential output estimates provided by the ECB and the OECD, as well as for the change of the growth rate of money. (The time-series properties of the explanatory variables are discussed in more detail in Chapter 3.4.2.)

Whether the inflation rate is a unit root process or not has been under lively discussion. (See e.g. the studies by Juselius (1999) and Juselius and McDonald (2000).) The line graph of the quarterly GDP inflation that is used as the inflation measure in the study is plotted in Figure A.5 and the results of the formal unit root tests for inflation as well as for all the monetary indicator series are reported in Table A.4 in Appendix A. According to the ADF test, inflation seems to be a unit root process, while the PP-test suggests inflation to be trend-stationary series. The obvious linear trend in inflation during the sample period, seen in Figure A.5, can be explained by the anti-inflationary tendency, beginning at the beginning of the 1980's, when the inflation was brought down from the initial double-digit numbers in two decades. The uncertainties due to the low power of the unit root tests, on the other hand, are emphasized here because of the relatively short sample period. All in all, whether the correct description for the inflation series for our relatively short sample period is a unit root process or a trend stationary process, differencing the series is needed to make it stationary. Thus, the growth rate of inflation rather than the inflation itself is to be predicted in the simulated out-of-sample forecasting exercise.

The forecasting exercise proceeds recursively so that the parameters  $\beta(L)$  and  $\gamma(L)$  of the forecasting equation (3.7) of (3.8) are first estimated by using the first 44 observations of the data. After the model is estimated, an  $h$ -period ahead inflation forecast is made. Moving one period forward, the forecasting equation is re-estimated using now  $k+1$  observations, a new  $h$ -period forecast is made, and so on, until the end of the sample period is reached.

In each recursive step, the lag length for the estimated model was selected using the Rissanen-Schwarz information criterion (SBC) so that the lag length for both the inflation and the

explanatory variable was allowed to vary from 1 to 4. The procedure for choosing the lag length implies that 16 models at each step of forecasting were estimated so that only one of these models, chosen according to the SBC information criterion, was used for computing the forecast.

The sample period allows for estimating totally 29 forecasts for each of the twelve forecast horizons. The h-period forecasting performance for the variable under discussion is then evaluated by calculating the MSE of the forecast errors. This way, the forecasting performance of the Divisia money based indicators can also be compared to the performance of their simple sum M3 based counterparts.

### 3.3. Data

The data set for calculating the synthetic Divisia money was provided by Stracca, consisting of the same set of time series that was originally used in Stracca (2001)<sup>10</sup>. The sample period begins at 1980:1 and ends at 2000:4. The data are seasonally adjusted, quarterly, harmonized time series data from countries of the euro 12 area, excluding Greece. For calculating the Divisia monetary index, four components of the broad monetary aggregate M3 were considered, namely the currency in circulation (CC), overnight deposits (OD), short-term deposits other than overnight deposits (SD), and marketable instruments (MI)<sup>11</sup>.

The calculation of the Divisia monetary index requires measures of the own rates of return of the component assets. For the overnight deposits (OD), the own rate of return can be obtained by applying the formula

$$r_{CC} \frac{CC}{M1} + r_{OD} \frac{OD}{M1} = r_{M1},$$

where  $r_i$ :s refer to the own rate of return of  $i$ :th monetary asset. Given that the return to the cash in circulation ( $r_{CC}$ ) is equal to zero, we have

<sup>10</sup> The methods used for calculating the own rates of return to the component assets, and later, the price dual for the Divisia money are also originally from Stracca (2001).

<sup>11</sup> For a more detailed description of the data set, see Stracca (2001).

$$r_{OD} = r_{M1} \frac{M1}{OD},$$

where  $r_{M1}$ , the own rate of return of the euro area M1, is originally from Stracca (2001b).

The own rate of return for the short-term deposits other than overnight deposits ( $r_{sd}$ ) is obtained likewise, using the  $r_{M1}$  and the estimate for the own rate of return of M3, originally estimated in Calza et al. (2001). The own rate of return for the marketable instruments ( $r_{MI}$ ), is approximated by the short-term market interest rate calculated as the weighted average over the 3-month money market interest rates of the member states. The yield of a pure investment asset that is also needed for the calculation of the Divisia index, finally, is approximated by the long-term market rate, which is calculated as the weighted average of the 10-year government bond yields.

Figure A.1 in Appendix A shows the annual growth rates of the M3 Divisia money and the simple sum M3 aggregate. The correlation between the two monies seems to have become stronger in the latter half of the nineties. Before the mid-nineties the growth rate of the traditional M3 money tended to be higher than that of the Divisia money, but towards the end of our sample period the stock of the Divisia money starts to grow faster.

Figure A.2, in turn, plots the annual inflation and the growth rate of the Divisia money in the same figure<sup>12</sup>. By visual inspection, the time-paths of the variables were more closely connected during the first half of the sample period than during the second. The relation between the variables seems to have been particularly loose during the last five years of the sample period. During this period the inflation was at a record low level, while the growth rates of both the Divisia and simple sum M3 aggregates increased sharply.

The series for the Divisia M3 and its price dual in logarithmic levels are seen in Figures A.3 and A.4. The initial level of the Divisia money was standardized as 100 and the calculation of the price dual using formula (2.7) is also based on this standardization of the level of the Divisia money. Other time-series data used in the study consist of quarterly series for the real

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<sup>12</sup> Note that the estimations are based on quarterly series for the inflation, however.

GDP (see Figure A.6) and the GDP deflator (see Figure A.5) aggregated for the euro area, as well as of the estimates for the potential output of the euro area needed for calculating the real money gap series<sup>13</sup>.

The problems in calculating reliable estimates for the potential output are well known. To control for the sensitivity of the results to the way the potential output is measured, three different potential output series were used in calculating the real money gap series. The first of the series was obtained simply by Hodrick-Prescott filtering the real GDP series. The other two potential output series were provided by the ECB and the OECD and were derived using more structural methods. The ECB estimates are based on the ECB's area-wide model, where the potential output is obtained from a constant-return-to scale Cobb-Douglas production function with calibrated factor share parameters. The OECD estimates are also based on the Cobb-Douglas production function. All the three measures of the potential level of the real GDP along with the real GDP itself, are seen in Figure A.7 in Appendix A. Figure A.8 in turn plots the corresponding output gaps for the three potential output series. It can be seen in the figures that the output gap estimates based on potential output series based on HP-filtering and the ECB follow each other quite closely, although the HP-filter based estimate lies above, while the output gap series based on the OECD data fluctuates more wildly.

### **3.4. Money demand equations**

#### *3.4.1. Estimation of the long-run money demand equations for the euro area*

Each recursive step for calculating the real money gap and the monetary overhang series for both the Divisia and simple sum M3 monies to be used in the forecasting equations (3.7) and (3.8) requires new, updated estimates of the parameters of the respective long-run money demand function. There have been numerous attempts to estimate a stable money demand equation for the euro area in the previous literature. Stracca (2001) and Reimers (2002), for example, provide stable estimates for the long-run money demand equation for the Divisia M3 money. Coenen and Vega (1999), Brand and Cassola (2000), Calza et al. (2001) and Trecroci and Vega (2000), among others, provide evidence for the possibility of estimating a stable

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<sup>13</sup> The euro area wide aggregates for the GDP and its deflator are the same as in Stracca (2001)

money demand equation for the euro area wide simple sum M3 money. Table A1 in Appendix A presents a short review of the recent estimates for the income elasticity and the interest rate semi-elasticity parameters for the long-run money demand equation estimated for the euro area (for both the Divisia and the simple sum M3 money). The value of the income coefficient in particular has been under discussion, since if its value exceeds unity, the observed declining trend in the Euro area money demand could be attributed to the trend in the GDP growth. As it appears in the table, most estimates, including those of Stracca (2001) and Reimers (2002), indeed exceed unity. On the other hand, not all the studies included a formal statistical test of whether the income coefficient differs significantly from unity.

