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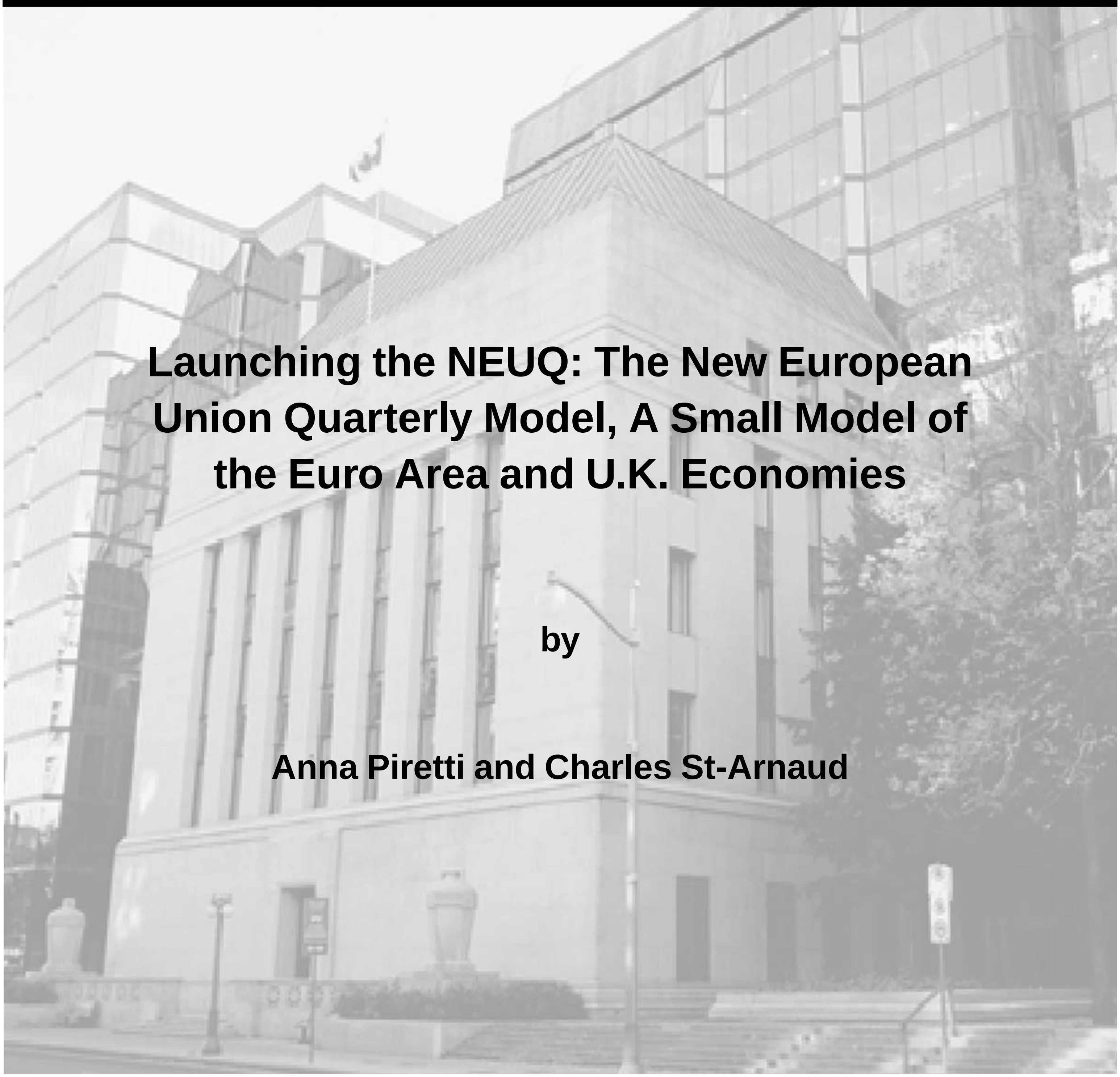

Launching the NEUQ: The New European Union Quarterly Model, A Small Model of the Euro Area and U.K. Economies

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Anna Piretti and Charles St-Arnaud

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Anna Piretti and Charles St-Arnaud

International Department
Bank of Canada
Ottawa, Ontario, Canada K1A 0G9

Contents

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Abstract

The authors develop a projection model of the euro area and the United Kingdom. The model consists of two country blocks, endogenous to each other via the foreign demand channel. Each country block features an aggregate IS curve, a forward-looking Phillips curve, and an estimated forward-looking monetary policy reaction function. Potential output is estimated by means of a Hodrick-Prescott filter, conditioned by an equilibrium path generated by a structural vector autoregression (Rennison 2003 and Gosselin and Lalonde 2002). The Phillips curve is specified in terms of the output gap, and inflation dynamics are described by the polynomial adjustment cost (PAC) approach, as in Kozicki and Tinsley (2002). The model delivers relatively accurate projections at a variety of forecast horizons and provides a useful tool for policy analysis. The authors' simulation results suggest that output and inflation exhibit a greater degree of persistence to shocks in the euro area than in the United Kingdom.

