BANCA D'ITALIA

Temi di discussione

del Servizio Studi

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Number 458 - December 2002

THE ECONOMIC CONSEQUENCES OF EURO AREA MODELLING SHORTCUTS

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Abstract

The available empirical evidence suggests that non-negligible differences in economic structures persist among euro area countries. Because of these asymmetries, an area-wide modelling approach is arguably less reliable, from a strictly statistical viewpoint, than a multi-country one. This paper revolves around the following issue: are those (statistically detectable) asymmetries of any practical relevance when it comes to supporting monetary policy decision-making? To answer this question, we compute optimal parameter values of a Taylor-type rule, using two simple area-wide and multi-country models for the three largest economies in the euro area, and compare the corresponding optimized loss functions. The results suggest that the welfare under performance of an area-wide modelling approach is likely to be far from trifling.

JEL classification: C53, E52.

Keywords: euro area, aggregation, monetary policy rules.

Contents

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1. Introduction and main findings[1]

The introduction of the single currency in a number of European countries on 1st January 1999 and the establishment of a single monetary authority for the euro area have raised a number of novel challenges for European policy-makers, economic scholars and practitioners alike. As regards specifically the implications for monetary policy, they have naturally been remarkably deep: a new monetary policy strategy has been adopted, new operating instruments have been put in place, and new tools and procedures have been developed to support monetary policy decision-making.

Concerning specifically tools and procedures, it is clear that conducting monetary policy for the euro area as a whole requires that short-term assessments, medium-term projections and policy analyses – previously run on a country-by-country basis – should now be extended to cover consistently all economies in the area.[2]

Regarding the tools to be used in those contexts, the following basic issue has to be faced: can the euro area monetary policy-maker safely rely on forecasts and policy analyses that are based on an area-wide modelling approach (i.e., an approach that treats aggregate time-series for all countries in the area as if they referred to just one large single economy)? Or, alternatively, should euro area monetary policy-making be based on a multi-country modelling approach (that consists in using disaggregate data to build inter-linked single-country models for the various countries)? One's preference is bound to go to the second approach, to the extent that significant structural differences still persist among the economies in the area.

This issue may be, and frequently has been, addressed from a statistical and econometric viewpoint by investigating the extent of the differences in economic structures, and particularly in the monetary transmission mechanisms, of the countries participating in the euro area. A large and ever-growing body of evidence is available on these issues, the main goal usually being a different one, i.e., to assess whether the single monetary policy is likely to have

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1 We thank Andrea Brandolini, Riccardo Cristadoro, Marco Lippi, Daniele Terlizzese and participants in a workshop at the Banque de France for many helpful comments and suggestions. The usual disclaimers apply. The views expressed in this paper are those of the authors and do not necessarily represent those of the Bank of Italy. Email: monteforte.libero@insedia.interbusiness.it; siviero.stefano@insedia.interbusiness.it.

2 Indeed, the tools and procedures currently underlying the Eurosystem macroeconomic projections have been carefully designed, starting prior to the introduction of the single currency, to meet that requirement; for a description see ECB (2001).

different macroeconomic effects in the various countries because of asymmetries among the economies in the area.[3] Most studies indicate that relevant asymmetries still exist, and that they are likely to reflect deep structural differences.[4] Albeit serving a different purpose from the one we have here, those findings tentatively suggest that a multi-country modelling approach is preferable to an area-wide one.

More formally, one may test whether or not parameter estimates based on aggregate data for the area as a whole are affected by aggregation bias.[5] Monteforte (2002) has recently argued, on the basis of aggregation tests computed with the models used for the experiments presented in this paper, that on the whole the empirical evidence does call for a rebuttal of the hypothesis that econometric modelling of aggregate euro area data is a statistically appropriate modelling strategy.

One might nevertheless tentatively conjecture that, while an aggregate modelling strategy may well be inappropriate from a statistical viewpoint – as it overlooks a number of differences in economic structures – it may still be "good enough" for any practical purposes. In other words, one might speculate that the evidence of statistically significant structural differences indicated by aggregation bias tests does not *per se* entail that an area-wide modelling approach would provide the monetary policy-maker with unreliable analyses

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[3] A (very) partial list of recent works that have a bearing on this issue includes Dornbusch, Favero and Giavazzi (1998), Ramaswamy and Sloek (1997), Guiso, Kashyap, Panetta and Terlizzese (1999), Hughes Hallett and Piscitelli (1999), Dedola and Lippi (2000), Clements, Kontolemis and Levy (2001), Ciccarelli and Rebucci (2002), and the papers presented at a recent ECB conference ("Monetary Policy Transmission in the Euro Area", ECB, Frankfurt, 18-19 December 2001).

[4] On the structural determinants of the observed asymmetries, not much is available in the literature yet. Fragmentary evidence may be found in van Els, Locarno, Morgan and Villetelle (2001).

[5] The econometric literature on aggregation bias does not univocally predict that using disaggregate data is preferable to relying on the corresponding aggregates (see, e.g., Barker and Pesaran (1990) Lippi and Forni (1990), Pesaran, Pierse and Kumar (1989) for extensive reviews of all related issues). It is well known, ever since Theil (1954) at least , that an aggregate modelling approach is the preferable one if either the structural parameters of the disaggregate models are all the same, or if compositional stability holds. Since these conditions are usually found not to hold in practice, aggregation bias is a very frequent occurrence. Hence, a disaggregate approach is generally advisable. Grunfeld and Griliches (1960) show that this is no longer true if one considers the possibility of measurement errors and/or misspecification of the disaggregate relationships. In our case, it is unlikely that these latter arguments apply: national statistics are themselves the result of aggregating a large number of primary data; while the statistical criteria underlying national data are well established, the choice of the most appropriate aggregating functions to be used in constructing euro area figures is an issue still under debate (see, e.g., Winder (1997), Beyer, Doornik and Hendry (2000) and Labhard, Weeken and Westaway (2001)); there is long experience in the econometric modelling of individual countries; finally, multi-country modelling may take into account a number of relevant aspects (e.g., cross-country trade links) that either are not well-defined or are hard to incorporate in an aggregate model.

and insight. This would be the case if it were possible to show that the welfare loss incurred by a hypothetical policy-maker relying on the information provided by an aggregate model is likely not to be significantly different from the welfare loss incurred by a policy-maker relying on disaggregate econometric tools. If no big welfare losses were at the stake, the area-wide approach would clearly be preferable for a number of obvious reasons (e.g., parsimony and transparency).[6]

In this paper we tackle the issue of choosing an econometric modelling strategy for the euro area from the viewpoint outlined above. Specifically, we measure the size of the additional welfare cost that would be incurred by the euro area policy-maker if monetary policy decisions relied on an area-wide modelling approach, rather than a multi-country one.[7]

Our approach may be sketchily described as follows: first, we compute optimal monetary policy rules subject to the assumption that the euro area economy can be satisfactorily described by an aggregate area-wide model (Aggregate Euro Area Model, AEAM), or, alternatively, by a disaggregate multi-country one (Disaggregate Euro Area Model, DEAM). The choice was made to compute optimal Taylor-type rules, in which the policy-controlled interest rate reacts only to current inflation and a measure of the output gap; in addition, the rule is allowed to include an instrument-smoothing term. Second, using the structure and the variance-covariance matrix of the DEAM, we assess the welfare losses associated with either the AEAM-based rule or the DEAM-based one. The choice of comparing both rules based on the DEAM is justified by the empirical evidence briefly recalled above, and in particular the results presented in Monteforte (2002), where it is shown that the conditions for aggregability do not hold for inflation and output gap euro area data. Third, we compare the welfare losses.

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[6] An obvious objection comes mind: why should one be concerned about this issue only as far as the euro area is concerned? Why is it that this issue has never been raised, at least as far as we know, for other monetary unions? There is hardly any doubt that heterogeneity among euro area countries is widely presumed to be considerably more pronounced than in other monetary unions or federal states (the US naturally coming to mind), largely because of differences in the institutional structures of participating countries, which are expected to persist, at least to a certain extent, for some time into the future. Hence, one may conjecture that the potential loss associated with the use of aggregate econometric tools is likely to be larger for the euro area than for other economies. Whether this is indeed the case is precisely the issue we tackle.

[7] It should be emphasized that, in reality, the process through which Eurosystem decisions are made does not strictly correspond to either of the two extreme hypothetical cases that, for the sake of the argument, we contrast and compare in this paper. As described in ECB (2001), both area-wide and multi-country tools, developed by both the ECB and NCBs, are being used for forecasting and policy analysis purposes. Thus, the possibility that relying exclusively on area-wide tools might be sub-optimal was implicitly recognized when the forecasting tools used and the procedures now followed by the Eurosystem were designed.

If the difference between the two were trifling, then one could conclude that an area-wide modelling approach is a reasonable choice when it comes to supporting the single monetary policy; vice versa, if the differences were sizeable, it would be wiser to resort to the DEAM. Hence, in a way, our approach may be viewed as an indirect method of testing whether the convenient simplification of aggregability can be maintained.

The foregoing description reveals that our approach has, by construction, a clear implication about the ranking of the two rules: the DEAM-based rule is bound not to be inferior to the AEAM-based one. The issue then becomes one of size: by how much is the DEAM-based rule preferable to the alternative? Because of the inevitable superiority of the DEAM, we not only compute the difference in the performance of the two rules, but also appraise the significance and robustness of that difference, taking into account both the stochastic structure of the DEAM's disturbances and that of its estimated parameters. Moreover we assess how the main results would be affected should the national stochastic disturbance processes become increasingly homogeneous across countries.

Our findings suggests that the additional welfare losses that are incurred by relying on an aggregate modelling approach (as opposed to a disaggregate one) are all but trifling. On the whole, we believe that our conclusions, while obviously model-dependent, are satisfactorily robust with respect to a number of sensitivity analyses, and suggest that this issue is worth investigating further, possibly using more realistic and fully-fledged models of the euro area economy; we conjecture that this would, if anything, reinforce our results.

This paper may be viewed as complementing some recent contributions focusing on optimal monetary policy rules for the euro area.

De Grauwe and Piskorski (2001) use a multi-country model to compute optimal monetary policy rules for the euro area under two different assumptions regarding the loss function: (i) the loss function depends on aggregate inflation and output gap (aggregate loss-function); (ii) the loss function is given by a weighted average of the individual countries' loss function, the arguments of the latter being, again, inflation and the output gap (multi-country loss function). Their (comforting) finding is that the second specification of the loss function, while clearly inconsistent with the Eurosystem's primary objective as specified in the ECB's Statute, would lead to approximately the same outcome as what they label "aggregate data targeting."

Angelini, Del Giovane, Siviero and Terlizzese (2002) focus on the role that can be played by information at the national level in setting the single monetary policy of the euro area. They find that the performance of a central bank that chooses the nominal interest rate to minimize a standard quadratic loss function of area-wide inflation and output gap significantly improves if the reaction function includes national variables – as opposed to the case in which the interest rate reacts to area-wide variables only.

Our paper shares the same key assumption as De Grauwe and Piskorski (2001) and Angelini, Del Giovane, Siviero and Terlizzese (2002) as far as the Data Generating Process (DGP) is concerned: specifically, we postulate that the DGP is more accurately described by the DEAM. On the basis of this maintained assumption, we assess the welfare losses associated with following an area-wide modelling approach.

Table 1 schematically describes the issues explored in the three papers.

Table 1

Issues explored in the recent literature on euro area monetary policy decision-making.

Paper	Loss function	Data Generating Process	Model	Rule
DGP (2001)	***MC*** ***AW***	MC	MC	MC
ADGST (2002)	AW	MC	MC	***MC*** ***AW***
This paper	AW	MC	***AW*** ***MC***	***AW=f(AW model)*** ***AW=f(MC model)***

Legenda: AW=area-wide; MC=multi-country; DGP= De Grauwe and Piskorski (2001); ADGST=Angelini, Del Giovane, Siviero and Terlizzese (2002); bold letters are used to highlight the specific AW-MC trade-off examined in each of the three papers.

The paper is organized as follows. Section 2 describes the two basic modelling options available to support monetary policy-making in the euro area and presents the main features of the stylized aggregate-demand/aggregate-supply AEAM and DEAM used in the remainder of the paper; a full listing of both models is provided in the appendices. Section 3 outlines the experimental design (see above for a short description). The results of our experiments are discussed in Section 4. Section 5 draws some tentative conclusions as to what we believe our results imply concerning the choice of a modelling approach to support euro area monetary policy-making.

2. Simple area-wide and multi-country models for the euro area

A modeller wishing to build empirical tools for forecasting and policy analysis purposes in the euro area faces two basic options: as a first alternative, one could build a multi-country model, i.e., a model that describes the functioning of the economic mechanisms in the individual countries of the area and the inter-linkages amongst them. A model of this kind may of course allow for idiosyncratic factors to be taken into account for individual countries, so that any country-specific features may be reflected by either the structure of the model and/or the value of the estimated parameters. In the course of forecast and policy analysis exercises, area-wide economic developments would then be computed by aggregating the individual country results. As a second, much less onerous, alternative, one may first aggregate the individual country data[8] and model the latter as if they referred to one single, homogeneous economy.

Both approaches are being pursued in practice, even by the same institutions. For instance, the Eurosystem projections, which have been published by the ECB since December 2000, are the result of a multi-staged process that involves aggregating country-specific projections (mostly based on the national models of participating NCBs) while also using information derived from the ECB's Area-Wide Model (AWM),[9] to come to one single, consistent picture (see ECB (2001)).

The advantages of adopting an area-wide approach are obvious: an area-wide model is more parsimonious, less costly, more readily available, arguably more transparent. Unfortunately, snappiness often comes at a cost.

Monteforte (2002) tackles the issue of the choice between the two approaches outlined above from a statistical viewpoint, testing whether one may model aggregate data for the euro area without incurring significant bias and loss of information, the term of comparison

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[8] Labhard, Weeken and Westaway (2001) argue that the actual choice of the aggregating function is unlikely to affect significantly the properties of the model. Full details as to the aggregating function(s) adopted in this paper are provided in the appendices.

[9] For a description of the structure and properties of the AWM see Fagan, Henry and Mestre (2001).

being working with disaggregate data. Empirical testing shows that there are considerable information losses to be incurred in following an area-wide modelling approach. Specifically, Monteforte (2002) developed two separate models for the three largest economies in the euro area (Germany, France and Italy, covering some 70 per cent of the area GDP). In both models the functioning of the economy is described by just two equations: (i) a Phillips curve (or aggregate supply equation), modelling inflation as a function of the output gap; (ii) an IS curve (or aggregate demand equation), that determines the output gap as a function of the real short-term interest rate. The first model (AEAM) uses aggregate data; the second model (DEAM), on the contrary, specifies a two-equation sub-model for each of the three countries (so that it comprises 6 equations altogether), and includes a number of inter-linkages among the three sub-models[10] as well as two identities that define area-wide aggregates.[11] Formally testing for aggregation bias, Monteforte (2002) finds that the data are sharply in favor of the disaggregate modelling.