In our simulated out-of-sample exercise, the estimation of money demand equation for each recursive step of creating new series for the real money gap and the monetary overhang is conducted simply by OLS. When the Divisia M3 money was considered, our money demand specification included a constant term, the real GDP the price dual of the Divisia money along with its square. The price dual measures the opportunity cost of holding the real Divisia money balances and its square is included in the specification to capture possible non-linearities in the money demand. With this specification we again follow the practice of Stracca (2001).<sup>14</sup>

Since the variables of the money demand equations for both the Divisia and simple sum M3 monies are all I(1)-variables, estimating the money demands simply by linear regressions actually corresponds to the Engle-Granger cointegration analysis. Using linear regressions instead of the more elaborate Johansen procedure is further justified by the fact that, according to the economic theory, there should be no other cointegration relations between the variables than that defining the money demand equation.

When the full sample was considered, the money demand equation for the Divisia money was estimated to be

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<sup>14</sup> In fact, including the square of the price dual in the money demand specification has been called into question by Reimers (2002) both on the grounds of some methodological considerations (see Reimers (2002, p.19.) and on empirical grounds (see Reimers (2002, p. 34). Including the square term in our specification was partly motivated by an estimation exercise with the Johansen procedure, which suggested that the square term is included in the cointegration space.

$$(m - p)_t = k + 1.2 \cdot gdp_t - 0.43 \cdot DUAL_t + 0.01(DUAL_t)^2$$

Thus, in the study at hand the income elasticity of the real Divisia money also exceeds unity, which is in line with Stracca (2001) and Reimers (2002). The overall stability of the parameters of the money demand equation was examined by plotting the coefficient estimates against time (see Figure A.9 in Appendix A). The income elasticity and the squared price dual elasticity seem to be remarkably stable, while there seems to be a structural shift in the price dual elasticity and in the constant term at around 1991. Correctly estimating the value for the price dual elasticity matters only for calculating the monetary overhang series, however. Since the equilibrium value for the price dual is measured as a sample average, the product of the price dual elasticity and the equilibrium rate of the price dual ( $k_i i_t^*$  in Eq. (3.4)) becomes a part of the constant term of the equation defining the real money gap. Accordingly, the forecasts based on the real money gap series are unaffected by the value of  $k_i i_t^*$ , since it does not affect the variation of the real money gap series.<sup>15</sup>

Calza et al. (2001) argue that the correct opportunity cost variable to be used in the money demand specification for the euro area simple sum M3 money is the spread between the short-term interest rate and the own rate of interest of the M3 money. This opportunity cost variable for the simple sum M3 money is also adopted here. Thus, when the full sample was considered, the money estimated money demand equation for the simple sum M3 money of the euro area takes the form

$$(m - p)_t = k + 1.5 \cdot gdp_t - 0.005 \cdot userm3_t$$

The line graph representing the recursive estimates of the parameters of the money demand equation is presented in Figure A 10. The estimate for the income elasticity again seems to be remarkably stable and exceeds unity, just as was the case in Calza et al. (2001) referred to above, as well as in the studies e.g. by Coenen and Vega (1999) and Brand and Cassola (2000). The interest rate elasticity however, takes a value near zero, which does not sound plausible. However, the same argument applies here as in the case of the Divisia money, so

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<sup>15</sup> Likewise, the value of the constant term  $k$  does not affect the inflation forecasts based on the residuals of the money demand equations (monetary overhang series).

that the interest rate elasticity term matters only for calculating the monetary overhang series, the stability of which will be discussed later.

#### *3.4.2. Time series properties of the monetary indicator variables*

Line graphs of the five different monetary indicator series for the Divisia money are shown in Figures A.11 – A.14 in Appendix A, while Figures A.15 – A.18 show them for the simple sum M3 money. The results of the formal unit root tests for all the monetary indicator series are reported in Table A.4. Beginning with the nominal growth rates of the monies, according to the ADF and the PP tests, the growth rate of the nominal Divisia money seems to be  $I(0)$  process. Inspection of Figure A.1 however suggests the series rather to be trend-stationary or even following stochastic trend. Since the linear trend also turned out to be statistically significant in the unit root tests, I ended up with removing the trend –whether it ultimately is stochastic or deterministic in nature- by differencing the series. Likewise, according to the Figure A.1 the growth rate of the simple sum M3 money behaves much like the growth of the Divisia money in the sample period. Since now the ADF- test also suggests non-stationarity, the trend was also removed from the simple sum M3 series by differencing.

Figures A.11 – A.13 and A.15 – A.17 show that, as might be expected, the real money gap series are somewhat sensitive to the underlying estimate of the potential output. According to the unit root tests then, all the real money gap series for both the Divisia and the the simple sum M3 monies seem to be  $I(1)$  processes. Beginning with the real money gap series for the Divisia money, a closer inspection of Figure (A.11) suggests that in the case of the series based on the potential output estimates from HP filtering, the non-stationarity suggested by the unit root tests may follow from the structural break at the end of the series. Thus, the stationarity of the series was re-examined ignoring the last three years of the data. Accordingly, the tests now indicated stationarity. Thus, in the forecasting exercise the specification (3.7) was used for this series.

In the case of the the real money gap series based on the ECB estimate of the potential output, Figure (A.12) in fact suggests a deterministic trend in the data. For the real money gap series based on the OECD estimate of potential output, in turn, the possibility of a stochastic trend in the data is also supported by inspection of the line-graph of the series (Figure (A.13)),

according to which the series contains relatively large upswings and downswings. The volatility of the series also seems to be largest of all the three real money gap measures considered.<sup>16</sup> Thus, the real money gap series based on the ECB and the OECD estimates of the potential output were considered as non-stationary series and specification (3.8) was used in the forecasting exercise for these series. On purely a priori grounds, the real money gap series are in fact expected to be  $I(0)$  variables, since the gap reflects only deviations of the real money stock from its equilibrium level and this gap should be closed in the long-run. Because of the short sample period, modelling the series as  $I(1)$  processes can, however, be considered as a good approximation of the data generating process during this period.

The monetary overhang series for the Divisia money is shown in Figure A.14. Testing the stationarity of the monetary overhang series in fact means simply that our Engle-Granger type of cointegration analysis is completed. Since the monetary overhang series consists of residuals of the money demand equation, the series should be stationary or otherwise no stable cointegration relationship between the variables would exist at all. According to Figure A.14 the series looks stationary even in our short sample period considered, except an obvious structural break in the end of the sample. When the full sample was considered, both the ADF and PP tests suggested non-stationarity, but when the last four observations were excluded, the tests also suggested stationarity.

The real money gap series for the simple sum M3 real money gaps are plotted in Figures A.15 – A.17. The unit root tests of Table A.4 suggest non-stationarity as in the cases of the corresponding Divisia money series, and according to the figures, there are at least as good reasons for considering the real money gap series for the simple sum M3 as non-stationary as in the case of the Divisia M3 based series. The HP-filter based real money gap series is, however, again included in the forecast equation in levels (specification 3.7) to make easier the comparison of the performance of this series with its Divisia money counterpart<sup>17</sup>. The line graph of the monetary overhang for the simple sum M3 series, in turn, is plotted in Figure A.18. A notable feature in the figure is the large structural break between 1992 – 1994, although the series otherwise looks as stationary. The unit root tests mostly reported non-

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<sup>16</sup> Note that because of some measurement issues, the constant terms of the real money gap and the monetary overhang series are probably not correctly estimated. The “wrong” value for the constant term does not affect the results of our forecasting exercise, but there is now no sense in offering any interpretation for the absolute values of the real money gap and monetary overhang series.

stationarity, but this may well be due to the structural break. Since there are also many previous studies reporting a stable money demand equation for the M3 money in the euro area, we interpret the non-stationarity suggested by the unit root tests as being due the structural break and the small sample considered.