JEL classification: C53, E17, E37
Bank classification: Economic models; Business fluctuations and cycles

Résumé

Les auteurs élaborent pour la zone euro et le Royaume-Uni un modèle de projection où chacune de ces deux économies est intégrée à l'autre de façon endogène par le biais de la demande extérieure. Une courbe IS agrégée, une courbe de Phillips prospective et une fonction de réaction prospective de la politique monétaire sont estimées pour chacune des deux économies. La production potentielle est obtenue en appliquant un filtre de Hodrick-Prescott, lui-même conditionné par un sentier d'équilibre tiré de l'utilisation d'un vecteur autorégressif structurel (Rennison, 2003; Gosselin et Lalonde, 2002). La courbe de Phillips est spécifiée en fonction de l'écart de production, et la dynamique de l'inflation exprimée au moyen de l'approche des coûts d'ajustement polynomiaux de Kozicki et Tinsley (2002). Le modèle donne des projections assez justes à divers horizons de prévision et offre un outil d'analyse intéressant des politiques économiques. D'après les résultats de simulation, la production et l'inflation dans la zone euro seraient plus durablement influencées par les chocs qu'au Royaume-Uni.

Classification JEL : C53, E17, E37
Classification de la Banque : Modèles économiques; Cycles et fluctuations économiques

1. Introduction

In the context of the Bank of Canada quarterly economic projection, we develop a forecasting model (which we name NEUQ, for **N**ew **E**uropean **U**nion **Q**uarterly projection model) describing a simple macroeconomic framework for the euro area and the United Kingdom (U.K.) economies.

The euro area and the United Kingdom combined account for around 5 per cent of Canadian exports and represent the second most important Canadian trading partner after the United States. Although their effect on the Canadian economy is not large, it is magnified indirectly by the effect that the euro area and the United Kingdom have on the U.S. economy (they account for around 20 per cent of U.S. exports and represent the second largest U.S. trading partner) and on world commodity prices. To account for the effect of foreign shocks on the Canadian economy, results from NEUQ are explicitly linked to the Bank of Canada quarterly economic projection as inputs into QPM/TOTEM[1] (the Bank of Canada main projection model describing the Canadian economy), MUSE (the Bank of Canada projection model of the U.S. economy), and the Bank of Canada internal commodity prices projection.

Numerous forecasting models exist for the euro area and the United Kingdom. Among large models, the Area-Wide Model (AWM) (Fagan, Henry, and Mestre 2001), developed by the European Central Bank (ECB), and the Bank of England Quarterly Model (BEQM) (Harrison et al. 2005), developed by the Bank of England, are quarterly structural macroeconomic models whose primary focus is to produce economic forecasts for the domestic economy, while rest-of-the-world variables are not explicitly modelled and therefore are treated as exogenous in simulation exercises.

On the other hand, MULTIMOD (Laxton et al. 1998), developed by the IMF, NIGEM (Barrell et al. 2001), developed by the U.K. National Institute of Economic and Social Research, and QUEST (Roeger and in’t Veld 1997), developed by the European Commission, are dynamic multi-country macroeconomic models primarily designed to serve as tools for policy simulation, by analyzing the transmission of the effects of economic policy, both on the domestic and the international economy. Less emphasis is therefore attributed to the models’ ability to serve as forecasting tools.

1. QPM: Quarterly Projection Model. TOTEM: Terms-of-Trade Economic Model.

A number of small models describing the euro area and the U.K. economies have also been estimated in the literature. Examples include Doménech, Ledo, and Taguas (2001a) for the euro area and Larsen and McKeown (2004) for the United Kingdom. Such small models are used primarily to describe the path of aggregate output, inflation, and the nominal interest rate in a fashion similar to NEUQ. However, unlike NEUQ, these two models rely on a closed-economy framework, thus ignoring important trade channels.

All the aforementioned models follow the prevailing view of a neoclassical macroeconomic equilibrium where output is determined by technological change and by factors of production, and where money is neutral, while short-run dynamics are demand driven and the adjustment process is sticky. This view implies that, while in the long run the level of activity is independent of prices, in the short run there can be significant real and nominal inertia.

AWM, BEQM, NIGEM, and the smaller models (as developed by Doménech, Ledo, and Taguas 2001a, and Larsen and McKeown 2004) rely mostly on estimated cointegrating relationships in characterizing the steady-state equilibrium, while MULTIMOD and QUEST have more thoroughly developed theoretical foundations.