A detailed description of those models is beyond the objective of this work (although a complete listing of both models is provided in the appendices). To provide some insight into the properties of the models, Figures 1, 2 and 3 show the impulse responses of both models to a number of shocks. Since the Phillips curve is vertical in both models, neither of them would be stable if they were not augmented with a stabilizing policy rule. To compute impulse

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[10] In particular, inflation in any of the three countries may depend on "imported inflation" from the other two (imported inflation, in turn, reflects not only foreign inflation, but also, in the estimation sample, the dynamics of the bilateral exchange rates); similarly, the cyclical position of any of the three economies may depend – because of the intense trade linkages amongst the three countries – on the cyclical positions of the other two.

[11] The simple models presented in this section are entirely backward-looking and their parameters cannot be given a structural interpretation in terms of "deep" underlying parameters relating to preferences and technology. Hence, they are clearly potentially affected by the well-known difficulties associated with the evaluation of policy changes on the basis of behavioural relationships found to hold under a different policy set-up (Lucas (1976)). There are, however, several general reasons to believe that the Lucas Critique may in practice be less disruptive than is widely held. First, the behaviour of economic agents may be backward-looking rather than forward-looking, the latter being a key ingredient in Lucas-type non-structurality. It is thus possible to test empirically which of the two behavioural schemes is indeed appropriate (Hendry (1988) and Favero and Hendry (1992)). Second, even if the agents' expectation formation process is assumed to be forward-looking, the possibility exists that, because the equilibrium is indeterminate, one may still specify rational and "Lucas-proof" decisional rules (Farmer (1991)). Third, the institutional changes or policy measures in question could not be the "regime shifts" that are needed for the Lucas Critique to apply (Sims (1982)). Finally, even if each individual agent were to modify her/his decisional rule as a consequence of a policy regime shift, the aggregation of heterogeneous reactions may result in an aggregate response that is much less pronounced than each of the underlying individual reactions, so that the actual, aggregate macroeconomic effects of a policy change may well be better approximated by an approach that disregards the inherent non-structurality (Altissimo, Siviero and Terlizzese (1999)). In our specific case, the empirical evidence presented below overwhelmingly supports the hypothesis of structural stability, even for the most recent period, when, arguably, a major shock to the policy regime took place.

responses, both models were supplemented with the same monetary policy reaction function. Specifically, a Taylor-type rule, with coefficients 1.5, 0.5 and 0.5, for current inflation, the output gap and the lagged interest rate, respectively, was added to both models. As shown by the results reported in the figures, both models are stable, although even temporary shocks may result in very persistent deviations from equilibrium.[12]

The results show a number of similarities between the AEAM and the DEAM. First, in both models the effects of the shocks are rather long-lasting. Second, a shock to the aggregate supply equation induces a (dampened) oscillatory response of both inflation and the nominal interest rate. Third, the general pattern of responses is very similar across models: e.g., a Phillips curve shock induces a contraction of output that reaches its maximum, in both models, in the third and fourth years after the shock; similarly, a (temporary) increase in the policy-controlled interest rate results in a temporary contraction of output that reaches its maximum at the end of the first year after the shock (moreover, the size of the contraction is roughly similar for the two models). Fourth, the response of inflation to a monetary policy shock comes with a further lag with respect to the reaction of output (the lag is somewhat more pronounced in the case of the DEAM).

The results, however, also signal several relevant differences. First, according to the DEAM the economy takes a longer time to get back to equilibrium after being hit by a shock. Second, the size of the responses is usually larger for the DEAM model (e.g., while the contractionary effect of an aggregate supply shock reaches a maximum, for both models, in the third and fourth years after the shock, the reaction of output in the DEAM is about three times as large as in the AEAM; also, the DEAM is more reactive to monetary policy as far as inflation is concerned, while it is somewhat less sensitive than the AEAM if one considers the effects on the output gap). Third, because of the overall more pronounced impact of aggregate supply and aggregate demand shocks on the economy, monetary policy is more activist in the DEAM, notwithstanding the fact that both models were augmented with exactly the same Taylor-type rule.

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[12] For both the aggregate demand and aggregate supply equations, the shock amounts to one standard deviation of the corresponding estimation residuals. In the case of a monetary policy shock, the short-term interest rate is raised (for just one period) by 100 basis points.

3. Design of experiments

Our experiments must be designed so as to mimic the following two hypothetical cases: (i) the European monetary policy-maker relies on the AEAM; (ii) monetary policy-making relies, instead, on the DEAM.

Accordingly, we compute two distinct monetary policy rules for the euro area: (i) a rule in which the optimal parameter values are computed on the basis of the set of constraints given by the AEAM; (ii) a rule whose optimal parameter values are computed on the basis of the DEAM.

It would of course be possible to compute fully optimal instrument rules (i.e., rules that exploit all the information provided by the whole set of state variables, which we label FO rules) for both the AEAM and the DEAM. However, the vector of state variables is different for the two models (in particular, it is larger for the DEAM than for the AEAM). For the sake of making the comparison as fair as possible, the two rules should be put on an equal footing. To this end, our experimental design restricts them both to be Taylor-type rules, and further requires that the hypothetical policy-maker who relies on the DEAM only respond to area-wide aggregates.[13] To sum up, we postulate that both hypothetical policy-makers set the current value of the policy interest rate on the basis of current area-wide inflation and output gap and of the lagged value of the policy instrument.

In both cases, a standard time-separable quadratic loss function is assumed, its arguments being the euro area average inflation rate and output gap, and a term that attaches a cost to the volatility of the policy instrument; i.e.:

$$L_t = E_t \sum_{\tau=0}^{\infty} \delta^{\tau} [\pi_{t+\tau}^2 + \lambda \cdot y_{t+\tau}^2 + \mu \cdot (\Delta i_{t+\tau})^2] \tag{1}$$

where δ is a discount factor, and λ and μ are parameters that reflect the policy-maker's preferences (the weight on deviations of inflation from its target is normalized to 1); π_{t+1} is the (euro area average) quarter-on-quarter consumer inflation rate; y_{t+1} is the output gap; i_{t+1} is the short-term policy-controlled interest rate.

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[13] In Angelini, Del Giovane, Siviero and Terlizzese (2002), where only the DEAM model is used, the policy-maker is also allowed to respond to country-specific variables.

It is worth stressing that our specification of the loss function implies that the euro area policy-maker is only interested in euro area average outcomes, and hence is consistent with the official Eurosystem's view of the monetary policy objective and strategy.

For $\delta \to 1$ the sum in eq. (1) becomes unbounded; however, following Rudebusch and Svensson (1999), p. 215, "the value of the inter-temporal loss function approaches the infinite sum of the unconditional means of the period loss function"; this implies that one can "interpret the inter-temporal loss function as the unconditional mean of the period loss function, "which is given by the weighted sum of the unconditional variances of the target variables:

$$L_t = \text{var}[\pi_t] + \lambda \cdot \text{var}[y_t] + \mu \cdot \text{var}[\Delta i_t] \tag{2}$$

In the following we adopt the loss function defined as in eq.(2). The quest for optimal policy was repeated with a wide range of values for λ and μ, ranging from a case in which the monetary policy-maker is only interested in inflation ($\lambda = \mu = 0$) to the opposite extreme, in which the policy-maker attaches a very high cost to deviations of the output gap from its equilibrium value (zero) and to the volatility of the policy-controlled interest rate ($\lambda = \mu = 3$).[14]

The two competing rules may thus be synthetically described as follows:

AEAM-based rule	
$\min\limits_{\gamma_1^A,\gamma_2^A,\gamma_3^A}$	$E_t \sum_{\tau=0}^{\infty} L_{t+\tau} = \min\limits_{\gamma_1^A,\gamma_2^A,\gamma_3^A} E_t \sum_{\tau=0}^{\infty}[\pi_{t+\tau}^2 + \lambda \cdot y_{t+\tau}^2 + \mu \cdot (\Delta i_{t+\tau})^2]$
s.to:	• AEAM (see Appendix 1) • $i_t = \gamma_1^A \cdot \pi_t + \gamma_2^A \cdot y_t + \gamma_3^A \cdot i_{t-1}$

[14] The ranges chosen for the loss function parameters are similar to the ones typically assumed in the literature; see, e.g., the papers collected in Taylor (1999).

and:

DEAM-based rule	
$\min\limits_{\gamma_1^M,\gamma_2^M,\gamma_3^M}$	$E_t \sum_{\tau=0}^{\infty} L_{t+\tau} = \min\limits_{\gamma_1^M,\gamma_2^M,\gamma_3^M} E_t \sum_{\tau=0}^{\infty} [\pi_{t+\tau}^2 + \lambda \cdot y_{t+\tau}^2 + \mu \cdot (\Delta i_{t+\tau})^2]$
s.to:	• DEAM (see Appendix 2) • $i_t = \gamma_1^M \cdot \pi_t + \gamma_2^M \cdot y_t + \gamma_3^M \cdot i_{t-1}$

Let us now tackle the crucial issue of how the performance of these two rules may be compared. On the one hand, it is by construction the case that a rule obtained from optimizing of the objective function under the assumption that the constraints are given by the DEAM will outperform the alternative rule (computed on the basis of the AEAM) if the performance of both rules is assessed on the basis of the DEAM, and vice versa. On the other hand, a comparison is only sensible if both rules are made to compete within the same framework. Consistently with the conclusions of virtually all relevant empirical literature – pointing to sizeable differences in the responses of the economies participating in the euro area to a number of shocks, and particularly to monetary policy ones – and with the findings of Monteforte (2002) – suggesting that aggregation bias affects aggregate estimates – the maintained assumption in the remainder of this paper is that the economy of the euro area is more accurately described by the DEAM. In the light of the foregoing arguments, it is on the basis of the DEAM that the performance of the competing monetary policy rules we compute will be assessed and compared.[15].

The issue then becomes: by how much does the DEAM-based rule outperform the AEAM-based one? Note that, while our experimental design has by construction a clear implication as to the ranking of the two rules, it does not *a priori* imply that their performances should necessarily be remarkably different. At any rate, we investigate not only the size of the difference in the performance of the two rules, but also its significance.

We further compute, as a benchmark, the fully optimal instrument rule (based on the DEAM) and the associated optimized variances.[16] This third set of results is used to

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[15] Specifically, we compute the unconditional variances of inflation and output gap on the basis of the DEAM and the corresponding variance-covariance matrix of residuals, imposing that the parameters of the rules are those derived with the DEAM itself, or, alternatively, that they are the AEAM-based ones.

[16] For this purpose, we first derive the state-space representation of the DEAM, and then solve a standard

assess whether the gains associated with following a DEAM-based rule are significant when compared with the (larger) gains that could be attained by relying on the truly optimal one.

Following an approach similar to the one suggested by De Grauwe and Piskorski (2001), optimal parameters for the AEAM-based and DEAM-based rules are also computed under different assumptions regarding the stochastic process generating the stochastic disturbances. It is worth noting, before we briefly describe those additional experiments, that the variance-covariance matrix of the historical residuals of the DEAM may be seen as consisting of two main diagonal blocks: the first one gives the variance-covariance matrix of the stochastic elements of the Phillips curve sub-block in the three countries; the second block contains the variances and covariances of the stochastic terms of the aggregate demand functions in the three countries. The elements of the off-diagonal blocks in the historical variance-covariance matrix are all very small. Indeed, assuming that they are all zero does not significantly change the results. The alternative assumption we formulate is that, once full convergence is reached, all stochastic processes that belong to the same diagonal block are exactly the same; their (common and identical) variance (as well as covariances) is given by a (sort of) weighted average of the three corresponding historical variances.[17] We also consider a range of less-than-full convergence. The alternative assumption just described may be viewed as a way to mimicking, in an admittedly very extreme and hence unrealistic fashion, the possibility that euro area economies become increasingly similar, if not in their structures, at least insofar as the exogenous shocks hitting the economies are concerned. Indeed, to the extent that the major source of asymmetric shocks before 1999 was exchange rates,[18] postulating some convergence of the stochastic processes seems sensible.

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stochastic linear regulator problem (see Chow (1970), Sargent (1987), and, for an application to the issue of optimal monetary policy design, Rudebusch and Svensson (1999)). For the sake of brevity, we omit the technical details here.

[17] More precisely, as in De Grauwe and Piskorski (2001), the average variances are calculated as squared weighted sums of the standard deviations of the country-specific Phillips curve and aggregate demand shocks.

[18] One may indeed conjecture that pre-1999 disturbance asymmetries reflected the different behavior of the exchange rates *vis-à-vis* the rest of the world (by contrast, the bilateral exchange rates among the three countries we consider are included in the estimated Phillips curve equations and so cannot be, by construction, a source of the observed asymmetries in stochastic residuals).

4. The results

4.1 *Basic findings*

The main results of our experiments are shown in Figure 4 and Table 2.

Let us focus first on the final outcome of the two competing rules (Figure 4). The top chart of the figure reports the percentage reduction in the optimized value of the objective function if the DEAM-based rule is followed instead of the AEAM-based one. The welfare gains appear to be far from negligible, ranging from a minimum of about 10 per cent (when both λ and μ are close to zero; note, however, that the case of pure inflation targeting results in a welfare gain of almost 20 per cent) to over 32 per cent; they tend to exceed 20 per cent as soon as the policy-maker's preference structure is postulated to attach a non-zero cost to instrument volatility and/or to deviations of the output gap from zero. The key message given by the figure is that ignoring the structural differences among the euro area economies, and so adopting a model that treats them as a single and homogeneous "whole," would lead to a very sizeable worsening of the performance of monetary policy, particularly when the policy-maker pays some attention to output and is concerned about excessive interest rate variability.

In principle, for given preferences, the loss function is identified only up to a positive linear transformation: hence, it could be argued that the actual size of the percentage loss reduction could be made as little, or as large, as desired, simply by applying an appropriate transformation. However, the results may be appraised in such a way as to defuse this potential criticism.

First, one may appraise the loss function reduction in relative terms, using the FO rule as a benchmark. The bottom chart of Figure 4 shows that the hypothetical policy-maker relying on the DEAM would go a long way towards reducing the distance (measured in terms of welfare) between a policy rule based on the AEAM and the optimal instrument rule. Specifically, for $\lambda = \mu = 0$ the DEAM-based rule makes up for almost 70 per cent of the total distance (in terms of optimized loss functions) between the AEAM-based rule and the FO one. As before, this becomes less evident in the immediate neighborhood of $\lambda = \mu = 0$ (where the figure drops to 20-30 per cent), but it becomes once again sizeable for most other combinations of preference parameters (most figures being comprised between 40 and 60 per cent). Thus, not only is the size of the gains that can be attained with a multi-country modelling approach far from negligible, but adopting the true optimum rule as a benchmark, those gains are even more considerable.