#### 4. RESULTS

The (out-of-sample) forecasting performance of the monetary indicators is discussed by examining the ratios between the MSE of the forecasts based on the forecasting equations (3.7) and (3.8) and the MSE of a univariate forecast based only on the own history of the euro area inflation. Clearly, if the MSE ratio is assigned a value below unity, the indicator studied contains some additional predicting power for inflation. The results are reported in Tables 4.1 and 4.2 below. In addition, the MSE ratios have been plotted against the forecast horizon in line graphs of Appendix B.

Table (4.1) reports the MSE ratios for the monetary indicator series for both the Divisia and the simple sum monies that are considered as stationary and thus included as levels in the forecasting equation (specification 3.7). These series include monetary overhang series and the real money gap series calculated with HP-filter estimate for the potential output. In addition, Table 4.1 reports the forecasting performance of the growth rate of the nominal money. Although the growth rates of the two nominal monies have been considered as I(1) variables so that the levels of the monies should be included as second differences in the forecasting equation, it is nevertheless illuminating to also study the forecasting performance of the first differences of the series, since after all, the growth rate of the nominal M3 money is the variable that the ECB has given the special role in its announced monetary policy strategy. Thus, the growth rates of the two monies are kind of benchmarks against which to compare the performance of the real money gap and monetary overhang series.

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<sup>17</sup> The robustness of this specification will later be checked, however, by making alternative forecasts, using now differenced series for the HP-filter based real money gap series for the simple sum money (specification 3.8).

Table (4.2) in turn reports the results for the series considered as I(1) variables and thus included as differences in forecasting equation (specification 3.8). In Table (4.1) the forecasts are made 1 - 12 and in Table (4.2) 1 - 11 quarters ahead and the evaluation of the performance of each indicator is based on the period 1991:1– 2001:4. The results can be inspected visually in the graphs in Appendix B, where the MSE ratios are plotted against the length of the forecast horizon.

**Table 4.1. MSE-ratios of both the Divisia M3 and simple sum M3 money based monetary indicators for specification (3.7).**

Divisia M3

Period	1	2	3	4	5	6	7	8	9	10	11	avg	count
RMSE univ %	0,4	0,4	0,43	0,45	0,43	0,42	0,42	0,42	0,43	0,45	0,46	0,39	
RMSE univ pp	0,93	1,82	1,4	1,23	1,1	0,99	0,95	0,97	0,97	1	1	1,03	
Real money gap HP	0,78	0,79	0,98	0,63	0,73	0,94	1,11	1,14	1,42	1,54	1,93	1,00	5
Monetary overhang	1,06	1,07	1,04	0,89	0,89	0,88	0,9	0,85	0,99	0,9	0,97	0,87	11
Diff nominal money	0,43	0,48	0,45	0,46	0,58	0,63	0,68	0,76	0,82	0,85	0,89	0,59	11

Simple sum M3

Period	1	2	3	4	5	6	7	8	9	10	11	avg	count
Real money gap HP	0,84	0,71	0,82	0,9	1,26	1,33	1,25	1,15	1,15	1,18	1,22	0,98	6
Monetary overhang	1,16	1,35	1,16	1,09	1,33	1,52	1,39	1,34	1,38	1,38	1,39	1,21	0
Diff nominal money	0,58	0,74	0,67	0,7	0,84	0,98	0,82	0,86	0,89	0,91	0,95	0,75	0

The upper table gives the MSE ratios for the Divisia M3 money based indicators, while the lower table gives them for the indicators based on the simple sum M3. The first line gives the relative magnitude of the forecast error of the univariate forecast and the second row gives the absolute values of the univariate forecast error (in percentage points). The rest of the figures tell the ratios between the MSE of the respective bivariate inflation forecasts based on the forecasting equation (3.7) and the MSE of the univariate forecast, based only on the own history of inflation. HP refers to the real money gap series based on potential output estimate from HP filtering. “Diff nominal money” refers to the growth rates of the two monies (the first difference of the series).

**Table 4.2. MSE-ratios of both the Divisia M3 and the simple sum M3 based indicators for specification (3.8).**

Divisia M3

Period	1	2	3	4	5	6	7	8	9	10	11	avg	count
Real money gap ECB	1,02	1,01	0,97	0,75	0,77	0,77	0,75	0,75	0,7	0,7	0,75	0,82	9
Real money gap OECD	1,38	1,07	0,98	0,73	0,71	0,71	0,7	0,74	0,7	0,8	0,76	0,84	8
2 <sup>nd</sup> diff nominal money	0,95	0,85	0,84	0,85	1,01	1,11	1,05	1,06	1,1	1,1	1,1	1	6

Simple sum M3

Period	1	2	3	4	5	6	7	8	9	10	11	avg	count
Real money gap ECB	1,02	0,95	1,01	0,96	1,11	1,15	0,93	0,87	0,8	0,8	0,86	0,96	1
Real money gap OECD	1,47	1,03	0,9	0,68	0,89	1	0,99	0,98	1	0,9	0,96	0,98	3
2 <sup>nd</sup> diff nominal money	0,98	0,81	1,12	1,32	1,78	1,13	1,31	0,94	0,9	0,9	0,86	1,09	5

The upper table gives the MSE ratios for the Divisia M3 money based indicators, while the lower table gives them for the indicators based on the simple sum M3. The ratios between the MSE:s of the forecasts based on the forecasting equation (3.7) and monetary indicators calculated for the simple sum M3 money, and the MSE of an univariate inflation forecast. ECB and OECD refer to the real money gap series based on the potential output estimates provided by the ECB and the OECD. 2<sup>nd</sup> diff refers to the growth of growth rates (the second differences) of the two types of nominal monies

The first lines of Table (4.1) reports the mean square errors (MSE) of the univariate forecasts for the change of inflation, divided by the concurrent actual values of the change of inflation, whereas the second line tells the MSE of the univariate forecasts in percentage points. The change of inflation appears to be rather difficult to predict, since the forecast errors for the change of inflation exceeds 100 % of its actual value in all periods. The two columns in the extreme right in the tables report two simple summary statistics to help making the comparison between the performances of the two monetary aggregates: Column (avg) gives the average of the MSE ratios over the forecast horizons, while column (count) reports the number of the forecast horizons in which the given series has yielded lower MSE ratio than its counterpart based on the other sort of money.

When the Divisia M3 based indicators are compared with each other, it can be seen in Tables (4.1) and (4.2) that the Divisia M3 based indicators perform fairly well, tending to beat the univariate forecasts in most cases. Both because the relation between money and inflation should be seen only with lag and because the univariate forecasts should perform best in the short run, it should be expected that the relative performance of the monetary indicators is

increasing in the length of the forecast horizon. This seems, however, not to be the case as is also shown by the mostly flat or upward sloping graphs of Appendix B. Interestingly, among all the Divisia money based indicators based on specification (3.7) the best forecasts are yielded by the growth rate of the nominal Divisia M3 money, even though the series clearly did not even seem to be stationary. The finding is also interesting in light of the previous findings by Altamari (2001), Gerlach and Svensson (2001), and Trecroci and Vega (2000) for the relation between the simple sum M3 money and inflation, since according to these studies the growth rate of nominal money should be outperformed by the real money gap series. On the other hand, in Reimers (2002) the growth rates of both the Divisia money and the simple sum M3 seemed to perform equally as well as the P-star indicator, when the inflation was defined as GDP inflation. Moreover, all those studies focused on forecasting inflation itself rather than changes in it as it is the case in the paper at hand. For specification (3.8) the best forecasts are yielded by the real money gap series based on the ECB estimate of the potential output.