Wallis (2004) provides a useful comparative analysis of AWM, MULTIMOD, NIGEM, and QUEST, and compares the results of two policy simulations. He finds that the principal source of simulation differences across the four models is the different degree of forward-looking behaviour they incorporate in their treatment of consumption and investment decisions, and the setting of wages and prices. Results from Wallis's study are not directly comparable to our findings, since the aforementioned models are fully developed structural models, while we estimate a small reduced-form model. However, for the purpose of the Bank of Canada quarterly economic projection, a small, estimated model strikes the appropriate balance between transparency, simplicity, and sound theoretical foundations, while still ensuring a relatively accurate forecasting performance.

NEUQ relies on the prevailing view in which a broadly neoclassical long-run macroeconomic equilibrium coexists with a New Keynesian view of short- to medium-term adjustment. The model is based on the Phillips curve paradigm where the output gap is used as a measure of the inflationary pressures in the economic system. In particular, a positive output gap implies that the economy is in a situation of excess demand, which leads to increasing inflationary pressures. On the other hand, when the output gap is negative, the economy is in a situation of excess supply, and resources are not being used to their full capacity, thus leading to falls in the rate of price growth.

Each country block is described by three equations.[2] Aggregate demand is modelled as an IS curve, relating real output to the monetary policy stance, a measure of foreign activity and the real exchange rate.[3] Inflation is modelled by a forward-looking Phillips curve, where prices are affected by capacity constraints, the exchange rate, and the price of oil. The model is closed by a forward-looking, estimated, monetary policy reaction function, in which the current monetary stance depends on the deviations of expected inflation from the monetary authority's explicit inflation target, and on a measure of economic activity.[4] Each dynamic equation has a steady-state counterpart, and the system of steady-state equations describes the equilibrium to which the model converges in the long run. In this paper, the long-run equilibrium is defined as the steady-state growth path for real variables, which is consistent with a nominal "anchor" (the inflation target) and achieved through a feedback rule for nominal interest rates.

At steady state, the economy operates at full potential, implying that the output gap is zero. As a result, the inflation rate will converge to the monetary authority's explicit inflation target and interest rates will converge to the level consistent with a zero output gap.

In the short to medium term, the model can deviate from its steady state due to a number of shocks. The estimated lag dynamic introduces a certain persistence in the adjustment process, which is reflective of short-run rigidities.

Our model contributes to the literature by providing a simple framework to forecast economic developments in the two major European economies. Among the model's advantages is that all the parameters are estimated with the data; this procedure generally leads to more robust results when there is uncertainty about the true structure of the economy. Moreover, to our knowledge, NEUQ is alone among small forecasting models to explicitly link the euro area and the U.K. economies, thus allowing an endogenous response to shocks in the partner economy.

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2. Following AWM and Doménech, Ledo, and Taguas (2001a), we model the euro area as a single entity, since this is the approach adopted by the European Central Bank in the conduct of monetary policy.

3. In the current version of the model, exchange rates are exogenous. Over the projection period, the exchange rate series are based on external judgment and are therefore independent of the model's dynamics. As a result, improved economic prospects abroad, or interest rate differentials between the home and foreign countries, will not be automatically reflected by exchange rate changes. Work to endogenize the exchange rate is under way, which will ensure consistency among the forecasts of the different model's variables.

4. In the case of the euro area, we model the behaviour of a fictitious monetary authority, since the ECB did not exist before 1999. For practical purposes, we assume that the modelled monetary authority is an explicit inflation targeter, with a point target of 2 per cent for yearly consumer price growth. We acknowledge that the ECB does not explicitly define itself as an inflation targeter and that the ECB aims to maintain consumer price inflation "close to but below 2 per cent over the medium term."

Estimation results appear to be broadly in line with the empirical literature, and the model delivers relatively accurate projections at a variety of forecast horizons. In addition, our simulation results suggest that output and inflation exhibit a greater degree of persistence to shocks in the euro area than in the United Kingdom.

This paper is organized as follows. Section 2 describes the model's equations in detail. Section 3 discusses the estimation results, and in section 4 we analyze the model's response to a number of simulated shocks. Section 5 evaluates the forecasting performance of the model. Section 6 concludes and suggests areas for future research.

2. The Euro Area and U.K. Model

This section describes the theoretical foundations of each equation, starting with a brief description of the method used to estimate potential output.

2.1 Estimation of potential output

Potential output is estimated by means of a *hybrid approach* combining a variation of the multivariate filter developed by Laxton and Tetlow (1992) with the equilibrium path generated by a structural vector autoregression (SVAR).

Using Monte Carlo simulations, Renisson (2003) shows that this combined approach generates an estimate of potential output which benefits from the advantages of both methods while minimizing their shortcomings. In particular, using a structural VAR allows the inclusion of theoretical fundamentals in the estimation process and reduces the end-of-sample bias generated by the filter. On the other hand, the use of filters allows a reduction in the volatility generated by the SVAR while still accounting for the presence of structural breaks.

Following Gosselin and Lalonde (2002), a structural VAR is applied to the components of output, with the aim of separating the trend (interpreted as the supply component or equilibrium path) from the temporary factors (interpreted as the demand component). Subsequently, the equilibrium path obtained from the SVAR is used as conditional information in a Hodrick-Prescott (HP) filter, which is applied to the components of output, allowing a clearer identification of the sources of potential output fluctuations.