Second, the results can be assessed directly in terms of the optimized unconditional standard deviations of inflation, the output gap and interest rate changes. This is done in Figure 5, showing the optimal inflation/output gap frontier (in terms of optimized standard deviations of those variables) for the AEAM-based, DEAM-based and FO rules. The frontiers have been computed, for given μ, by letting λ take a grid of values between 0 (north-west) and 3 (south-east). As a further benchmark, we also report the inflation/output gap trade-off associated with a standard Taylor rule with no instrument smoothing (i.e., with $\gamma_1 = 1.5, \gamma_2 = 0.5$ and $\gamma_3 = 0$ in our notation). While the frontier associated with the FO rule is positioned considerably to the south-west with respect to the frontier associated with the DEAM-based rule, the latter consistently attains a combination of inflation and output gap volatility that is sizeably better than that of the AEAM-based rule. For no combination of preference parameters do the performances of the DEAM-based and AEAM-based rules come close to one another. As the cost attached to instrument volatility is raised, the relative performance of the DEAM-based rule becomes better and better, confirming the remarks made when discussing Figure 4 above. Moreover, as the weight of the output gap and the change in the interest rates in the loss function increases, the performance of the DEAM-based rule become relatively closer to that of the FO one.

Can one trace these outcomes back to the properties of the different optimal rules, and in particular to the optimized parameters on inflation, the output gap and the lagged interest rate in the monetary policy reaction functions? The latter are presented in Table 2.[19] The optimal instrument rule obviously depends on the complete set of the 15 state variables in the DEAM: the latter set comprises inflation and output gap in the various countries for different lags. For ease of comparison, the coefficient on inflation reported in Table 2 is given, for the optimal instrument rule, by the sum of the value of all coefficients that the rule assigns to inflation in all countries and for all lags; similarly for the output gap.

A number of features are noteworthy in that table. First, the optimized parameters of the DEAM-based rule come generally much closer to the corresponding optimized parameters in

[19] Table 2 does not show the results for the cases in which either μ or λ are exactly zero. While a solution may be computed for any of those cases, the resulting coefficients are not plausible, as they differ dramatically from any estimates that may be computed on the basis of the observed behavior of the monetary policy-maker.

the optimal instrument rule, while those of the AEAM-based rule are often distant. Consider, for instance, the first set of loss function weights ($\lambda = \mu = 0.1$): the fully optimal parameter on inflation is 1.00; for the DEAM-based rule, the corresponding value is 0.86, while for the AEAM-based rule it is as low as 0.59. Similarly for the output gap, and for all other combinations of loss function weights. Second, the AEAM-based rule is consistently not "reactive" enough to either inflation or the output gap compared with the other two rules. On the whole, the features commented so far are consistent with the relative performance of the three rules as shown in Figures 4 and 5.

It may be instructive to examine the response of the DEAM to a number of different shocks if monetary policy-making is assumed to be conducted on the basis of the three different rules alternatively. This is done, for one particular choice of the preference parameters, in Figures 6, 7 and 8. In light of the foregoing remarks, it is hardly surprising that the responses of the model under the DEAM-based and FO rules do not, in general, differ much from one another, as compared with the behavior of the model under the AEAM-based rule. Generally speaking, the latter induces a more pronounced oscillatory behavior compared with the other two rules, especially in response to a Phillips curve shock; it is worth noting that the instrument volatility is also comparatively large. It may be conjectured that a multi-country modelling approach results in a more complicated dynamic structure than is detected by an area-wide modelling approach:[20] because of the AEAM's simpler dynamics, setting a rule on the basis of the latter results in dynamic responses that differ significantly from the optimal ones.

4.2 *Testing the significance of the results*

The results presented so far suggest that, were the euro area policy-maker to formulate his/her decision on the basis of the indications of an aggregate area-wide model, he/she would be likely to incur non-negligible welfare losses as opposed to the case in which he/she relied on a multi-country tool. However, while the size of the welfare gains that are at stake appear to be large, it remains to be establish whether they are significant from a statistical viewpoint.

To tackle this issue, we perform two stochastic simulation exercises. In the first we compute, for a (large) number of realizations of the stochastic disturbances (drawn from

[20] Indeed, it is well-known that the dynamics of aggregate series are, in general, much more complicated than the dynamics of the elementary series from which the aggregate data are computed, although it may be difficult, in practice, to detect statistically the significance of all lagged variable values that should in principle be included in the estimated aggregate relationship.

the distribution of the estimation residuals), the value of the objective function under the alternative assumptions that the optimal rule is computed on the basis of the AEAM or the DEAM. The second exercise is similar, except that we sample from the stochastic distribution of the estimated parameters.

Focusing on the first exercise, we extract 1,000 replications from the set of estimated residuals and simulate the model, for each replication, under either one or the other of the two competing rules. Each replication consists of 800 realizations of the shocks for the six stochastic equations in the model, one realization per period. Although the model is simulated for 800 periods, only the average outcomes in the last 400 periods are used to evaluate the objective function. This is done to prevent the results from being biased by the initial conditions (we begin simulating the model from a situation of equilibrium; by scrapping the first 400 results, the simulated variance of the objective variables should provide a reasonable approximation of their unconditional variance which indeed turns out to be the case). This we repeat for all combinations of preference parameters in the welfare function.

For all combinations of preference parameters, the DEAM-based rule delivers a better outcome than the alternative in the overwhelming majority of replications (for most preference parameters, the figure is comprised between 80 and 85 per cent, the lowest figure being almost 75 per cent when $\lambda = 0$ and $\mu = 0.1$, the highest being virtually 100 per cent in the case of pure inflation targeting; see the top chart of Figure 9). Hence, not only is the gain large on average, it is also systematic. The bottom chart of Figure 9 also shows that, for most combinations of preference parameters, the welfare gain associated with the DEAM-based rule amounts to at least 20 per cent of the loss associated with the AEAM-based rule in 50 to 60 per cent of all replications, with the exception of a neighborhood around (but not including) $\lambda = \mu = 0$ (the lowest figure being around 15 per cent).

We also formally tested the hypothesis that the average welfare loss associated with following the DEAM-based rule is lower than the average loss with the AEAM-based rule (the test is a one-sided test based on comparing the averages of the objective function outcomes associated with either one or the other of the two rules for all 1,000 replications).[21] The results are overwhelmingly supportive of the hypothesis: for all combinations of policy parameters the tail probability of the test is virtually zero.

[21] The test is based on the standard statistic for the equality of the means of normally distributed variables.

Overall, these results indicate that the gain associated with adopting the DEAM-based rule is not only large, but also significantly so, and systematic, moreover.

The second exercise explicitly accounts for the stochastic nature of the estimated model coefficients. In the previous paragraph, as well as in much of the literature on policy rules, the model used to derive and appraise the optimal rules is assumed to describe accurately the functioning of the economy. Actually, the most one could argue is that with a certain probability the "true" model parameters lie in the neighborhood of the estimated ones. It could then be that their variance-covariance matrix is so "large" as to make whatever differences one finds between the performances of competing rules statistically irrelevant. In a sense, this exercise can be interpreted as a check on the robustness of our main result: indeed, we check whether the latter would survive were the "true" model somewhat different from the one used to derive the two rules. The need for such a check is particularly acute in the case at hand, since we compare the performance of the DEAM-based and AEAM-based rules by computing the respective loss functions under the assumption that the DEAM is the true model, an assumption that, while justified by the empirical findings recalled earlier, has a clear implication as to the ranking of the two rules (although it says nothing about their distance).

In more detail, to account for the variability of the estimated coefficients we extract 5,000 replications from the empirical distribution of the estimated DEAM coefficients and, without re-computing the DEAM-based and AEAM-based rules, we compute, for each replication of the model coefficients, the associated loss function (almost half of the replications had to be discarded, as they produced explosive estimates of the unconditional variance-covariance matrix with either the DEAM-based or the AEAM-based rules, and in general with both; see below for more details). We then examine the distribution of the loss function under the two rules. These steps are repeated for 49 combinations of values of the preference parameters λ and μ.

A first set of results is shown in Figure 10 (top chart). It can be seen that in (almost) 70 to 80 per cent of all the "alternative worlds" that are plausible given the estimate of the DEAM, the DEAM-based rule does strictly better than the AEAM-based one for any combination of preference parameters. Hence, coefficient variability is not such as to jeopardize our conclusions above. For 35 to over 50 per cent of the replications (depending on the particular combination of preference parameters) the DEAM-based rule delivers a reduction of the loss function of at least 20 per cent (bottom chart of Figure 10). Overall, it seems safe to conclude that the results are systematic across "alternative worlds" (as long as the latter are statistically compatible with the estimated DEAM), and the gains are large relatively often.

Finally, as in the exercise above, we formally test the hypothesis that the average (across replications) welfare loss associated with the DEAM-based rule is lower than the average loss obtainable with the AEAM-based one (Figure 11). Except in the case of pure inflation targeting and its immediate neighborhood, one is not able to reject the null hypothesis with a confidence level of at most 10 per cent (actually, for three quarters of the 49 combinations of the preference parameters for which the statistic was computed the tail probability is virtually zero). The few rejections reflect the fact that some of the individual drawings of the parameters of the model result in extreme outcomes, and arguably not fully realistic (e.g. the inflation process has roots larger than 1 while at the same time the policy instrument becomes virtually ineffective). Indeed, if those additional (few) outliers are eliminated, the tail probability of the test is always much lower than 1 per cent for all preference parameters.

Overall, these results clearly indicate that, whatever the "true" data generating process, the DEAM-based rule tends to be significantly better than the AEAM-based alternative (provided that our multi-country model is a reasonable approximation of the DGP). Not only is the welfare loss associated with the AEAM-based rule large, but it is also statistically significant and generally "robust" to parameter uncertainty.

4.3 *Stability testing*

In the following we present some evidence regarding the stability of the parameters of the DEAM and AEAM in the last few years, or lack thereof.

While the euro was officially introduced only on January 1st, 1999, one may argue that, at least since late 1996, the monetary policies for the three countries we consider had been tightly constrained. The bilateral exchange rates remained basically constant at about the same level as the irrevocable exchange rates with which those countries joined the euro area two years later,[22] and the financial markets considered it to be highly probable that those countries would participate in the single courrency (with the exception, at least for 1997, of

[22] In particular, Italy, having abandoned the ERM of the EMS in September 1992, re-joined it in late 1996 at the same bilateral exchange rate with the DM as the one irrevocably fixed when the euro was introduced in 1999.

Italy). Moreover, fiscal policies were also tightly constrained by the convergence process. Hence, we consider the whole period 1996-2001 as representative, at least approximately, of what might happen in the near future in the euro era. For these reasons we argue that, if our pre-euro models were to show any instabilities, those instabilities could be expected at least as early as the beginning of 1997, which we take to be the beginning of the euro era.

Thus, we re-estimated both models using data from 1978.Q1 to 1996.Q4; for both models, the parameter estimates are basically unchanged with respect to those obtained with the original estimation sample (which included 1997 and 1998). We then tested over the five years 1997-2001 the out-of-sample stability of the models estimated with data up to the end of 1996. The results are shown in Tables 3 and 4 and Figures 13 and 14. For both models, the empirical evidence overwhelmingly rejects the hypothesis of parameter instability; moreover, few signs of convergence of the DEAM parameters can be detected. Actually, although the coefficient variability is negligible (as shown in Figure 14), it turns out that the cross-country dispersion of a given parameter (say, the autoregressive term in the AD equation) is, if anything, slightly higher using the whole sample up to 2001 than using the samples up to 1996 or 1998 (the only exception being that of the impact on interest rates in the AD equation, that tends to be just slightly more similar across countries). Although these results clearly do not rule out sizeable changes in the future, we can at least conclude that the relevance of country-specific information for the conduct of the single monetary policy has not (yet?) faded and is expected to remain at least in the near future.[23]

The DEAM variance-covariance matrix computed with the 20 out-of-sample observations suggests, by contrast, that the symmetry of shock has somewhat risen since 1996, in particular for the disturbances in the AD equations. However, not too much emphasis should be put on a variance-covariance matrix for 6 stochastic disturbances estimated with just 20 observations, and one cannot reject the hypothesis that the matrix is the same as the one computed in-sample with data up to 1996 or 1998 (both of the latter are almost-diagonal matrices).

At any rate, taking the most recent estimate of the variance-covariance matrix, we computed the value of the objective function, using rules subject to DEAM and AEAM

[23] This evidence is of course of relevance also from the viewpoint of the Lucas Critique. Although the introduction of the euro can safely be deemed a major change in the policy rules, our simple model shows no sign of instability of behavioral equations.

estimated with data up to 1996. In other words, we investigated what would have happened if optimal monetary policy rules computed on the basis of pre-euro models had been used in the early stages of the euro era (which, as explained above, we take to have started in 1997; as the model parameters are rather stable, we keep using the models estimated with data up to the end of 1996). *A priori*, the results could come out either way: the under-performance of the AEAM-based rule could be somewhat attenuated in comparison with the benchmark case (because of the recent higher cross-country correlation of shocks), or could be magnified (if the pre-euro AEAM-based rule is less robust with respect to the change in the variance-covariance matrix).

On average, the results tend to be about as unfavorable to the AEAM-based rule as in the benchmark experiment, with the exception of a very small neighborhood around $\lambda = \mu = 0$ (but not including the latter point, where the welfare gain associated with using the DEAM-based rule amounts to about 16 per cent). For $\lambda = \mu = 0.2$ or higher, the welfare gain stemming from following the DEAM-based rule ranges from 15 to 36 per cent.

To sum up, the recent evidence supports the claim that the gains associated with using the DEAM-based rule, as opposed to the AEAM-based rule, have not started to diminish yet. One tends to conjecture that they will remain non-negligible at least in the near future.

4.4 *What could be ahead?*

Despite the evidence presented above, in this paragraph we explore how the comparison between the AEAM-based and DEAM-based rules would be affected were more symmetry of stochastic disturbances to prevail among the euro area countries than detected in the past.

Of course, convergence of disturbances might occur (if at all) in many different ways: all countries' shocks could become similar to some average of what they are now; the stochastic structure of the shocks of smaller countries could become more and more similar to that of the largest one; or the final outcome of the convergence process could well be something that does not at all resemble the current situation. In fact, there is no reason why convergence should necessarily take place; moreover, there is no compelling evidence that much convergence has taken place in the long run-up to the euro area.[24]

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[24] Eichengreen (1997) and Demertzis and Hughes Hallett (1998), have tackled the issue of the symmetry of the shocks to the European economies, or lack thereof; their empirical evidence shows that, although the European economies have followed rather similar policies in recent years, there is little evidence of a strengthening of the

This leaves us with many ways to model convergence, and we have no clear-cut criterion to offer as to which of them could be more plausible. Nevertheless, we believe that exploring the sensitivity of our results to some form of convergence can be informative, even if the eventual convergence process were to follow a different path.

To proceed, we will assume that countries that become more intimately tied to one another tend to share the same shocks, and influence those common shocks proportionately to their relative size (the largest country exerting a comparatively stronger effect on the common shocks than the other two, and so on).