Turning next to comparing the simple sum indicators with each other, it can be seen in the tables that now the univariate forecasts more often have outperformed the monetary indicators. The best forecasts in specification (3.7) are in fact again given by the growth rate of nominal money, while both the real money gap series based on the HP-filter based estimate of the potential output and the monetary overhang are mostly outperformed even by the univariate inflation forecasts. Among the forecasts based on the specification (3.8) the real money gap based on the potential output estimated by the ECB and OECD seem, however, perform better than the the “growth of the growth rate” of the nominal simple sum M3 money.

Overall comparison between the forecasting performance of the Divisia M3 based indicators and the indicators based on the simple sum M3 suggests that the Divisia money indicators slightly outperform their simple sum M3 counterparts. The conclusion is supported both by the average MSE ratios and the number of forecast horizons in which the Divisia M3 indicators are assigned lower MSE ratios than their simple sum M3 counterparts. The Divisia money based indicators yield better forecasts in cases of the monetary overhang and the real money gaps based on the potential output estimates provided by the ECB and the OECD. The difference in favour of the Divisia money based indicators does not seem to be large, however. The cases of the second difference of the nominal M3 monies and the real money gap series based on potential output estimates from HP-filtering, in turn, seem unclear, regardless of

which of our two criteria to assess the relative performance of the indicators is applied<sup>18</sup>. As it was previously noted, the Divisia money is expected to contain more information about future inflation especially in the short run, while in the long run the forecasts are likely to converge. This pattern is, however, not seen in the results. Except the case of the growth rates of the nominal monies, the difference in the forecast performance in favor of the Divisia money indicators does not seem to be notably larger in the short end than in the long end of the forecast horizons.<sup>19</sup>

Interestingly, the growth rate of the nominal Divisia M3 not only beats the other Divisia M3 based indicators but also yields the best forecasts among all the different monetary indicators considered. In horizons between one and four quarters, the forecast MSE:s of the growth rate of the nominal Divisia money remains below 50 % of the MSE of the univariate forecast. It is notable that the growth rate of the simple sum M3 money, the ECB's actual "target variable", also performs fairly well, although remains outperformed by its Divisia money counterpart in every forecast horizon.

## 5. CONCLUSIONS

The ECB has given the M3 monetary aggregate an important role as an indicator variable for the future inflation in the euro area. This study has discussed, whether the synthetic Divisia M3 monetary aggregate, computed as a weighted average of its component assets, could provide more information on the future price developments than the ordinary M3 aggregate, which does not take into account the differing degrees of liquidity of the component assets of the aggregate. Although in the long run the predictions based on the two aggregates are likely to converge, it is a priori assumed that the Divisia money may yield more accurate forecasts in the short-run. As an econometric method I have used simulated out-of-sample forecasting. The study differs from the previous studies on the information content of the Divisia money on the euro area inflation in that here inflation is assumed as I(1) variable and thus the change in inflation, rather than inflation itself, has been the variable to be forecasted. In addition to

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<sup>18</sup> The forecasting performance of the HP-filter based real money gap series for the simple sum money was in fact significantly improved when it was included in the forecast equation in differences, using specification (3.8). The relative performance between the HP-filter based real money gap series for the two monies remained unclear, however.

comparing the forecasting performance of the growth rates of the two nominal M3 monies, the study has focused on the performance of the real money gap and the monetary overhang variables calculated for the two types of monies.

It was found, firstly, that some of the monetary indicator series based on the synthetic Divisia M3 monetary aggregate really improved the out-of-sample forecasts for the (change in) the euro area inflation, when compared to the forecasts based on simple univariate forecasts. Secondly, comparison between the forecasting performance of the different monetary indicator series calculated for our two sort of monetary aggregates revealed that the Divisia money based indicators tend to outperform their simple sum money based counterparts at least in some cases.

It was also an interesting finding that the growth rate of the nominal Divisia money seemed to perform surprisingly well, even though the growth rates of both type of nominal monies were considered non-stationary variables and although it was the change in inflation rather than inflation itself that was to be forecasted. The growth rate of the Divisia money yielded the best forecasts not only within the Divisia money based indicators but it also outperformed the simple sum M3 based indicators. The finding contradicts the previous findings based on the simple sum M3 money, according to which real money gap and money overhang – variables that measure the gap between the desired and actual *level of real* money holdings, suit best for the forecasting purposes. From a theoretical perspective, the performance of the growth rate of the Divisia money is even more interesting, when taking into account the recent arguments according to which the estimations based on simple linear regressions in fact understate the relations between money and inflation, since this relation is probably too subtle to be revealed by a simple linear one-equation model<sup>20</sup>.

All in all, the results support the previous findings by Stracca (2001) and Reimers (2002), according to which the synthetic Divisia M3 monetary aggregate could play a role as a valuable indicator variable on the future price developments in the euro area, at least when used along with the ordinary, simple sum monetary aggregates. A longer inflation history will be needed, however, to ascertain whether it is the growth rate of the nominal Divisia money or

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<sup>19</sup> In fact, e.g. the “growth of growth rate” of the Divisia M3 also yields better forecasts in short horizons, but at the long end of the forecasts the simple sum M3 indicators now perform significantly better.

<sup>20</sup> See eg King (2002)

some Divisia money based measure for the excess liquidity in the economy, that the ECB should actually be looking at.

Some caution is needed in interpreting the results, however. Firstly, because the study is based on aggregated euro area wide data, all the relations between money and prices that the study suggests represent averages of these relations over the EMU member countries. Most of the time in the sample period, the transmission process between money and prices has been based on independent monetary policies in the member states, however. The average of these transmission processes may differ from the transmission process under the regime of common monetary policy, which may also have caused a structural shift in the relation between money and prices. Secondly, in the end of the sample period there might have occurred pure portfolio shift in the money demand, due to changes in the opportunity costs of holding money. This portfolio shift may in its part have obscured the link between money and inflation during the sample period. Thirdly, the relatively short sample period and some obvious structural breaks in the period resulted in some uncertainties concerning the time series properties of both the euro area inflation and the monetary indicator series.

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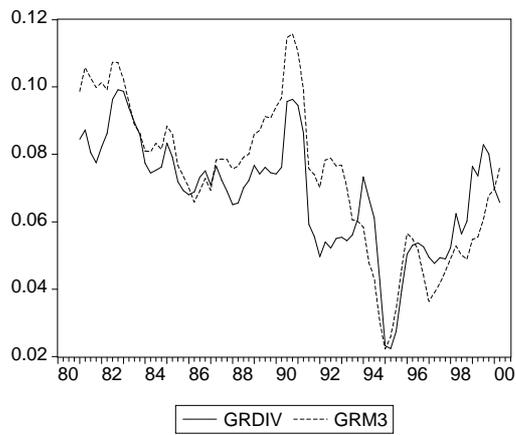
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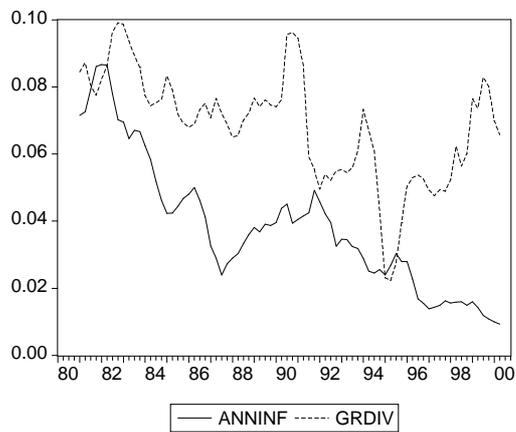
**The information content of M3 for future inflation**