St-Arnaud (2004) uses the approach developed by Gosselin and Lalonde (2002) to decompose United Kingdom GDP into trend labour input and trend labour productivity, where trend labour input is in turn decomposed into trend participation rate, trend unemployment rate, trend hours worked, and population. This breakdown allows a more accurate identification of the source of fluctuations in potential growth. For the euro area, the *hybrid approach* is applied directly to aggregate output (for details, see Appendix A).

In the United Kingdom, potential output growth fluctuates between 0.7 per cent and 3.9 per cent over the sample period, with an average of around 2.2 per cent (see Appendix B). As described in St-Arnaud (2004), the volatility of the growth rate of potential is linked to structural changes in the labour market, such as the labour market reforms implemented during the Thatcher era. In the euro area, potential output growth displays less volatility, fluctuating around 2.3 per cent, with a peak at 3.0 per cent and a trough at 1.7 per cent. In addition, during the first half of the sample, potential output average growth is higher in the euro area than in the United Kingdom. However, since the early 1990s, this trend is reversed, with potential output being higher in the United Kingdom, probably due to the structural reforms implemented in the 1980s and early 1990s. The observed downward trend of euro area potential output is in line with recent OECD studies pointing to shrinking productivity and participation rates, as well as higher long-term unemployment in most euro area countries (OECD 2005). In addition, unlike for the United Kingdom, we do not observe a pickup in the rate of euro area potential output growth following the recession in the early 1990s, which could be attributed in part to the costs of German reunification and in part to the slower pace of structural reforms observed in the euro area.

The output gaps resulting from the estimated potential output profiles are in line with the literature for both countries. In the euro area, our approach suggests that economic downturns occurred for the periods 1980 to 1982, 1992 to 1993, and 2001 to 2003. These results are in line with Artis et al. (2003), who set the dates of the euro area business cycle using a methodology similar to that proposed by the National Bureau of Economic Research in the United States. For the period 1970 to 2004, Artis et al. (2003) identify the following three recessions: 1974Q3 to 1975Q1, 1980Q1 to 1982Q3, and 1992Q1 to 1993Q3. With respect to the recent period, the authors judge that, based on data availability, the euro area has been experiencing a prolonged pause in the growth of economic activity, rather than a full-fledged recession. Altavilla and Landolfo (2005) use a sample from 1980 to 2001 and find the years 1986, 1990–92, 1996, and 1998–99 to be periods of recession. Artis (2002) conducts a similar study for the United Kingdom, using estimated monthly GDP series for the 1975 to 2002 period. He identifies three recessions: July 1974 to May 1975, June 1979 to February 1981, and March 1990 to August 1991. His study is in line with findings from the Economic Cyclical Research Institute (ECRI), which identifies troughs in August 1975, May 1981, and March 1992. In our case, we find a similar timing for the troughs of the cycle, specifically 1975Q3, 1981Q2, 1992Q2, and 2003Q2.

With respect to the amplitude of our cycles, a graphical analysis shows that the potential output series obtained with the *hybrid approach* displays more volatility than the series estimated, for example, by the OECD, which uses a production function approach (see Appendix B). This is due to the fact that the *hybrid approach* tends to interpret a larger proportion of output fluctuations as supply shocks, implying a larger cyclical component for potential output. The proportion of output fluctuations interpreted as demand shocks will therefore be lower, resulting in a smaller amplitude of the output gap.

2.2 The IS curve

Output is modelled using an IS curve that relates real output to the interest rate, the exchange rate, and foreign activity:

$$\begin{aligned}\Delta y_t = (1-\beta)\Delta y_{t-1} + \beta\Delta y_t^{pot} + \lambda_1 Ygap_{t-1} + \lambda_2(r_{t-i} - r_{t-i}^e) + \\ \lambda_3 Ygap_{t-i}^* + \lambda_4 YgapUS_{t-i} + \lambda_5 YgapAsia_{t-i} + \lambda_6 \Delta \mathrm{real}FX_{t-i}\,,\end{aligned} \tag{1}$$

where y_t represents real GDP, y_t^{pot} represents real potential output, $Ygap_t$ is the output gap, $(r_{t-i} - r_{t-i}^e)$ represents the monetary policy stance,[5] $Ygap_{t-i}^*$ is the output gap of the other European country (i.e., the U.K. output gap for the euro area IS curve, and vice versa), $YgapUS_{t-i}$ is the output gap of the United States, $YgapAsia_{t-i}$ is the output gap of Asia, and $\mathrm{real}FX_{t-i}$ is the real effective exchange rate of the domestic currency (with an increase representing a currency appreciation and a decrease representing a depreciation).[6,7]

The form chosen for the IS curve is standard and has been widely used in the literature. As shown in Fuhrer (2000), the hypothesis of habit formation in consumption justifies the introduction of lags of the output gap into the IS curve to match the persistence in the data. At steady state, when aggregate demand shocks are absent, output is at its potential value ($y_t = y_t^{pot}$), so that the output gap is zero and the monetary policy stance is neutral.