More in detail, we take full convergence of aggregate demand shocks to mean that the disturbances in the aggregate demand equation become exactly the same in all countries (hence, the cross-country correlation equals 1). As in De Grauwe and Piskorski (2001), we assume that, once full convergence has been reached, the common variance (as well as covariances) is given by the square of a weighted average of the historical estimated standard deviations:

(3) $$\sigma^2_{y|FC} = (\omega_{y_G}\sigma_{y_G} + \omega_{y_F}\sigma_{y_F} + \omega_{y_I}\sigma_{y_I})^2$$

where $\sigma^2_{y|FC}$ denotes the variance of the common AD shock under convergence; $\sigma_{y_G}, \sigma_{y_F}, \sigma_{y_I}$ are the estimated standard deviation of AD disturbances in the three countries; $\omega_{y_G}, \omega_{y_F}, \omega_{y_I}$ are the GDP weights of the three countries.

We also consider the possibility of partial convergence, which we assume to be parameterized by ξ_{AD}, ranging from 0 (no convergence) to 1 (full convergence). For any given choice of the ξ_{AD} parameter, the corresponding elements of the variance-covariance matrix of the disturbances are given by:

(4) $$\sigma^2_{y_i|PC} = \xi_{AD}\sigma^2_{y|FC} + (1-\xi_{AD})\sigma^2_{y_i}$$

(5) $$\sigma_{y_j y_i|PC} = \xi_{AD}\sigma_{y_i|PC}\sigma_{y_j|PC}$$

for all i, j, so that the correlation of shocks among countries is given by ξ_{AD} itself.[25]

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degree of symmetry of the disturbances affecting the various economies.

[25] It would, of course, be possible to introduce the further complication that the speed of convergence is not

Full and partial convergence of aggregate supply disturbances are defined in a similar way, with the convergence process now parameterized by ξ_{AS}.

Turning to the results, under the extreme assumption that there are only two stochastic processes in the euro area (specifically, one stochastic process driving Phillips curve shocks, and one driving aggregate demand shocks, common to all countries), the under-performance of the AEAM-based rule is considerably attenuated. Figure 14 reports, for the case $\lambda = \mu = 1$, the loss function gain that can be attained by moving from the AEAM-based rule to the DEAM-based rule, as the degree of similarity of supply- and demand-side shocks across countries increases (similar results are found for all other combinations of preference parameters).[26] The gain in the event of no convergence amounts to some 25 per cent (which is obviously the same value underlying the corresponding point in Figure 4). With full convergence of shocks, there remains virtually no scope at all for using the DEAM-based rule. Note, however, that a sizeable degree of (uniform) convergence is needed before the gain associated with using the DEAM-based rule becomes relatively small; for instance, for that gain to fall below 10 per cent, there must be at least $\xi_{AS} = \xi_{AD} = 0.7$. Examining what happens if the pace of convergence differs on the supply- and demand-sides (i.e., looking at the off-diagonal elements in the figure), one concludes that neither type of convergence is much more relevant than the other.

5. Conclusions: what implications for euro area econometric modelling?

The results presented in this paper support the conclusion that monetary policy in the euro area is likely to be more effective if the econometric tools used to help monetary policy decisions acknowledge the structural differences among the various economies in the area, and so do not model aggregate euro area data as if they referred to one single, relatively homogeneous economy. The differences in the economic structures of the various countries

the same for all countries. However, for the sake of simplicity we ignore that possibility. Let us just remark that our concept of partial convergence tends to make cross-country heterogeneity disappear more smoothly than it would be conceivably possible.

[26] All rules perform less satisfactorily than in the set of experiments where the historical variance-covariance matrix was assumed to hold, the worsening being, of course, much more pronounced for the DEAM-based rule (and for the optimal instrument one) than for the AEAM-based rule. A general worsening of the optimized losses should indeed be expected: in the latter experiment the shocks are perfectly correlated, while the historical ones are virtually independent, and hence do not tend to reinforce each other.

appear to be pronounced enough to induce significant aggregation errors in the parameter estimates of an AEAM (Monteforte (2002)).

Our results show that aggregation error is not irrelevant from the viewpoint of policy-making: an AEAM-based monetary policy rule is sizeably sub-optimal with respect to a DEAM-based one.

The welfare losses associated with adopting and AEAM-based rule are not only sizeable but also highly significant.

Moreover, our results are generally robust with respect to model parameter variability.

Finally, while our investigation of possible instabilities of the model in the most recent past does not suggest that euro area economies are becoming increasingly similar to one another, we nevertheless probe what could happen if convergence occurred in the future. We find that sizeable convergence has to occur before our conclusions no longer apply.

Our conclusions are apparent in our simplified model for the three main countries. Arguably they would be all the more supported by an analysis that included all 12 economies in the area – as well as a more sophisticated and detailed description of their actual functioning – than is provided by the simple aggregate demand-Phillips curve models we use. In particular, a fully-fledged model for each individual country could pay closer attention to country-specific institutional features, labor market arrangements, tax structures, etc., thereby probably increasing asymmetries amongst country models. In this respect, one could even conjecture that the reduction in the welfare losses that we measure is a lower bound estimate.

Our results make a clear case for relying on a multi-country modelling approach when offering advice in support of the single monetary policy, and suggest that a line of research worth pursuing is a systematic investigation of the aggregation bias that is likely to affect aggregate (area-wide) estimated relationships and their effects on optimal policies.

According to Angelini, Del Giovane, Siviero and Terlizzese (2002), the optimized value of the loss function could be further reduced if the single monetary policy were to exploit fully the available national information (by not simply relying on a DEAM, but also reacting to national information). Combining these results with ours, one can appreciate the full distance between a "pure aggregate approach" (using an AEAM model and computing an AEAM-based rule) and a "full multi-country one" (using a DEAM and allowing for the policy instrument to react to country-specific variable): the total reduction in the optimized value of the loss function is always in the neighborhood of 50 per cent or more.

On the whole, the combined results suggest that, given the structural differences and the asymmetries in the transmission mechanisms, monetary policy-making in the euro area has a lot to gain if a disaggregate approach is followed, both in setting up the tools for forecasting and policy analysis in support of policy decision-making, and in designing the way in which those tools are used.

Appendix 1: The area-wide model

The Area Wide Model (AEAM) is a simple two-equation model estimated using aggregate data for the three largest economies in the euro area (Germany, France and Italy, jointly accounting for over 70 per cent of the area GDP). It includes an aggregate supply equation (also referred to as Phillips curve) and an aggregate demand equation (also referred to as IS curve). The first equation determines inflation as a function of lagged inflation and output gap. The sum of the coefficients on lagged inflation is constrained to unit, so that we assume the Phillips curve to be of the accelerationist type. The second equation relates the output gap to its own lagged values and the real interest rate.

A general-to-specific modelling approach was followed in searching for a satisfactory empirical specification, starting with as many as 6 lags for all variables on the right-hand-side of the two equations. The final specification is the following:

$$\begin{aligned}\pi_{t+1} &= \alpha_1 \pi_t + (1-\alpha_1)\pi_{t-3} + \eta y_t + u_{t+1} \\ y_{t+1} &= \theta y_t + \psi(i_{t-1} - 4 \cdot \pi_{t-1}) + v_{t+1}\end{aligned}$$

where:

- $\pi_{t+1} =$ quarter-on-quarter consumer inflation rate;
- $y_{t+1} =$ output gap;
- $i_{t+1} =$ short-term interest rate;
- $i_{t+1-k} - 4 \cdot \pi_{t+1-k} = r_{t+1}$ is thus a measure of the ex-post real interest rate.

The model was estimated with SURE, in the light of the possibility that the structural errors of the two equations might be correlated. The sample period extends from 1978.Q1 to 1998.Q4; 84 quarterly observations were therefore used. The estimation results are presented in Table A.1.1. The corresponding variance-covariance matrix of estimation residuals is shown in Table A.1.2.

The source of data is the ESA-95 National Accounts for inflation and the output gap, and the BIS data-bank for the short-term interest rate. Inflation is measured by the quarter-on-quarter rate of change of the (seasonally adjusted) households' consumption deflator. Potential output was estimated by applying a band-pass filter (see Baxter and King (1995) for details) to the (log) GDP (selecting frequency components of 32 quarters and higher, with a truncation of 16 quarters).

National variables were aggregated using a fixed-weight procedure, largely similar to the one followed by the ECB. For inflation, 1999 PPP consumer spending shares (as computed by the ECB) were used; for output gap, the weights are given by 1999 PPP real GDP shares (again, the source of the shares is the ECB). For interest rates, the weights are the PPP nominal GDP shares computed by the OECD. Output gap and inflation shares are shown in Table A.1.3.

While an ample choice of methods to aggregate national macroeconomic data is available (see, e.g., the extensive analysis in Beyer, Doornik and Hendry (2000)), available evidence suggests that this is far from a crucial factor in shaping the features of estimated models.[27] Therefore, we did not deem it worthwhile to assess the sensitivity of our results to the choice of the aggregation method.

[27] This is already apparent in the results of Beyer, Doornik and Hendry (2000). For an appraisal of the sensitivity of estimated models (specifically SVARs) to the various aggregation methods, see Labhard, Weeken and Westaway (2001). The latter conclude that the impact of the choice of the aggregation method on the empirical results is negligible.

Appendix 2: The multi-country model

The Multi-Country Model (DEAM) includes, for each of the three major euro area countries, the same set of equations as the AEAM. The specification of both the aggregate supply and the aggregate demand equation is similar to the one adopted in the AEAM but, in addition, it allows for across-country linkages. Specifically, inflation in any given country depends not only on its own lagged values and on the corresponding output gap, but also, at least in principle, on inflation "imported" from the other two countries (imported inflation is given by the sum of inflation in the foreign country and the rate of change of the relevant bilateral exchange rate). Like the AEAM, the sum of the coefficients on lagged and imported inflation is constrained to be 1 (the restriction is accepted by the data). The output gap in any of the three countries depends on its own lagged values and the corresponding real interest rate, as in the AEAM; in addition, it may react to the output gap in the other two countries, reflecting the tight trade links in the area.

The DEAM also comprises two identities for euro area inflation and output gap (the weights being those described in Appendix 1).

As the model set-up allows for instantaneous cross-country linkages, 3SLS were used to estimate its parameters. The sample period extends from 1978.Q1 to 1998.Q4 (thus totalling 84 quarterly observations, as for the AEAM). For most of the sample period, the exchange rates among Germany, France and Italy, though constrained by the ERM of the EMS, were not fixed. Accordingly, the measure of "inflation imported in country i from country j" was constructed, as mentioned earlier, as the sum of the inflation rate in country j and the quarter-to-quarter percentage change in the exchange rate between the two countries (units of currency of country i needed for 1 unit of country j's currency). In theory, full 3SLS estimation would require the model to include a set of equations for bilateral exchange rates. Given the well-known difficulty of finding satisfactory empirical specifications for the exchange rate, no attempt was made to augment the model with exchange rate equations. However, lagged values of all variables included in the model were used as instruments for the exchange rates. At any rate, in the experiments presented below, the percentage change of the exchange rate was set identically equal to zero, consistently with the introduction of the single currency as of January 1, 1999.

It is worth emphasizing that while the model set-up allows for instantaneous cross-country linkages, so that a simultaneous system estimation strategy is required, we chose to assume that the real interest rate affects the output gaps only with a lag. Hence, 3SLS estimation could be carried out without augmenting the estimation model with interest rate reaction functions for the three countries.

The general form of the two-equation sub-model for country j is the following:

$$\begin{aligned}
\pi^j_{t+1} &= \sum_{k=1}^{p} \alpha_{j,k}\pi^j_{t+1-k} + \sum_{i\neq j}\sum_{k=0}^{p} \beta_{j,i,k}(\pi^i_{t+1-k} + \dot{e}^{i,j}_{t+1-k}) + \sum_{k=0}^{p} \eta_{j,k}y^j_{t+1-k} + u^j_{t+1} \\
y^j_{t+1} &= \sum_{k=1}^{p} \theta_{j,k}y^j_{t+1-k} + \sum_{i\neq j}\sum_{k=0}^{p} \varphi_{j,i,k}y^i_{t+1-k} + \sum_{k=1}^{p} \psi_{j,k}(i^j_{t+1-k} - 4\cdot\pi^j_{t+1-k}) + v^j_{t+1}
\end{aligned}$$

where:

- π^j_{t+1} = quarter-on-quarter consumer inflation rate in country j;
- $\dot{e}^{i,j}_{t+1-k}$= quarter-on-quarter rate of change of the exchange rate between country i and country j (units of country j's currency for 1 unit of country i's currency; in the experiments below, this variable is identically zero, consistently with the introduction of the single currency in January 1999);
- y^j_{t+1} = output gap in country j;
- i^j_{t+1} = short-term interest rate in country j (while in estimation a measure of country-specific short-term interest rates where used, in the experiments below it was imposed that the interest rate be the same for all countries, i.e, $i^j_{t+1} = i_{t+1}$ for all j's);
- $i^j_{t+1-k} - 4\cdot\pi^j_{t+1-k} = r^j_{t+1}$ is thus a measure of the ex-post real interest rate in country j.

The starting specification included on the right-hand-side of each estimated equation the first 6 lags of all relevant variables. Joint 3SLS estimation of the three sub-models resulted, after dropping all insignificant lags, in a much more parsimonious specification. The resulting specification is presented in Table A.2.1 (exchange rates have been omitted in the table, as they play no role in the version of the DEAM used in this paper). The corresponding variance-covariance matrix is shown in Table A.2.2.

In keeping with the approach followed in similar literature, the model does not include any constant terms, i.e., it may be taken to provide a description of the functioning of the euro area economy in the neighborhood of equilibrium. This amounts to implicitly assuming that the same equilibrium values apply to all countries, a condition that does not hold in the sample period, particularly regarding the (implied) equilibrium real interest rates. It is evident that, if we were to assume that the equilibrium interest rates of the individual country models differed from one another, then the case for following a disaggregate approach would probably be much stronger.