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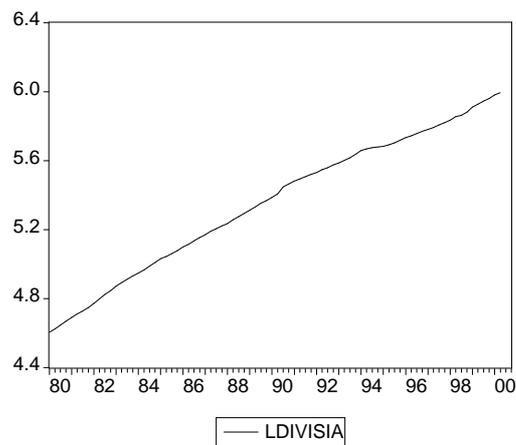
## APPENDIX A



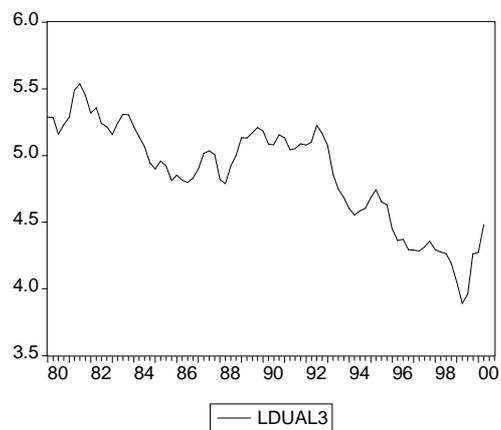
**Figure A1.** Annual growth rates of the Divisia (GRDIV) and simple sum (GRM3) M3 monetary aggregates.



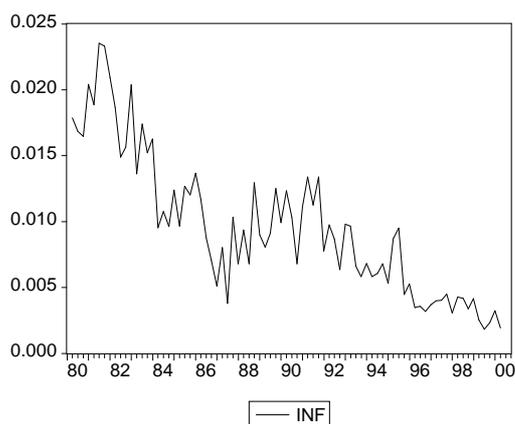
**Figure A2.** Annual GDP inflation (ANNINF) and the annual growth rate of the Divisia M3 (GRDIV).



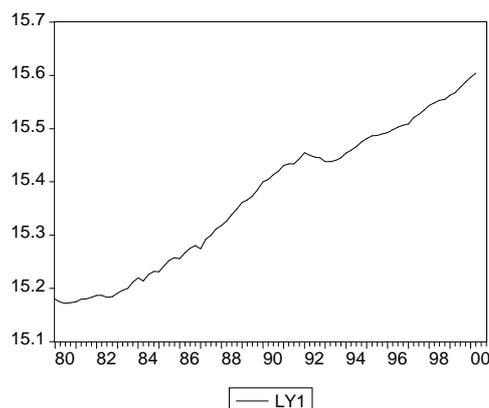
**Figure A3.** Log of the Divisia M3 money



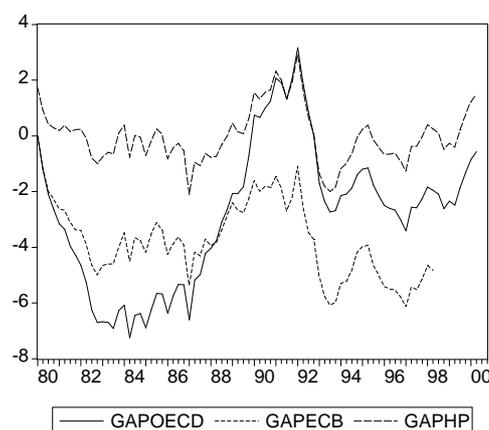
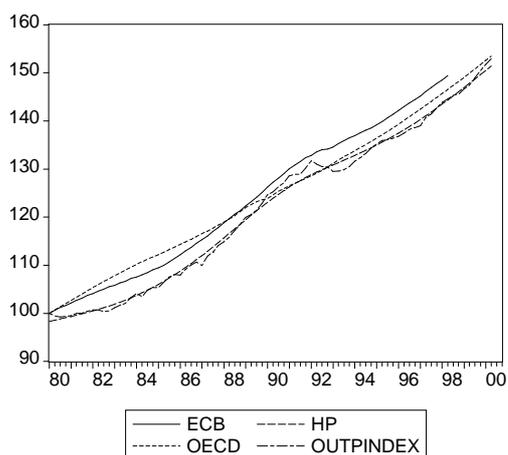
**Figure A4.** Log of the price dual for Divisia M3 money



**Figure A5.** Quarterly GDP inflation in the euro 11 area.



**Figure A6.** Real GDP in the euro 11 area



**Figures A7 and A8.** Three measures for the euro 11 potential output, along with the euro 11 real GDP (A7.) and the corresponding output gaps (A8.). OUTPINDEX denotes to the real GDP of the euro area, ECB and OECD correspond to the estimates for the potential output provided by the ECB and OECD respectively, while HP denotes to the potential output estimate obtained by Hodrick-Prescott-filtering. GAPOECD, GAPECB and GAPHP denote to the output gap estimates based on the respective series for the potential output. All the series have also been adjusted for German reunification. The OECD data for the potential output, (provided by the OECD Economic Outlook database) consists actually of semi-annual series, and the missing observations have been obtained by interpolation. Note also that all the series for the potential output are reported as index numbers with the first observation (1980:1) as standardised to 100. Thus, the figures tell only on the variability of the potential output and the output gap during the sample period, but it is not possible to make conclusions on the actual sign of the output gap.

**Table A1.** Parameter values of some previous estimated money demand equations for both the simple sum and the Divisia M3 aggregates of the Euro area.

<b>The model</b>				
The simple sum M3/	income	long interest	short interest	short own
Calza et al. (2001)	1,34			-0,86
Brand and Cassola (2000)	1,33	-1,61		
Trecroci and Vega (2000)	1,158			
Fagan and Henry (1998)	1,55 - 1,61	-0,20 - (-0,58)*	0,32	
Coenen and Vega (1999)	1,17	-1,26		
Gerlach and Svensson (2000)	1,51			
Kontolemis (2000)	1	-1,89		
Kontolemis (2002)	1	-1,45		
The Divisia money/	income	price dual		
Stracca (2001)	1,19	-1,72		
Reimers (2002)	1,00-1,36	-0,06 - (-0,11)		

“income” refers to the income elasticity, while “long interest” and “short interest” refer to the elasticity of the money demand on the short-term and long-term interest rate. “short own” in turn denotes to the elasticity on the spread between the short-term interest rate and the own return of M3. Fagan and Hendry (1998) and Reimers (2002) provided a number of estimates, each corresponding to a different specification of the model. Thus, in these cases the table reports the range where the estimates were located.