5. In the euro area, the monetary policy stance is expressed as an interest rate gap, or the deviation of the real short-term interest rate from its estimated equilibrium value. In the United Kingdom, the monetary policy stance is modelled by the yield curve, expressed as the difference between the short- and the long-term interest rates.
6. In the IS curve, the coefficient on the lagged GDP term and the coefficient on potential output must sum to one.
7. The United States gap and the Asia gap come from Bank of Canada estimates.

2.3 The Phillips curve

The supply side of the economy is summarized by a New Keynesian Phillips (NKP) curve and the output gap is used as a measure of inflationary pressures.

Although the purely forward-looking specification of the NKP curve is theoretically appealing because it relies on rational expectations, this specification is unable to reproduce the inflation persistence observed in the data (Galí and Gertler 1999). Therefore, as discussed in Kozicki and Tinsley (2002), leads and lags of inflation should be added to the Phillips curve to introduce persistence in the inflationary process (the leads representing the inflation expectations, and the lags representing stickiness due, for example, to contracts). Following Kozicki and Tinsley's (2002) work, the Phillips curve was estimated using the polynomial adjustment cost (PAC) approach. The intuition behind the PAC specification resides in the idea that, as economic agents plan for their future, they constantly form expectations about their desired level of prices. However, given the presence of frictions, such as contracts binding sellers and buyers or menu costs, the desired price level can be reached only gradually. Moreover, each decision taken today will have an effect on the future path of inflation, thus causing the agents to incur adjustment costs as they strive to reach their desired path. The deviation between the desired price level and the observed price level is due to unanticipated events, implying that the economy is generally in disequilibrium in the short run, but will converge to the desired state in the long run. Therefore, in the PAC model, agents face a trade-off, as they try to minimize the costs incurred by deviating from the desired path and the adjustment costs they must incur to modify their behaviour. The presence of such adjustment costs forces agents to smooth the price profile, thus introducing persistence in inflation, while remaining consistent with the rational-expectations theory. Naturally, because of discounting, the costs associated with periods that are further away, both in the past and in the future, will be assigned a smaller weight than the costs associated with closer periods.

Kozicki and Tinsley (2002) show that the deviation between the equilibrium price path and the observed price level can be approximated by a factor proportional to the output gap. From this, we obtain the following equation:

$$\pi_t = \frac{\left(G_1\beta E_t\pi_{t+1} + G_2\beta^2 E_t\pi_{t+2} + G_3\beta^3 E_t\pi_{t+3} + G_1\pi_{t-1} + G_2\pi_{t-2} + G_3\pi_{t-3}\right)}{\left(1 + G_1\beta + G_2\beta^2 + G_3\beta^3\right)} + \tag{2}$$

$$+ \lambda_1 Ygap_{t-i} + \lambda_2 \Delta \text{real} FX_{t-i} + \lambda_3 \Delta \text{real} WTI_{t-i} ,$$

where inflation at time *t* depends on the future expected levels of inflation ($E_t\pi_{t+i}$), as well as on past levels of observed inflation (π_{t-i}), to account for the presence of stickiness in the adjustment process. Note that, for the system to be stable, we must have $G_1 = 1 - G_2 - G_3$, where the G_i are parameters derived from Kozicki and Tinsley's underlying structural model and represent the weights assigned to the different time periods. β represents a discount parameter, $Ygap_{t-i}$ is the output gap, $\Delta \text{real} FX_{t-i}$ indicates the real effective exchange rate of the domestic currency, and $\Delta \text{real} WTI_{t-i}$ is the real oil price as measured by West Texas Intermediate. The choice of three leads and lags follows Kozicki and Tinsley (2002), who show that this lead/lag structure is optimal for Canada and the United States.[8] The chosen inflation dynamics implies that it is costly for firms to adjust the first four price moments.[9]

2.4 The monetary policy reaction function

The model is closed by an estimated forward-looking, forecast-based interest rate rule for monetary policy, which relates the interest rate to the output gap and to the expected deviation of future inflation from the monetary authority's inflation target:

$$i_t = \alpha_1 i_{t-i} + \alpha_2(\pi_{t+i} - \pi^*) + \alpha_3 Ygap_t , \tag{3}$$

where i_t is the monetary policy tool, π_{t+i} is expected inflation, π^* is the explicit monetary authority inflation target, and $Ygap_t$ is the output gap.

Unlike an optimal rule, which minimizes the variability of output and inflation by minimizing a loss function, our reaction function is simply estimated to fit the data, and might therefore not be optimal. In addition, in the case of the euro area, we model the behaviour of a fictitious monetary authority, since the ECB did not exist before 1999.