Table 2

Reaction function coefficients and loss values for the optimal, the AWM-based and the MCM-based rules

Parameter values in the loss function:		Type of rule	Coefficients on:					Standard deviation of:			Loss
			Inflation	Output gap	Lagged interest rate	Inflation (long run)	Output gap (long run)	Inflation	Output gap	Interest rate change	
λ = 0.1	μ=0.1	FOR	1.00	1.16	0.67	2.99	3.48	0.58	1.23	1.05	0.60
		DEAM-based	0.86	0.82	0.82	4.86	4.63	0.76	1.47	1.54	1.03
		AEAM-based	0.59	0.61	0.84	3.72	3.85	0.92	1.38	1.08	1.16
	μ=1	FOR	0.43	0.50	0.79	2.08	2.40	0.75	1.22	0.57	1.04
		DEAM-based	0.35	0.44	0.91	3.73	4.72	1.04	1.45	0.84	1.99
		AEAM-based	0.27	0.29	0.90	2.56	2.75	1.37	1.36	0.61	2.45
λ = 1	μ=0.1	FOR	1.10	1.90	0.52	2.27	3.94	0.65	1.10	1.21	1.78
		DEAM-based	1.10	1.29	0.72	3.90	4.59	0.87	1.25	1.70	2.62
		AEAM-based	0.66	0.94	0.74	2.51	3.59	1.39	1.16	1.07	3.38
	μ=1	FOR	0.48	0.68	0.74	1.83	2.59	0.79	1.15	0.60	2.29
		DEAM-based	0.42	0.54	0.87	3.21	4.12	1.10	1.32	0.86	3.68
		AEAM-based	0.29	0.37	0.86	2.12	2.72	1.75	1.23	0.58	4.91
λ = 2	μ=0.1	FOR	1.15	2.41	0.43	2.03	4.25	0.71	1.06	1.40	2.93
		DEAM-based	1.24	1.66	0.65	3.55	4.77	0.96	1.19	1.89	4.09
		AEAM-based	0.72	1.23	0.67	2.17	3.68	1.73	1.10	1.19	5.56
	μ=1	FOR	0.52	0.83	0.70	1.71	2.75	0.83	1.11	0.63	3.57
		DEAM-based	0.48	0.64	0.84	2.97	3.96	1.17	1.26	0.90	5.33
		AEAM-based	0.31	0.44	0.84	1.91	2.77	2.07	1.18	0.59	7.42

Table 3

OUT_OF SAMPLE STABILITY, AEAM, 1997.Q1-2001.Q4

Equation	F-value	Tail probability
AS	0.91	57.49
AD	0.57	92.21

Table 4

OUT_OF SAMPLE STABILITY, DEAM, 1997.Q1-2001.Q4

Equation		F-value	Tail probability
Germany	AS	0.89	60.12
	AD	0.37	99.23
France	AS	0.67	84.46
	AD	0.76	75.38
Italy	AS	0.52	95.12
	AD	0.68	83.59

Table A.1.1

ESTIMATE OF THE AEAM

	Equation for:	
Input from:	π	y
π	0.652 [-1] (0.075) 0.348 [-4] (restr.)	
y	0.088 [-1] (0.035)	0.769 [-1] (0.060)
r		$-.050$ [-2] (0.022)
R^2	0.874	0.715
$\overline{R}^2$	0.869	0.704
σ	0.286	0.487
DW	2.209	1.800

In parentheses: standard error of the coefficients.

In brackets: lag with which the variables enter the equations.

Table A.1.2

CORRELATION MATRIX OF STOCHASTIC DISTURBANCES OF THE AEAM

	Aggregate supply	Aggregate demand
Aggregate supply	1	0.031
Aggregate demand		1

Table A.1.3

INFLATION AND OUTPUT GAP WEIGHTS

	Inflation weights	Output gap weights
Germany	0.45	0.43
France	0.27	0.29
Italy	0.28	0.28

Table A.2.1

ESTIMATE OF THE DEAM

		Equations for: Germany		Equations for: France		Equations for: Italy	
Input from:		π	y	π	y	π	y
Germany	π	0.292 [-1] (0.089) 0.600 [-4] (0.069)		0.063 [0] (restr.)		0.036 [0] (restr.)	
	y	0.095 [-1] (0.036)	0.785 [-1] (0.062)				0.173 [0] (0.058)
	r		−0.073 [-2] (0.038)				
France	π	0.108 [0] (restr.)		0.937 [-1] (0.044)			
	y			0.022 [-2] (0.012) 0.022 [-3] (0.012) 0.022 [-4] (0.012) 0.022 [-5] (0.012)	0.838 [-1] (0.052)		
	r				−0.036 [-2] (0.015)		
Italy	π					0.964 [-1] (0.010)	
	y					0.064 [0] (0.028)	0.657 [-1] (0.061)
	r						−0.038 [-1] (0.016)
	R^2	0.514	0.635	0.902	0.730	0.960	0.752
	$\overline{R}^2$	0.483	0.622	0.894	0.720	0.958	0.740
	σ	0.411	0.799	0.332	0.443	0.259	0.490
	DW	2.160	2.059	2.050	1.888	2.024	1.815

In parentheses: standard error of the coefficients.

In brackets: lag with which the variables enter the equations.

Table A.2.3

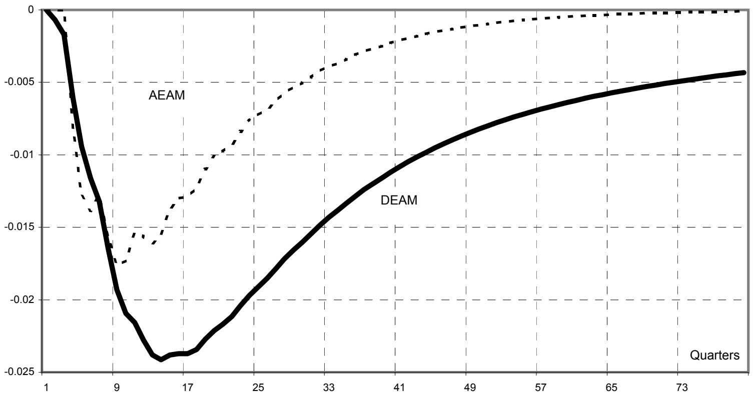
CORRELATION MATRIX OF STOCHASTIC DISTURBANCES OF THE DEAM

		Aggregate supply			Aggregate demand		
		Germany	France	Italy	Germany	France	Italy
Aggregate supply	Germany	1	-0.024	0.035	-0.056	-0.009	0.167
	France		1	0.188	-0.013	-0.128	-0.058
	Italy			1	0.182	0.009	0.002
Aggregate demand	Germany				1	0.387	0.026
	France					1	0.328
	Italy						1

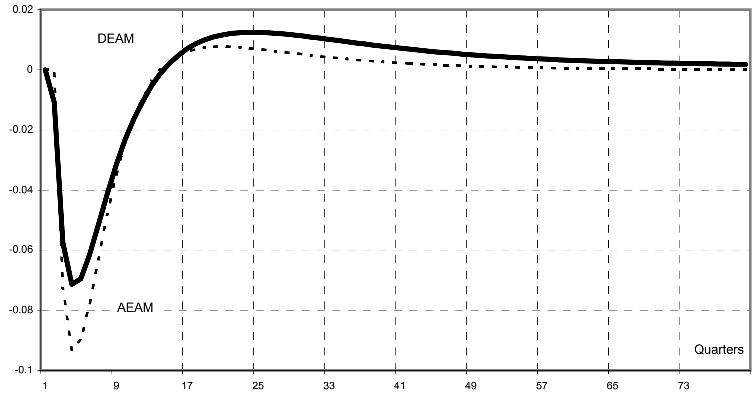
Figure 1

Impulse responses to a temporary monetary policy shock (+100 b.p.)

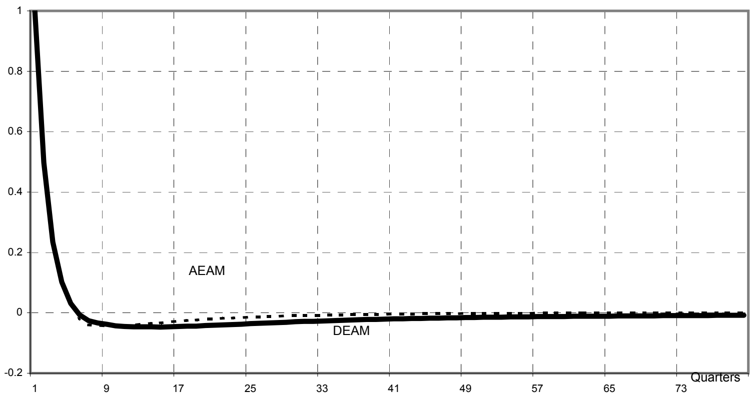
(a) Response of euro area inflation rate



(b) Response of euro area output gap



(a) Response of euro area real interest rate



(d) Response of euro area nominal interest rate

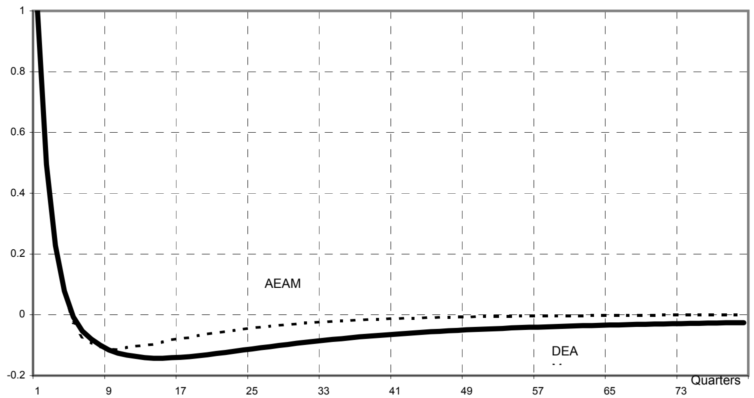
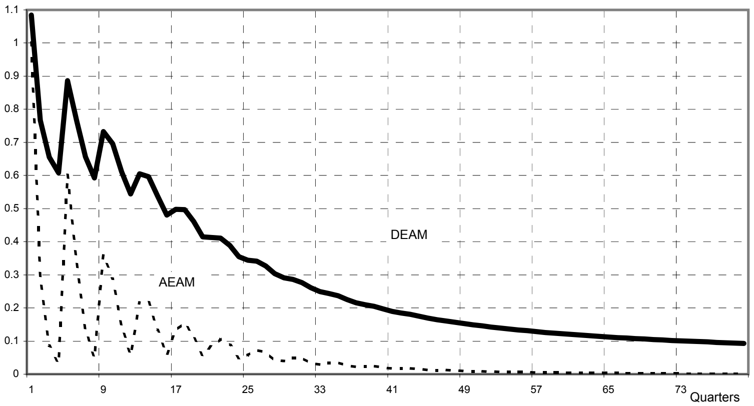


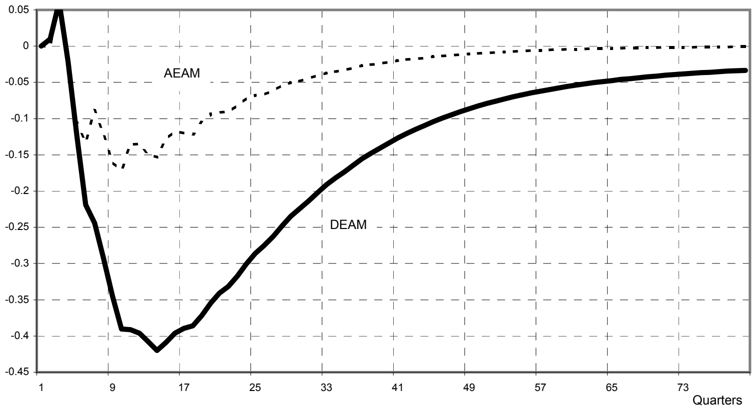
Figure 2

Impulse responses to a temporary Phillips curve shock (+1 per cent)

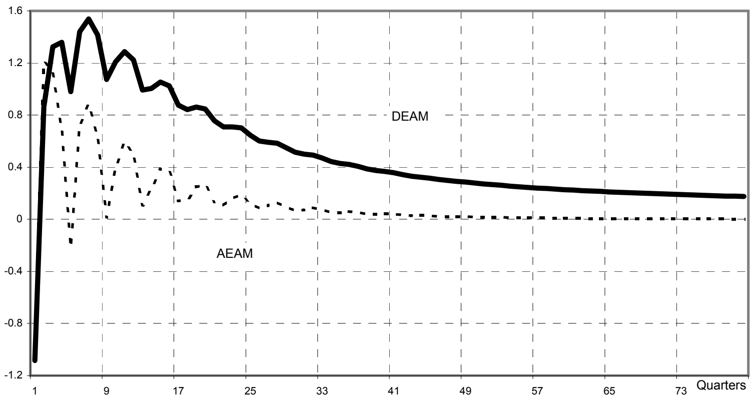
(a) Response of euro area inflation rate



(b) Response of euro area output gap



(a) Response of euro area real interest rate



(d) Response of euro area nominal interest rate

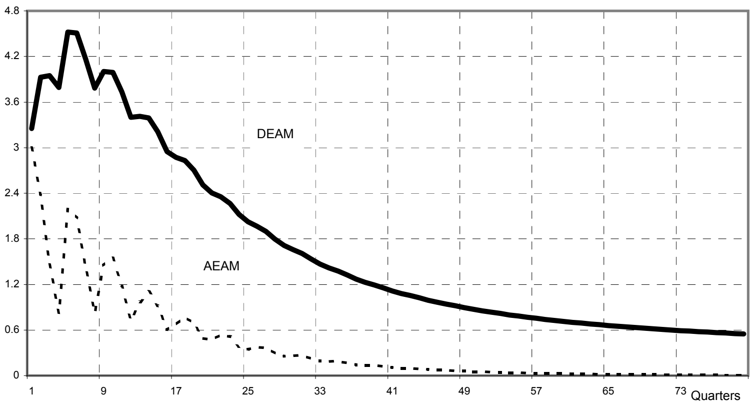
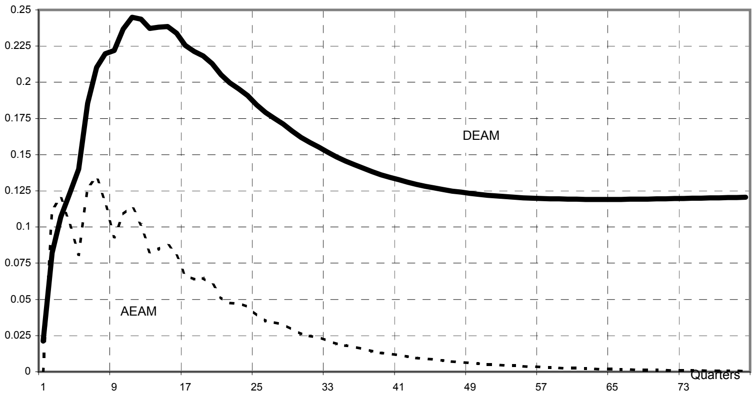


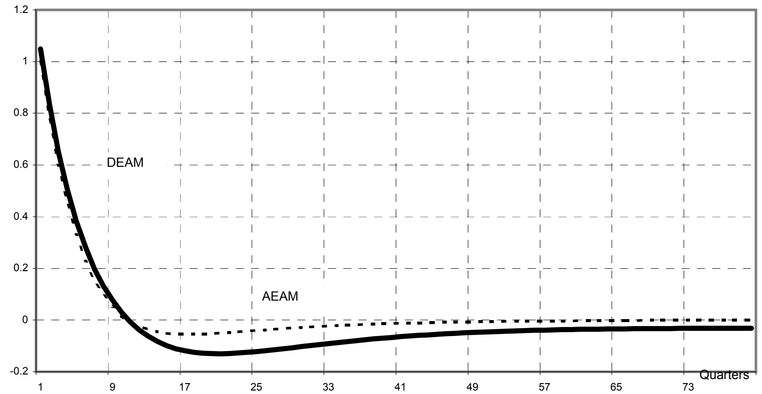
Figure 3

Impulse responses to a temporary aggregate demand shock (+1 per cent)