**Table A2.** Unit root tests for the variables in the Divisia M3 money demand equation.

Variable	specif.	ADF	PP
rdiv	1,c,t	-1.802741	-1.517845
GDP	1-4,c,t	-2.404955	-2.310080
Dual	1,c	-1.621749	-1.309498
Sqduall	1,c,t	-2.798961	-2.399084

Variable	specif.	ADF	PP
d(rdiv)	-	-2.872840 xx	-2.546454 x
d(GDP)	1	-2.654105 xx	-3.987920 xx
d(Dual)	1	-5.205564 xx	-5.998268 xx
d(sqduall)	1-2	-5.082891 xx	-6.052015 xx

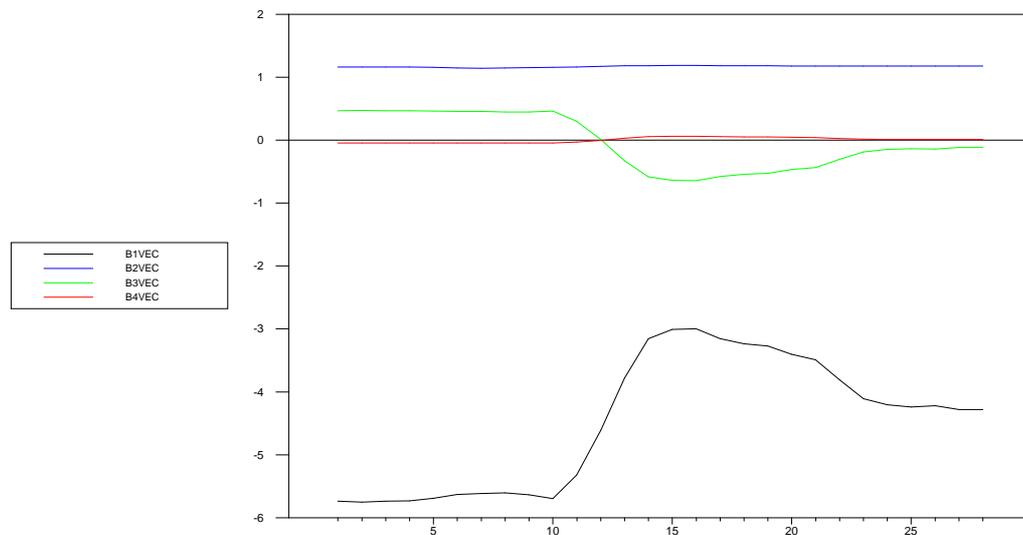
The figures in the column “specif” denote to the lag length used in the unit root test, while c and t refer to a constant and a linear trend if they were included into the specification. The upper table reports the unit root tests for the variables in levels and the lower table reports them for differences. “rdiv” denotes to the level of the real Divisia money, “GDP” denotes to the real euro area GDP, while “Dual” and “Sqduall” refer to the level and square of the price dual of the Divisia money. xx (x) in tables refers to the case when the null-hypothesis of unit root is rejected at 1 % (5 %) confidence level. The critical values for the ADF- and PP-tests are based on McKinnon (1991).

**Table A3.** Unit root tests for the variable in the simple sum M3 money demand specification..

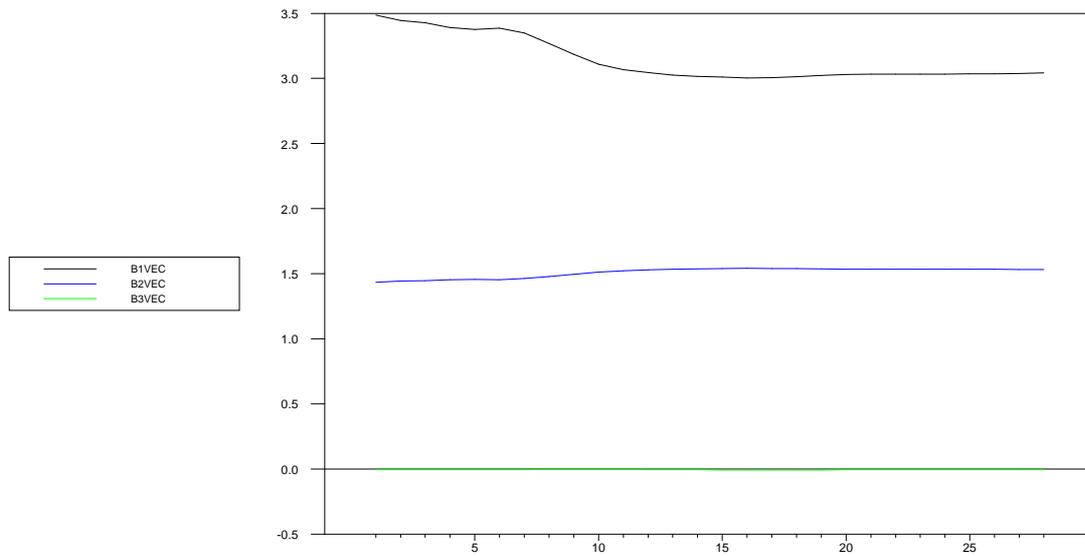
variable	specif.	ADF	PP
rm3	1,c,t	-1.797982	-1.604266
GDP	1-4,c,t	-2.404955	-2.310080
userm3	1,c,t	-3.184589	-2.640535

variable	specif.	ADF	PP
d(rm3)	1,c	-3.762986 xx	-4.548070 xx
d(GDP)	1	-2.654105 xx	-3.987920 xx
d(userm3)	1,c,t	-5.966100 xx	-6.388816 xx

For an explanation for the column “specif.,” see Table A2. “rm3” refers to the level of the simple sum real M3 money, “GDP” refers to the euro area GDP, while “userm3” denotes to the spread between the short-term interest rate and the own rate of interest of the M3 money. xx (x) in tables refers to the case when the null-hypothesis of unit root is rejected at 1 % (5 %)confidence level The critical values for the ADF- and PP-tests are based on McKinnon (1991).

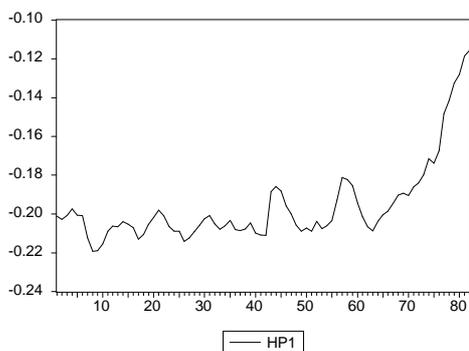


**Figure A9.** Recursive estimates for the coefficients of the money demand equation estimated for the Divisia money. B1VEC = constant term, B2VEC = coefficient for the log of output, B3VEC = the coefficient of the price dual and B4VEC = the coefficient of the squared price dual.

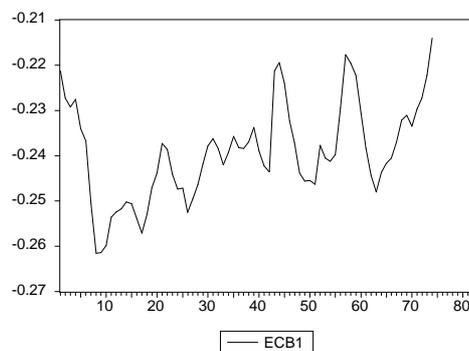


**Figure A10.** Recursive estimates for the coefficients of the money demand equation estimated for the simple sum M3 money. B1VEC = constant term, B2VEC = coefficient for the log of output and B3VEC = the coefficient of the interest rate variable. Note that the coefficient estimate for the interest rate elasticity is so close to zero that it is almost indistinguishable from the zero-line in the figure.