8. Our choice is also dictated by the absence of autocorrelation and by the level of significance in the maximum lag.
9. The first three moments can be identified as the level, the growth rate, and the acceleration of the price variable.

In choosing the specification of our estimated monetary policy rule, we adopt Batini and Haldane's approach (1999), whereby "simple feedback rules have some clear advantages. First, they are directly analogous to, and so comparable with, other policy rules specifications discussed in the literature, including Taylor rules. Second, simple rules are arguably more robust when there is uncertainty about the true structure of the economy. And third, simple rules may be advantageous on credibility and monitorability grounds." In addition, simple rules such as ours have been used by a number of authors to evaluate the stabilization policy of the U.S. Federal Reserve, the ECB, and other central banks, such as the Bank of England, the Bundesbank, and the Bank of Japan (see, for example, Doménech, Ledo, and Taguas 2001b). In fact, despite their simplicity, these rules appear to stabilize inflation and output in a way that is close to optimal policy rules.[10]

For simplicity, the monetary authority's reaction behaviour is assumed to be symmetric and linear, regardless of the phase of the business cycle. However, Altavilla and Landolfo (2005) attempt to estimate a regime-dependent Taylor rule for the euro area and the United Kingdom using a Hamilton Markov-switching model, and provide quantitative analysis of the asymmetric impact of a monetary policy action on the real economy. Altavilla and Landolfo conclude that a central bank cannot neglect the specific regime where the monetary action takes place. In particular, an interest rate increase will have a larger (negative) effect on the output gap during a recession than during an economic boom. While we recognize the importance of this conclusion, for the purpose of this paper we abstract from asymmetric policy reactions.

The literature identifies a number of different monetary policy reaction functions (see Taylor 1999 for a comprehensive review of various specifications). The most commonly used one is probably the Taylor-type rule that relates the monetary instrument to the current inflation rate and to the output gap (Taylor 1993). Another type of monetary policy rule is the Ball-type rule, which is based on a monetary conditions index (MCI) that also accounts for the effect of the exchange rate on the economy (Ball 1999). An extension of these kinds of rules are the inflation-forecast-based (IFB) rules (Batini and Haldane 1999), where the monetary instrument is a function of the deviation of expected inflation from the monetary authority's target.

Batini, Harrison, and Millard (2001) use a dynamic, stochastic general-equilibrium (DSGE) model calibrated on U.K. data and find "that an inflation-forecast-based rule (IFB), i.e. a rule that reacts to deviations of the expected inflation from target, is a good simple rule in this respect."

10. Batini and Haldane (1999) find that a simple, forecast-based interest rate rule similar to equation (4) mimics quite well the monetary policy behaviour of an inflation-targeting central bank.

They also conclude that an IFB rule, with or without an exchange rate adjustment, appears to be robust to different types of shocks, in contrast to a naïve specification or to Ball's MCI-based rules.

The monetary policy rule used in our model follows an IFB form. As discussed in Batini, Harrison, and Millard (2001), even when the exchange rate channel is not explicitly modelled in the reaction function, this class of monetary policy rules is still appropriate for open economies, because the exchange rate effects are incorporated in the forecast of inflation. In our model, we slightly modify the IFB rule by including the output gap. Doing so allows the monetary authority to also pursue output stabilization while setting monetary policy.

3. Estimation and Results

All equations are estimated using quarterly data, with the largest sample spanning from 1980 to 2004. In the case of the United Kingdom, data are obtained from the Office of National Statistics (ONS), while for the euro area data are obtained from the AWM database (Fagan, Henry, and Mestre 2001) and from Eurostat. Non-stationary variables are expressed in growth terms, calculated as the first difference of the natural logarithm.

Equations are estimated by the generalized methods of moment (GMM) to correct for possible endogeneity problems and for the presence of expected values among the regressors. In most cases, when choosing instruments for the GMM estimation, we use the lagged values of the dependent and explanatory variables. However, in the case of the Phillips curve, we also include lagged values of wage growth. When leads of a series are included among the explanatory variables, the expected values used in the estimation are derived from a simple VAR model. For example, to obtain the inflation forecast used in the estimation of the Phillips curve, we use a VAR model containing past values of observed inflation, the output gap, and wage growth.

The choice of regressor included in each equation is dictated by economic theory, while the included lags and leads of each regressor are selected depending on the significance of the coefficients (based on standard *t*-test statistics). When restrictions (other than theoretical) are introduced into the model, a likelihood ratio (LR) test is performed to ensure that the constrained model is not statistically different from the non-constrained model. To ensure the robustness of each equation, we also evaluate whether our results are sensitive to changes in the estimation sample or to the presence of a particular variable among the regressors. The importance of these changes, which are not found to significantly influence our results, is evaluated through standard *t*-tests for each individual coefficient, and through LR tests for the equation as a whole.