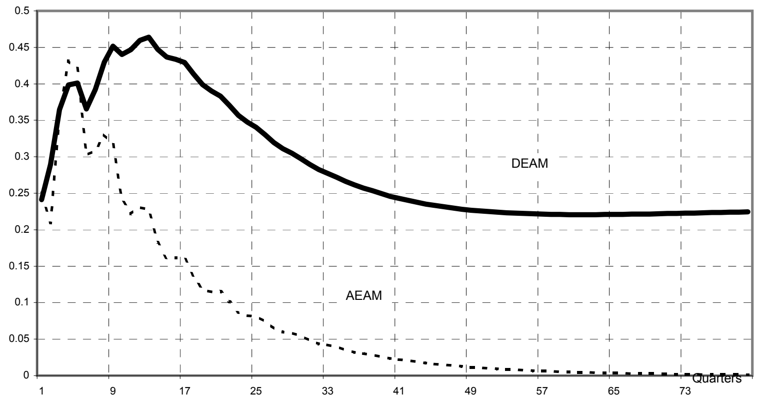
(a) Response of euro area inflation rate



(b) Response of euro area output gap



(a) Response of euro area real interest rate



(d) Response of euro area nominal interest rate

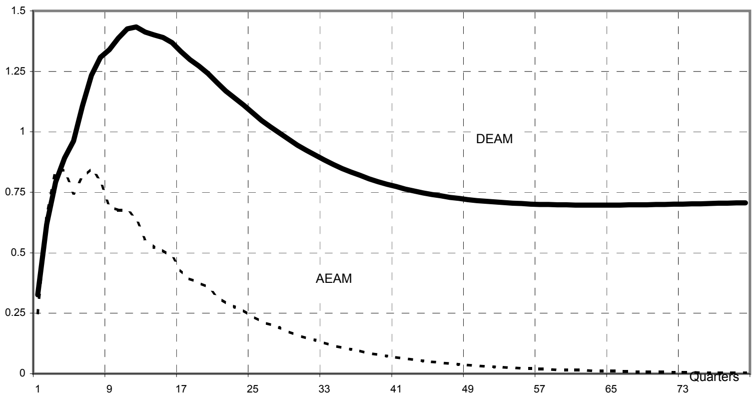
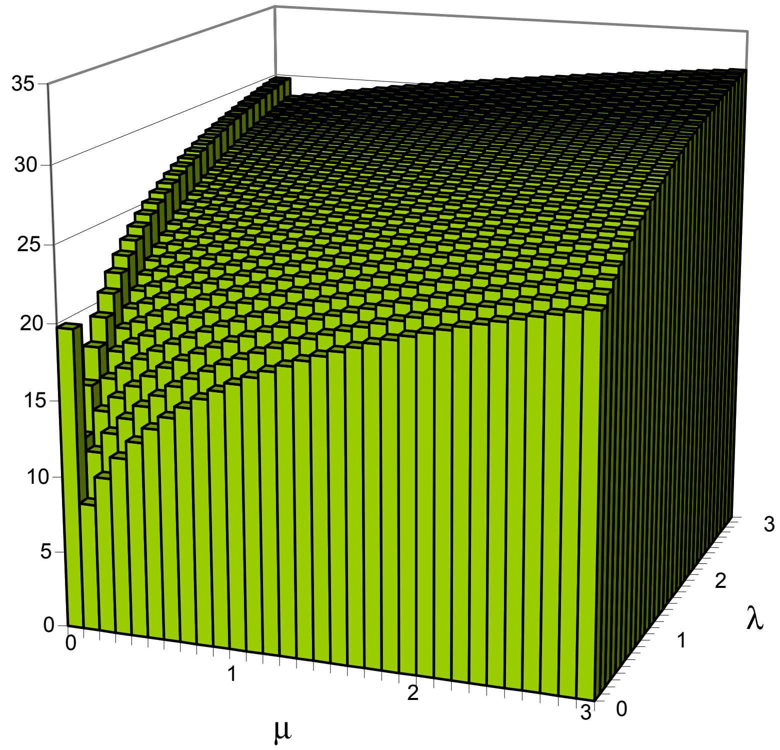


Figure 4

Percentage reduction in the optimised loss function,
DEAM-based rule vs. AEAM-based rule



Percentage reduction in the optimised loss function,
DEAM-based rule vs. AEAM-based rule
(as a share of overall reduction attainable with FO rule vs. AEAM-based rule)

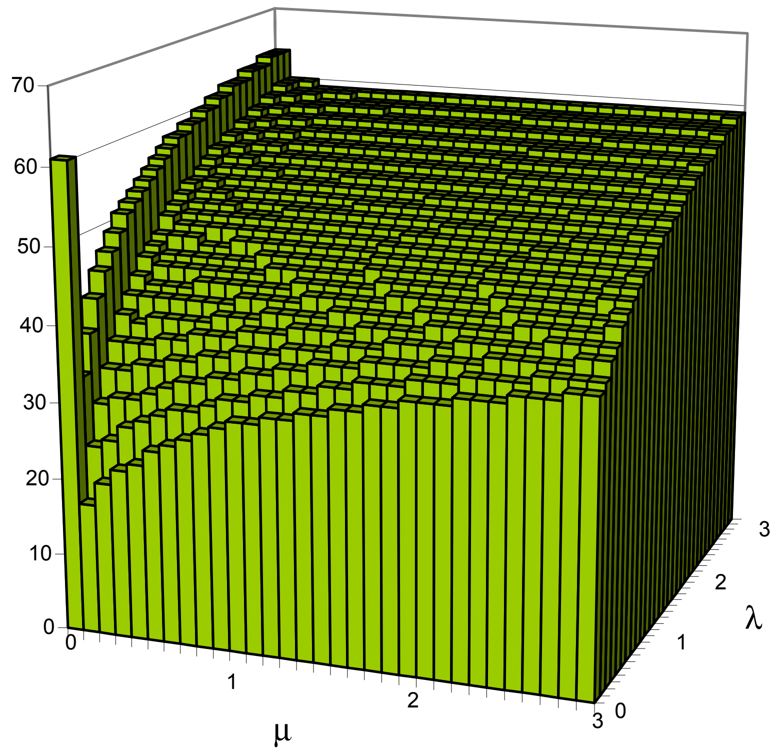
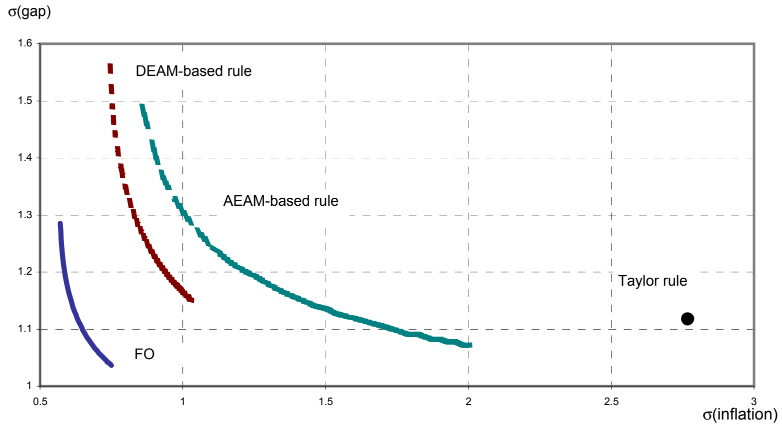


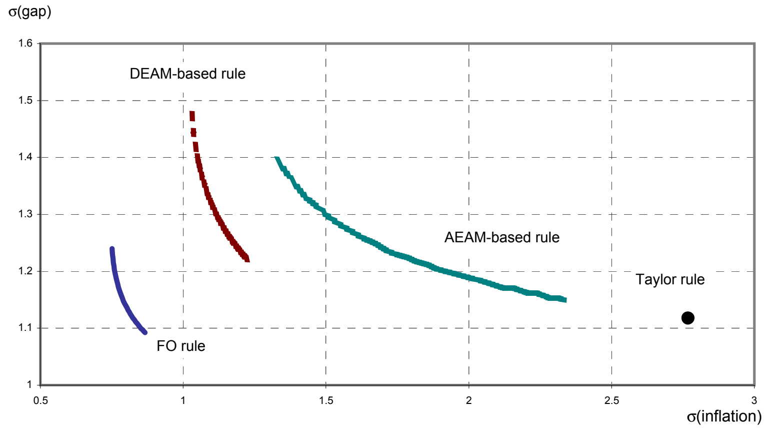
Figure 5

Inflation - output gap optimal frontiers

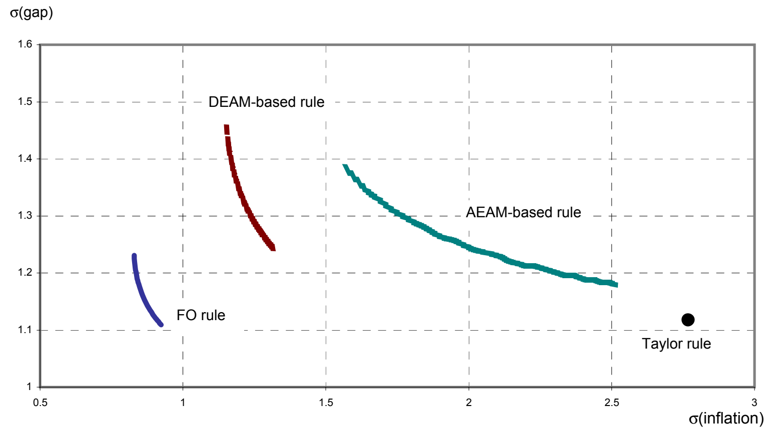
(a) μ=0.1



(b) μ=1.0



(c) μ=2.0



(d) μ=3.0

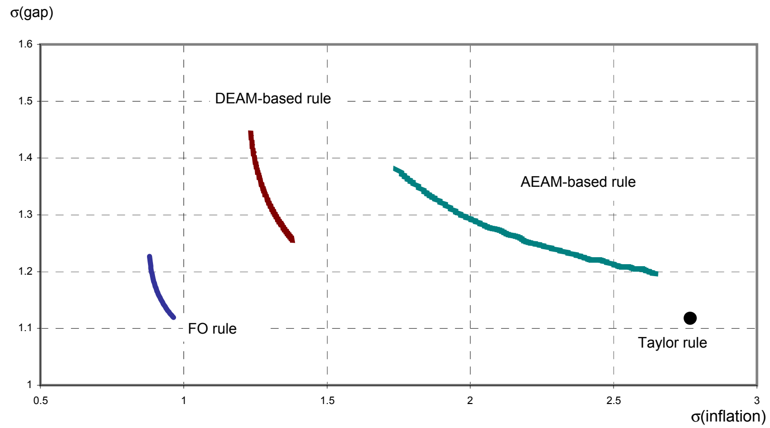
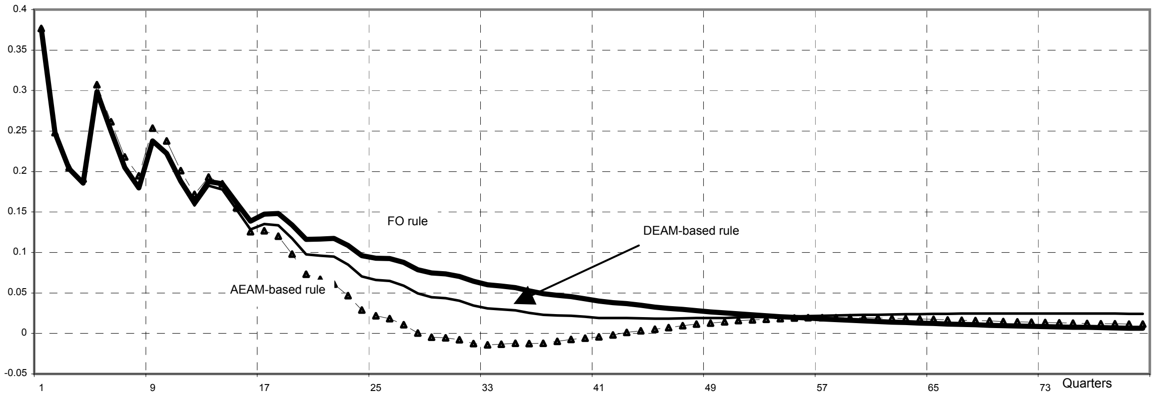


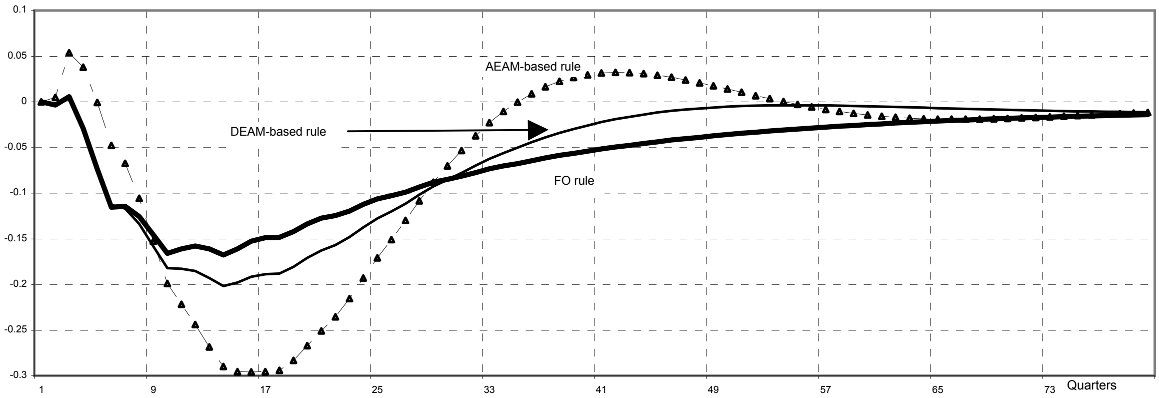
Figure 6

Impulse responses to a temporary Phillips curve shock (+1 s.d. of stochastic terms) under AEAM-based, DEAM-based and optimal instrument rules