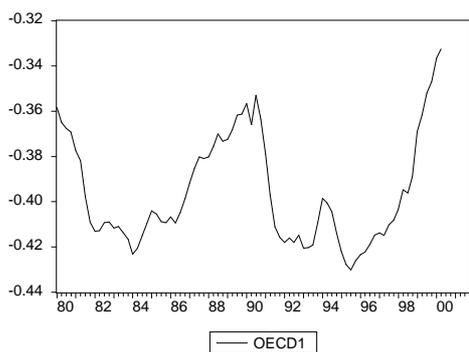
**Figures of the real money gap and monetary overhang measures calculated with the full sample and the Divisia M3 money.**



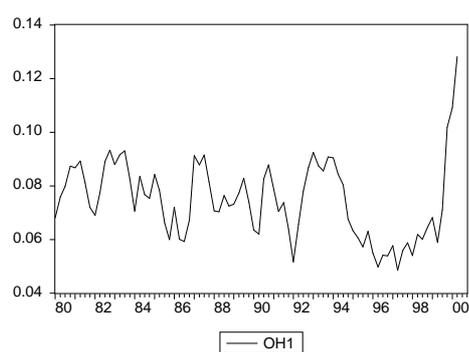
**Figure A. 11.**



**Figure A12.**



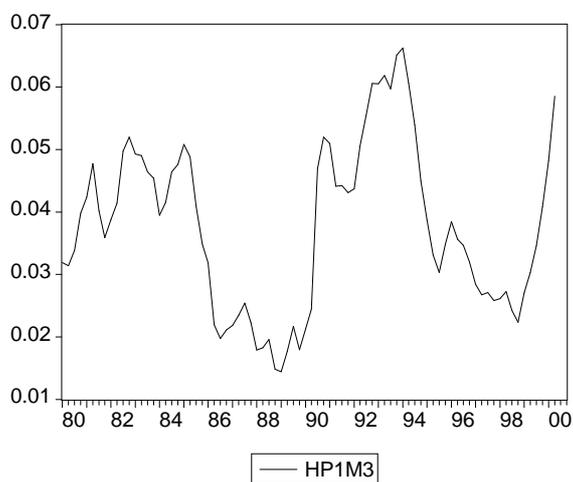
**. Figure A. 13.**



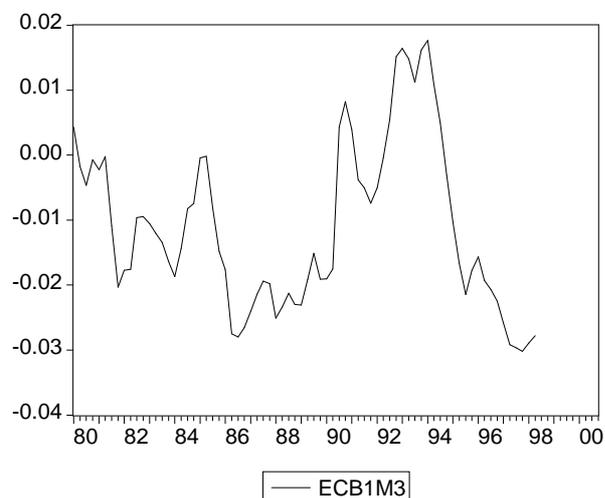
**Figure A.14**

Figures A11 – A13 plot the series for the real money gap series and Figure A14 represents the monetary overhang series. HP refers to the potential output estimate obtained by Hodrick-Prescott filtering, while ECB and OECD refer to the potential output estimates provided by the ECB and the OECD, respectively.

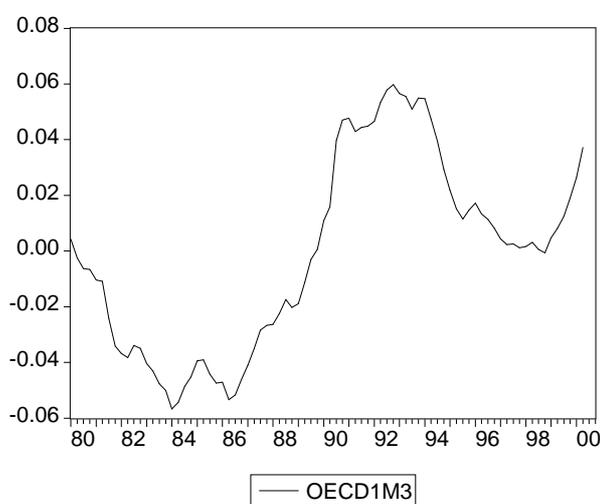
**Figures of the real money gap and monetary overhang measures calculated with the full sample and the simple sum M3 money.**



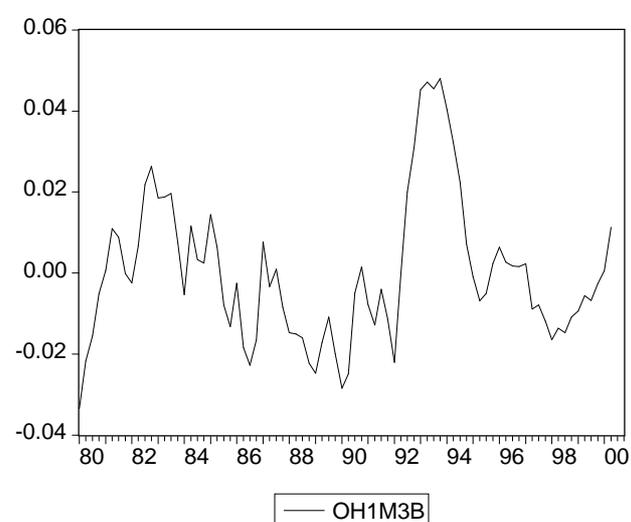
**Figure A. 15**



**Figure A. 16**



**Figure A.17**



**Figure A. 18**

Figures A15 – A17 plot the series for the real money gap series and Figure A18 represents the monetary overhang series. HP refers to the potential output estimate obtained by Hodrick-Prescott filtering, while ECB and OECD refer to the potential output estimates provided by the ECB and the OECD, respectively.

**Table A.4. Results of the unit root tests for the monetary indicator series**

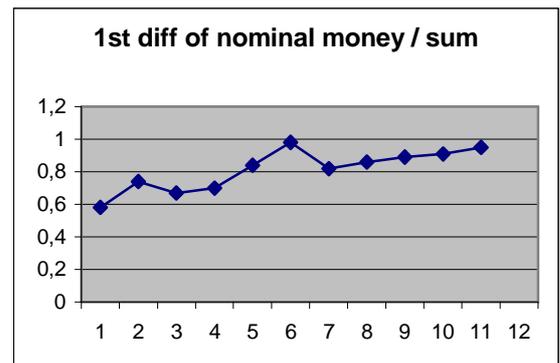
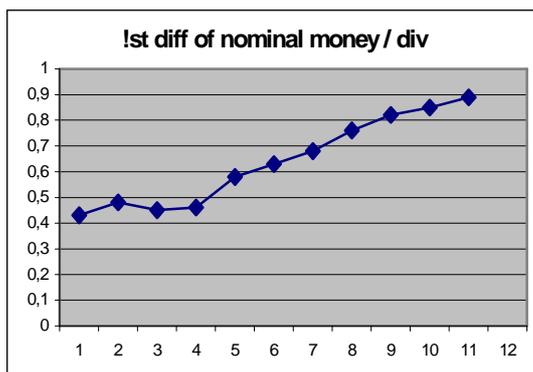
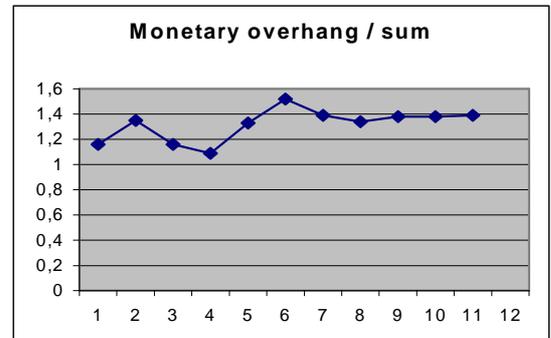
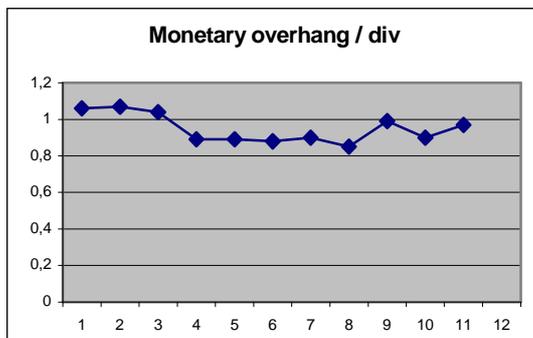
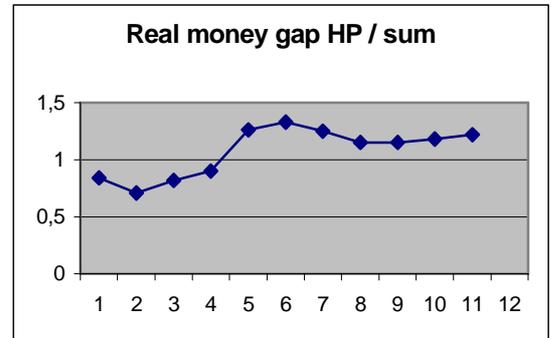
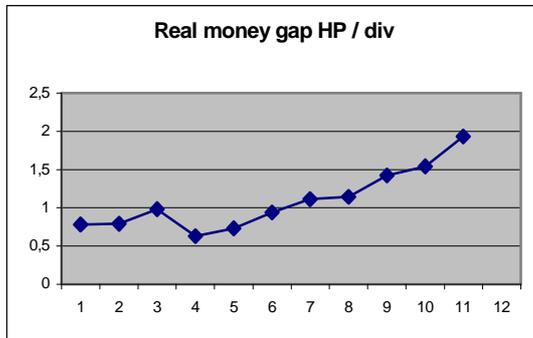
Variable	ADF	PP	specific.
inf	-2.964352	-4.925672 xx	c,t,1
dIM3	-2.604535	-3.414204 x	c,t,1
lddiv	-6.214867 xx	-6.244935 xx	c,t,0
div money gap hp	-1.166549	-0.834533	1
div money gap ecb	-1.578305	-0.916825	c,1
div money gap oecd	-2.177563	-1.477843	c,1
money gap hp	-2.380200	-1.957308	c,1
money gap ecb	-1.552156	-1.165160	1
money gap oecd	-1.888206	-1.815010	c,t,1
div monetary oh	-2.501796		1
monetary oh	-3.057139		1