In addition, we perform out-of-sample forecasting for each equation, for 1 to 12 quarters ahead, and compare the results against alternative specifications such as an AR process[11] or a purely backward-looking equation. The forecasting performance of each equation is evaluated on the basis of the root mean square error (RMSE), the mean absolute error (MAE), and the confusion index.

Tables E1 to E6 in Appendix E report the forecasting results for the chosen equations. Each table shows the RMSE and the MAE of each equation, as well as the U of Theil, comparing the RMSE of the chosen equations versus that of an AR process or purely backward-looking equation. Other indicators of forecasting performance listed in the tables include the confusion index, describing the percentage of times the chosen model wrongly predicts the variation sign. In addition, we list the decomposition of the MSE (Clements and Hendry 1998), which is used to assess the type of forecasting errors generated by the equation. Specifically, the bias proportion represents the percentage of systematic errors, and the covariance proportion represents the unsystematic errors.

3.1 The IS curve

In both economies, the IS curve is estimated over the period from 1980Q1 to 2004Q4. This sample is chosen to maximize the data points available, while avoiding the large oil shocks of the 1970s.

Estimation results are summarized in Appendix C (Table C1 for the U.K. IS curve and Table C2 for the euro area IS curve), and all reported coefficients are found to be significant at the 5 per cent level (based on standard *t*-test statistics). In both cases, we obtain an R^2 of around 0.4. As shown in Appendix D, both fitted IS curves follow actual GDP data quite well.

All the coefficients are found to have the expected sign. Current output growth is positively affected by potential output, with increasing productivity generating higher domestic demand. In addition, a tightening in the monetary policy stance leads to a slowdown in output growth, an appreciation of the exchange rate causes output to fall, and stronger foreign demand (represented by an increase in the foreign output-gap components) results in an increase in domestic aggregate demand.

11. The order of the AR process is determined by the minimization of the Schwartz criteria.

With respect to the implications of each specific coefficient, we find that, in the case of the euro area, we cannot reject the hypothesis that the coefficient of potential output equals 1, which implies that equation (1) can be rewritten in terms of the output gap:

$$Ygap_t = (1+\lambda_1)Ygap_{t-1} + \lambda_2(r_{t-i} - r^e_{t-i}) + \lambda_3 Ygap_{t-i}{}^* + \lambda_4 YgapUS_{t-i} + \lambda_5 YgapAsia_{t-i} + \lambda_6 \Delta \mathrm{real} FX_{t-i} . \quad (4)$$

As a result, supply shocks are immediately absorbed as a one-to-one increase in demand. For the United Kingdom, the coefficient of potential is estimated to be 0.8, implying that 80 per cent of a supply shock is immediately absorbed into demand. Therefore, in both cases, supply shocks, such as increases in labour productivity, are quickly reflected as an increase in real output, implying that the economy is immediately generating higher demand.[12] The result is in line with other works in the empirical literature, such as Doménech, Ledo, and Taguas (2001a), who also model the euro area IS curve in terms of the output gap, or Larsen and McKeown (2004) in the case of the United Kingdom.

In the euro area, the monetary policy stance is modelled as a real interest rate gap, measured as the difference between the current real interest rate and an equilibrium interest rate generated by an HP filter. In turn, the real interest rate is obtained from the nominal interest rate deflated by expected inflation, which is proxied by the growth rate of the seasonally adjusted CPI. In the case of the United Kingdom, the estimation of the IS curve leads to no significant coefficient on the interest rate gap. Instead, the monetary policy stance is modelled as a yield curve, defined as the difference between the short-term nominal interest rate and the long-term nominal interest rate. The yield curve is often used as the monetary policy stance variable due to its explanatory power in predicting GDP growth (Stock and Watson 1989).[13]

12. Empirical evidence shows that increases in productivity do not immediately result in higher output, due to delays in implementing new technologies. Our model, however, displays little or no lag between an increase in potential output and the resulting increase in real output. Although simplistic, this finding is not unusual in reduced-form models that describe output from an aggregate perspective, instead of modelling each demand component, such as consumption or investment. Indeed, such aggregate modelling might lead to biases. Monforte (2004) analyzes the problem of aggregation bias by comparing aggregate versus country-specific models. He concludes that non-negligible aggregation errors exist when using euro area data. As a result of the bias described, the estimated model is unable to characterize the economy's response to a permanent productivity shock (i.e., a change in the growth rate of potential output).

13. See also Estrella and Hardouvelis (1991), and Estrella and Mishkin (1997).

With respect to the level of foreign activity, when estimating the U.K. IS curve, only the euro area gap is found to be significant. The coefficients for the Asian and American gaps are calibrated in proportion to the euro area one using export-share weights.[14] In addition, foreign gaps are modelled in levels in the case of the euro area and in first difference for the United Kingdom. This result implies that, given a certain foreign demand shock, output in the United Kingdom will be affected only temporarily, resulting in a higher degree of persistence in the euro area.