(a) Response of euro area inflation rate



(b) Response of euro area output gap



(c) Response of euro area nominal interest rate

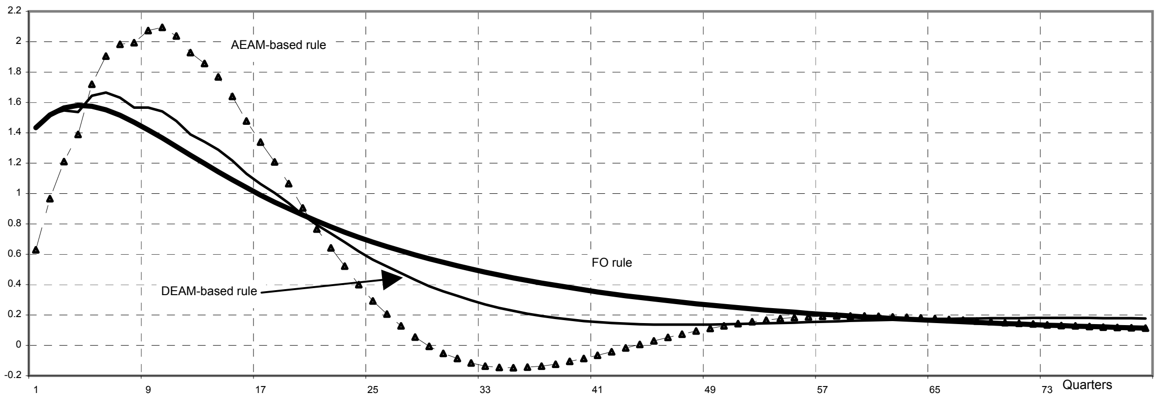
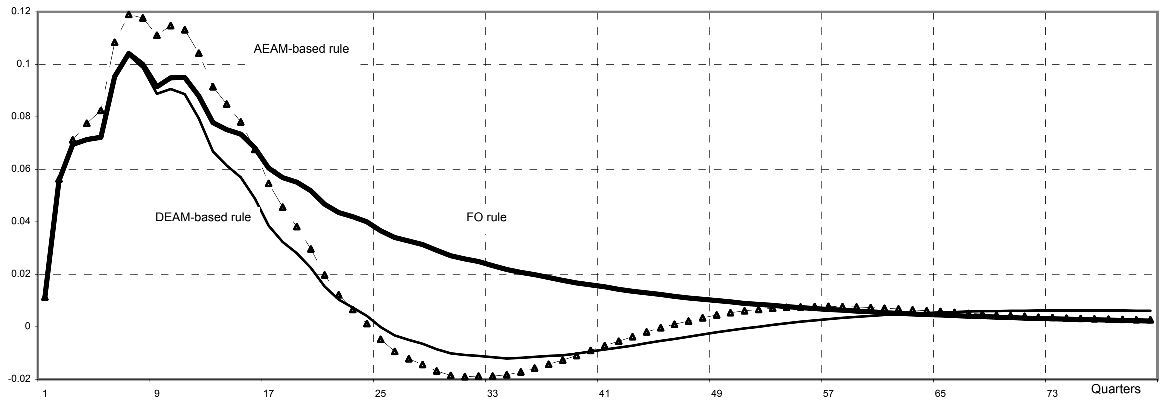


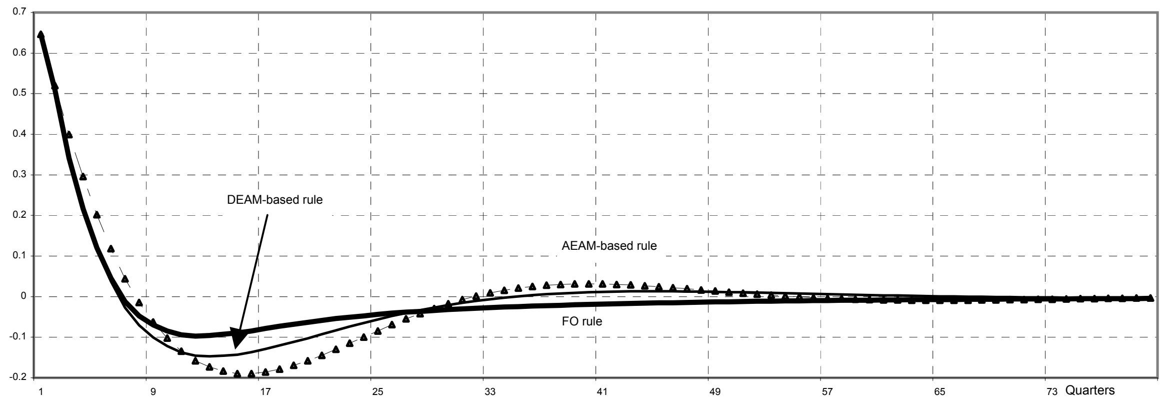
Figure 7

Impulse responses to a temporary aggregate demand shock (+1 s.d. of stochastic terms) under AEAM-based, DEAM-based and optimal instrument rules

(a) Response of euro area inflation rate



(b) Response of euro area output gap



(c) Response of euro area nominal interest rate

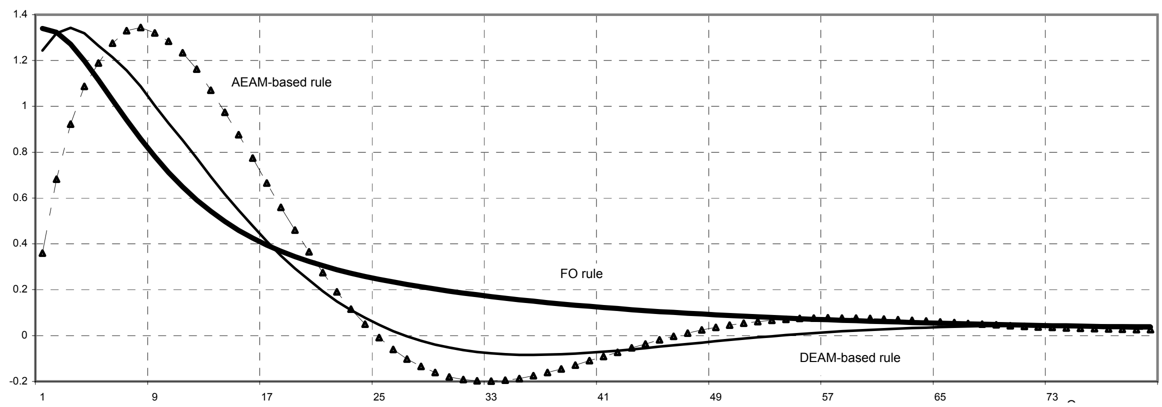
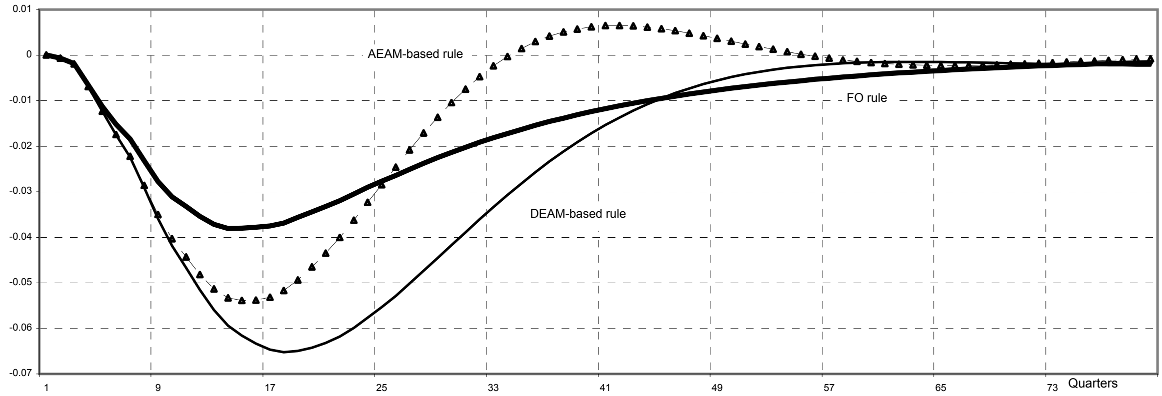


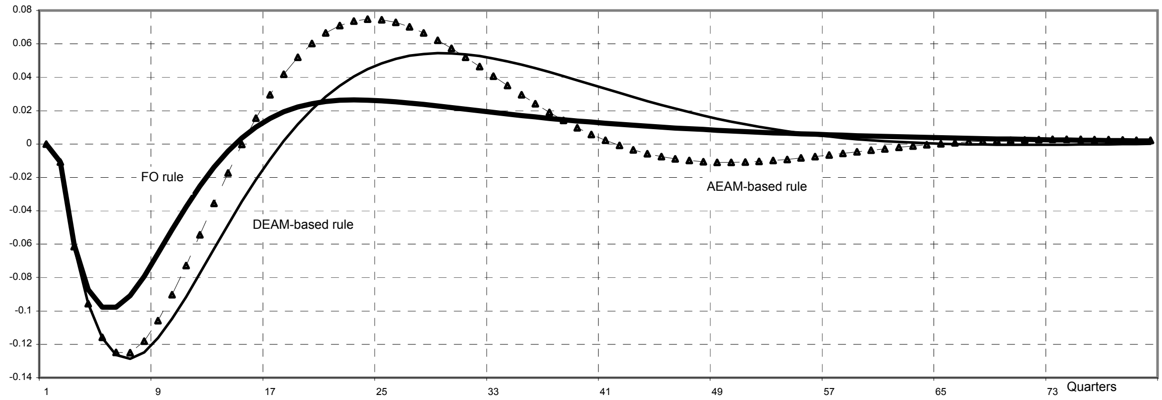
Figure 8

Impulse responses to a temporary monetary policy shock (+1 s.d. of stochastic terms) under AEAM-based, DEAM-based and optimal instrument rules

(a) Response of euro area inflation rate



(b) Response of euro area output gap



(c) Response of euro area nominal interest rate

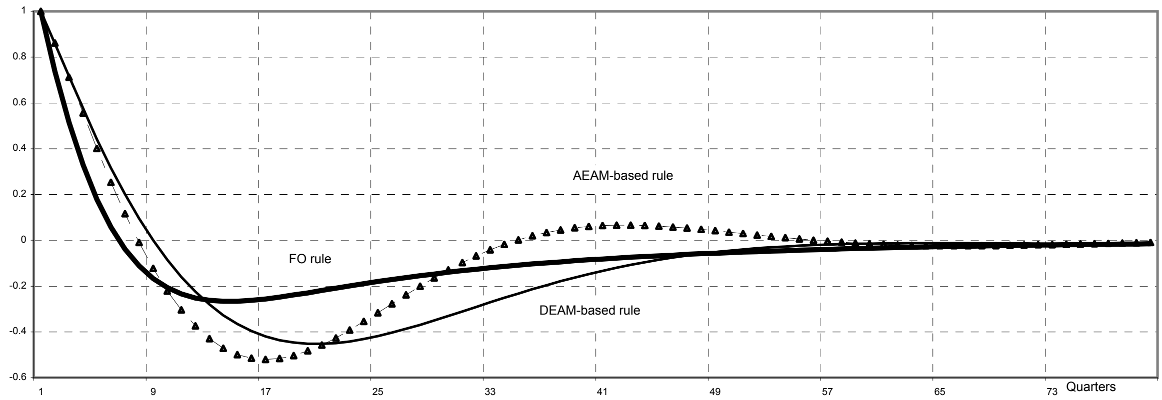
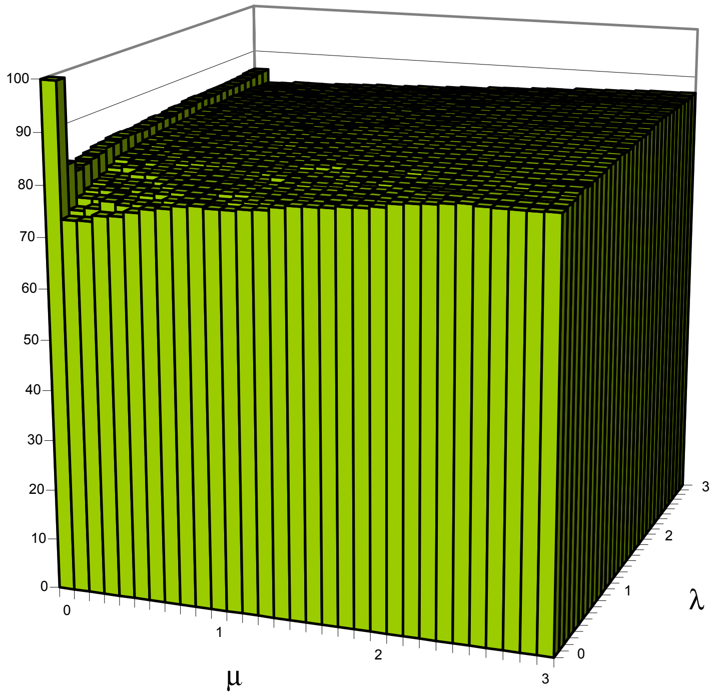


Figure 9

Random drawings from distribution of estimation residuals, DEAM-based rule vs. AEAM-based rule

Percentage of cases in which the DEAM-based rule outperforms the AEAM-based rule



Percentage of cases in which the DEAM-based rule outperforms the AEAM-based rule by at least 20 per cent of the oprimised loss function associated with the latter

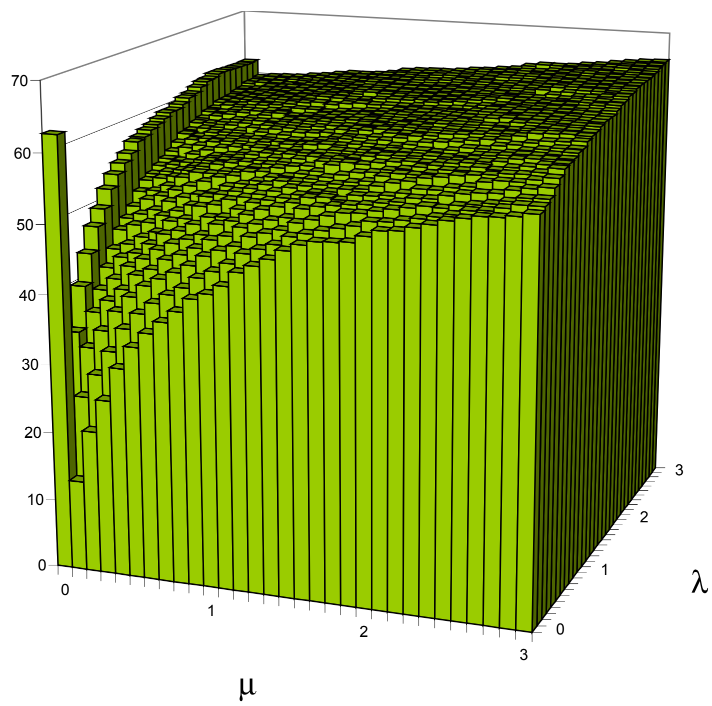
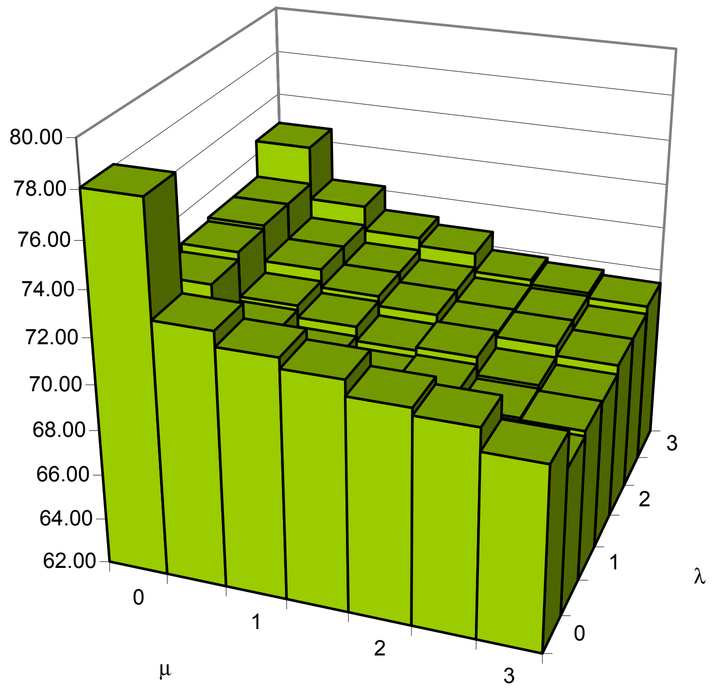