Variable	ADF	PP	specific.
inf	-5.655746 xx	-15.65367 xx	1-4
dd(IM3)	-8.228830 xx	-14.10893 xx	1
dd(ldiv)	-7.721356 xx	-14.93213 xx	1-2
d(div money gap hp)	-4.759501 xx	-5.753575 xx	1-2
d(div money gap ecb)	-5.202541 xx	-5.588230 xx	1
d(div money gap oecd)	-5.000505 xx	-5.031300 xx	0
d(money gap hp)	-5.289685 xx	-5.274300 xx	0
d(money gap ecb)	-5.488183 xx	-5.807593 xx	1
d(money gap oecd)	-4.489724 xx	-4.476430 xx	0

Results of the unit root tests for the different monetary indicators for both the Divisia M3 money (denoted by “div money” in the table) and the simple sum M3 money (denoted by “money” in the table). Money gap refers to the real money gap series and money on to the monetary overhang series. Hp, ecb and oecd again denote to the source of the series for the potential output. Lm3 and ldiv denote to the levels of nominal Divisia and the simple sum M3 monetary aggregates, “d” in the front of the variable name stands for the first difference and “dd” the second difference of that variable. xx (x) in tables refers to the case when the null-hypothesis of unit root is rejected at 1 % (5 %) confidence level. The critical values for the ADF- and PP-tests are based on McKinnon (1991).

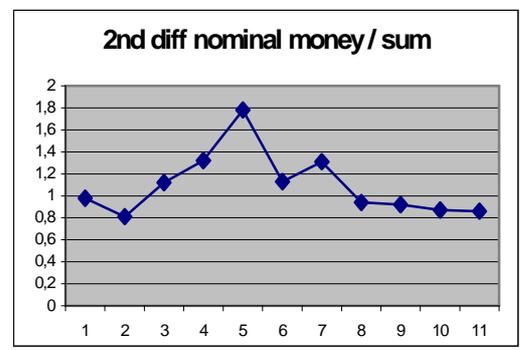
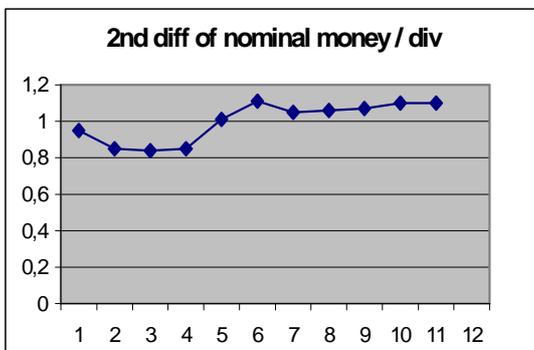
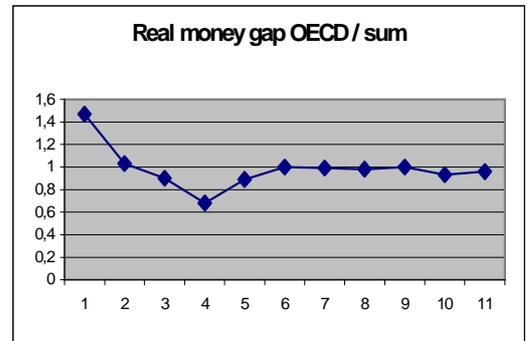
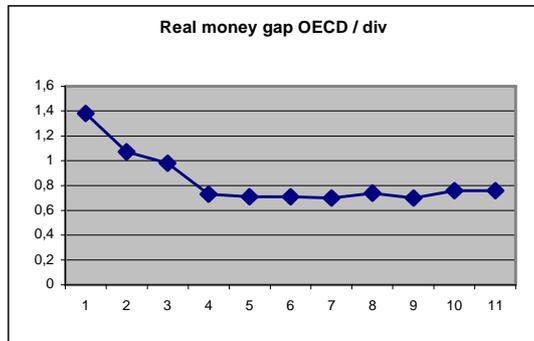
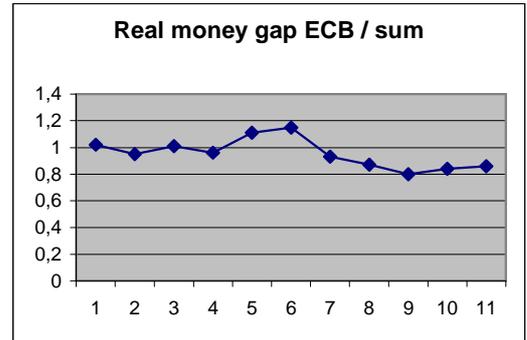
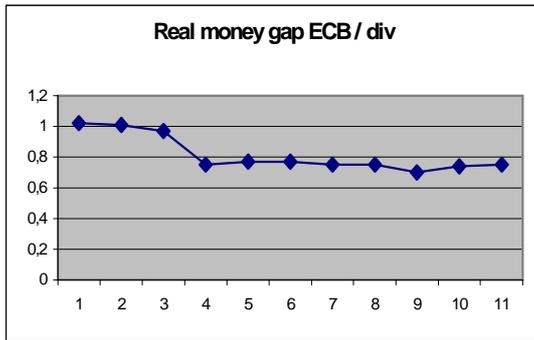
## APPENDIX B. LINE GRAPHS OF THE MSE RATIOS.

Relative MSE:s of the indicators based on forecasting equation (3.7) for both the Divisia and the simple sum M3 money.



The first pair of figures shows the MSE ratios for the real money gap series based on the potential output estimate from HP-filtering, the second pair shows them for the monetary overhang series, while the last pair shows the ratios for the growth rates of the nominal monies.

Relative MSE:s of the indicators based on forecasting equation (3.8) for bot the Divisia and the simple sum M3 money.



The first two pairs of figures plot the MSE ratios for the real money gap series based on the potential output estimates provided by the ECB and the OECD, respectively, while the last pair shows the MSE ratios for the growth of the growth rates of the nominal monies.