Figure 10

Random drawings from distribution of estimated DEAM parameters, DEAM-based rule vs. AEAM-based rule

Percentage of cases in which the DEAM-based rule outperforms the AEAM-based rule



Percentage of cases in which the DEAM-based rule outperforms the AEAM-based rule by at least 20 per cent of the oprimised loss function associated with the latter

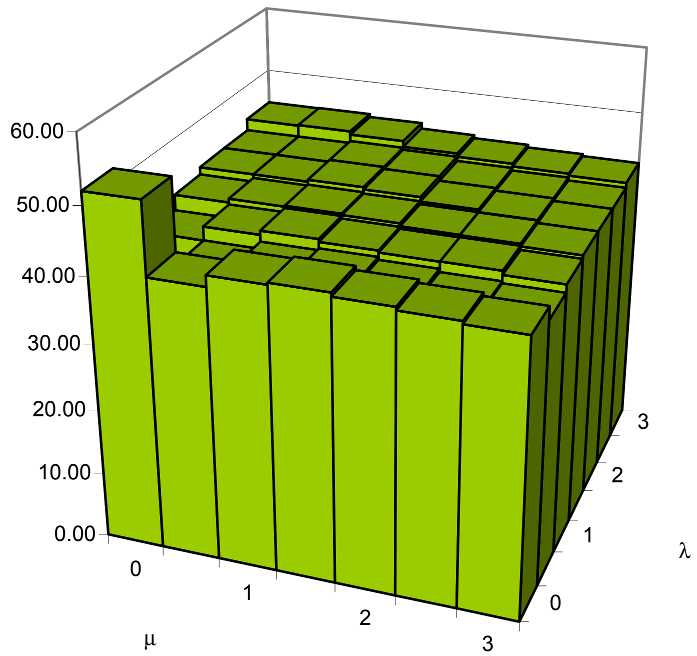


Figure 11

Random drawings from distribution of estimated DEAM parameters
Testing the significance of the underperformance of the AEAM-based rule

Test that the average loss associated with the DEAM-based rule is lower than the one associated with the AEAM-based rule
(tail probability)

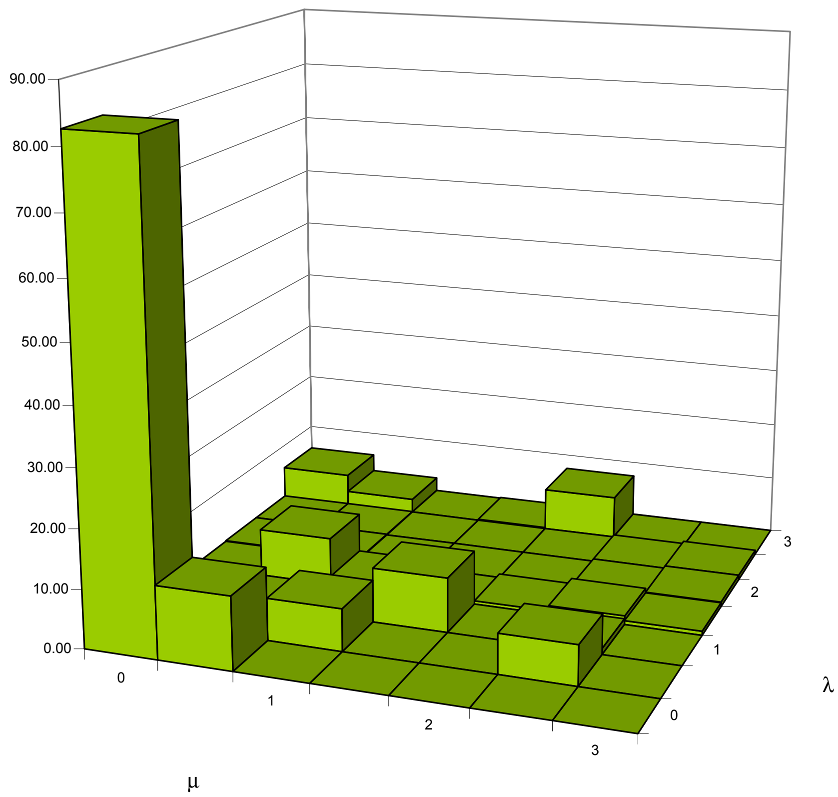
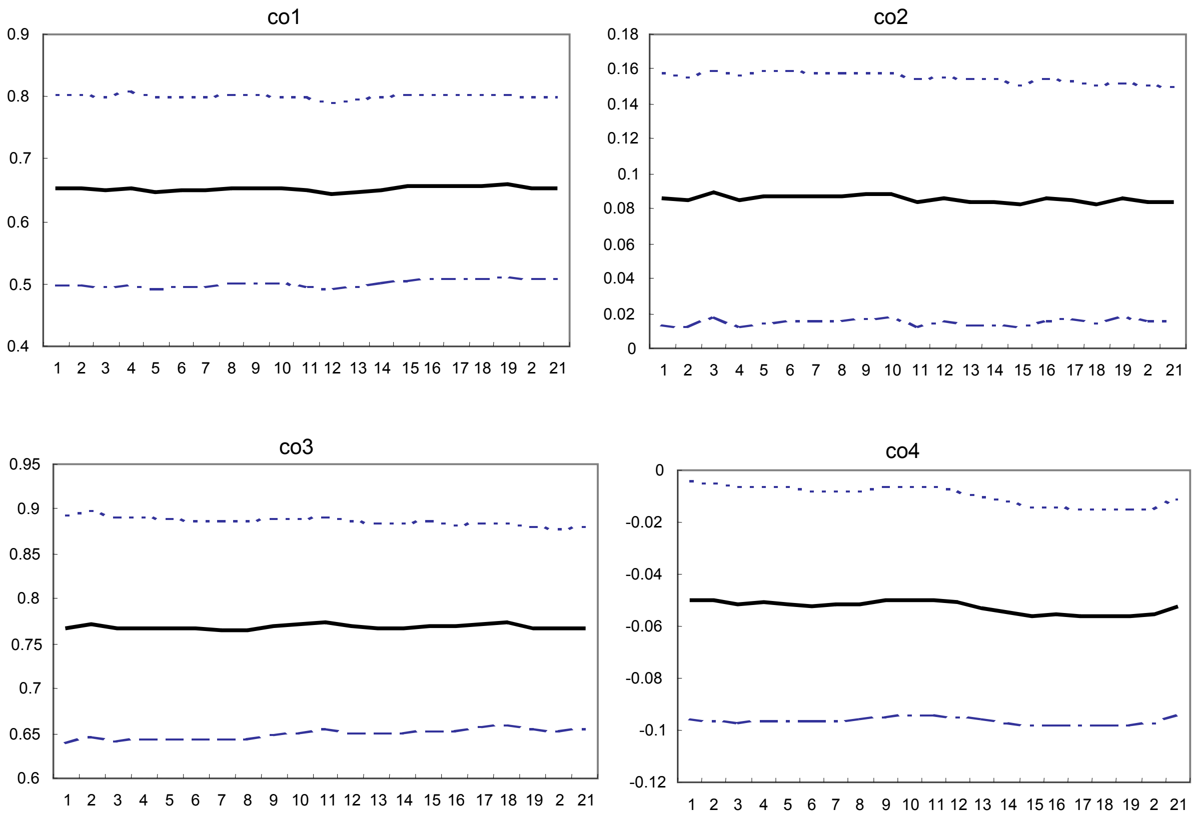


Figure 12

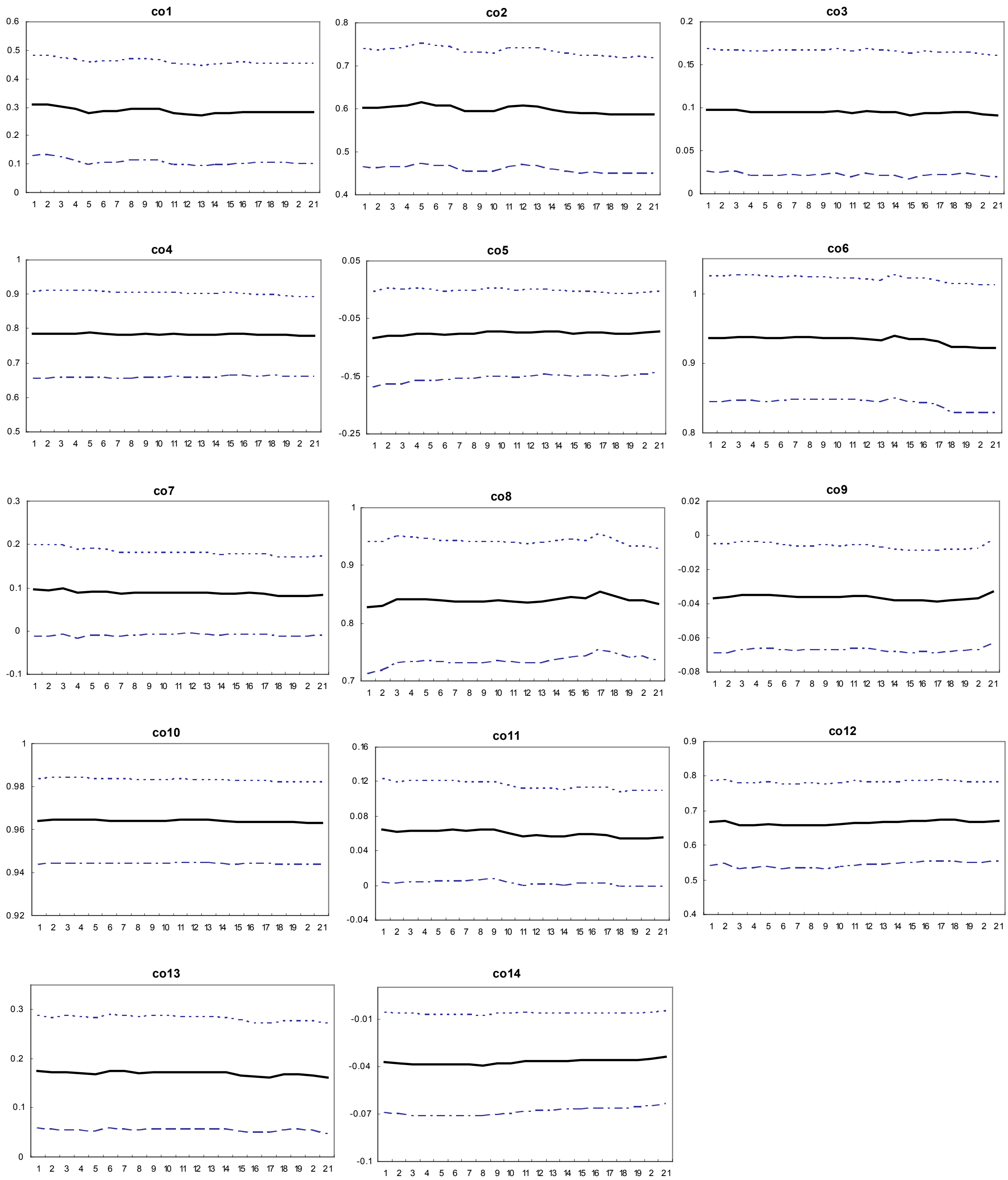
Recursive estimates of AEAM coefficients, 1996.Q4 – 2001.Q4



Legenda: co1: coeff. inflation (lag 1) in AS curve; co2: coeff. of output gap (lag 1) in AS curve; co3: coeff. of output gap (lag 1) in AD curve; co5: coeff. of real interest rate (lag 2)in AD curve

Figure 13

Recursive estimates of DEAM coefficients, 1996.Q4 – 2001.Q4

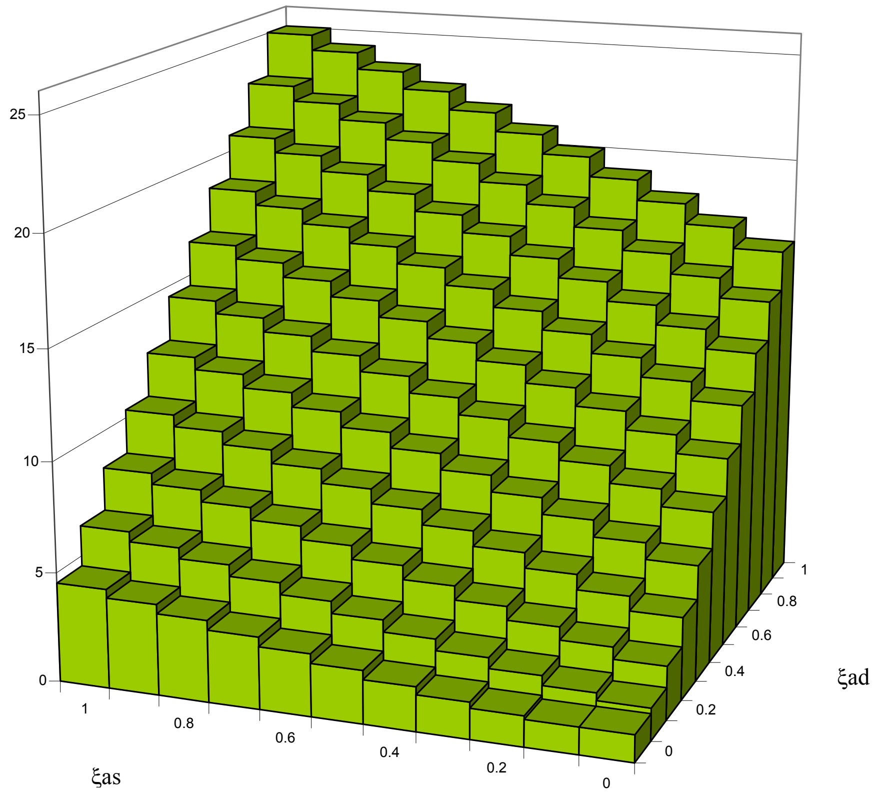


Legenda: co1: coeff. of German inflation (lag 1) in German AS curve; co2: coeff. of German inflation (lag 4) in German AS curve; co3: coeff. of German output gap (lag 1) in German AS curve; co4: coeff. of German output gap (lag 1) in German AD curve; co5: coeff. of real interest rate in German AD curve; co6: coeff. of French inflation (lag 1) in French AS curve; co7: coeff. of French output gap (average of lags 2-5) in French AS curve; co8: coeff. of French output gap (lag 1) in French AD curve; co9: coeff. of real interest rate in French AD curve; co10: coeff. of Italian inflation (lag 1) in Italian AS curve; co11: coeff. of Italian output gap (lag 1) in Italian AS curve; co12: coeff. of Italian output gap (lag 1) in Italian AD curve; co13: coeff. of German output gap in Italian AD curve; co14: coeff. of real interest rate in Italian AD curve

Figure 14

Percentage reduction in the optimised loss function, DEAM-based rule vs. AEAM-based rule

(with gradual convergence of Phillips curve and aggregate demand stochastic processes, $\lambda = \mu = 1$)



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