The estimated responses are broadly similar in both models. For example, the elasticity of the monetary policy stance is estimated at around -0.091 in the euro area and at -0.098 for the United Kingdom. In addition, the coefficient of the exchange rate is found to be -0.024 in the euro area and -0.034 in the United Kingdom. The slightly larger coefficients of the U.K. model are in line with the view of the U.K. economy as being less subject to structural rigidities[15] and more open to trade than the euro area economy.[16]

Our results appear to be in line with the literature. For the euro area, Doménech, Ledo, and Taguas (2001a) estimate an IS curve modelled in terms of the output gap and an interest rate gap but without an external sector. They find the elasticity of the interest rate gap to be around -0.09 (in line with our estimates) and include a forward-looking component of the output gap with a coefficient of 0.5.[17] Smets (2000) estimates the coefficient of the forward-looking gap at 0.56, while the elasticity of the interest rate gap is found to be slightly lower at around -0.06.

Larsen and McKeown (2004) conduct a very similar study using U.K. data and estimate the root from the lagged output gap to be around 0.81, in line with our findings (0.86).

With respect to forecasting performance, the estimated IS curves appear to perform better than an AR process,[18] reducing the RMSE by between 15 to 25 per cent for both countries (Appendix E, Tables E1 and E2). In addition, in the case of the United Kingdom, the confusion index is found to

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14. Export data are obtained from the OECD's *Monthly Statistics of International Trade*.
15. With respect to the effects of monetary policy on domestic output, our results are in line with those of the OECD, which argues that monetary policy tends to be less effective in the euro area than in other "English speaking" economies such as the United Kingdom (OECD 2005) due, among other factors, to weaker monetary policy transmission through the housing channel.
16. We calculate a measure of openness ((exports + imports) / GDP) for the euro area and the United Kingdom using the OECD's *Monthly Statistics of International Trade* over the 1995 to 2004 period. The U.K. average index over the sample is 34.7, versus the euro area's 20.3.
17. Since the coefficients of forward- and backward-looking gaps must add up to 1 by construction, the backward-looking component of the gap estimated by Doménech, Ledo, and Taguas (2001a) has an implied coefficient of 0.5. Although this is lower than our 0.93, the result is not surprising, given that, in our model, only the backward output gap is found to be significant.
18. The order of the AR process is determined by the minimization of the Schwartz criteria.

be significantly lower (0.35 versus 0.50), meaning that the equation is able to correctly forecast the direction of the change in GDP growth 65 per cent of the time.

3.2 The Phillips curve

The Phillips curve is estimated in the form described by equation (3) and results are shown in Appendix C. From there, we derive the following reduced-form equation:

$$\pi_t = \alpha_1\pi_{t-1} + \alpha_2\pi_{t-2} + \alpha_3\pi_{t-3} + \gamma_1\pi_{t+1} + \gamma_2\pi_{t+2} + \gamma_3\pi_{t+3} + \\ + \lambda_1 Ygap_{t-i} + \lambda_2 \Delta \mathrm{real} FX_{t-i} + \lambda_3 \Delta \mathrm{real} WTI_{t-i} . \quad (5)$$

In both countries, the Phillips curve is estimated over the period from 1980Q1 to 2004Q4. As in the case of the IS curve, this sample is chosen to maximize the data points available, while avoiding the large oil shocks of the 1970s, which are not representative for the entire sample.

Estimation results are summarized in Appendix C (Table C3 for the U.K. Phillips curve and Table C4 for the euro area Phillips curve) and all reported coefficients are found to be significant at the 5 per cent level (based on standard *t*-test statistics). In both cases we obtain a relatively high R^2, between 0.8 and 0.9. As shown in Appendix D, both fitted Phillips curves follow actual inflation data quite well.

All the coefficients are found to have the expected sign. Current inflation depends positively on past and future levels of inflation, generating persistence in the price growth dynamic. In addition, an increase in economic slack (signalled by a widening negative output gap) causes inflation to fall, an appreciation of the domestic currency has a deflationary effect, and stronger oil prices result in increasing domestic inflation.

With respect to the implications of each specific coefficient, we find that, in both countries, we could not reject the hypothesis that the combined effect of the leads equals the combined effect of the lags, implying that the same weight is assigned to past and future values of inflation.[19] As in Kozicki and Tinsley (2002), our result is just a special case of the general PAC function described in section 2.3, and implies an inflation dynamic similar to that obtained with Taylor-type staggered contracts.

19. Since all the coefficients of the leads and lags of inflation must sum up to 1 by construction, and the combined effects of the leads equals that of the lags, our combined forward-looking parameter is 0.5.

With respect to country-specific lag dynamics, we find that, in the United Kingdom, the inflationary process is characterized by three leads and three lags of inflation, with most of the adjustment taking place in the first and second lead/lag. In the case of the euro area, however, the first lead/lag is not found to have a significant weight, so all of the inflationary adjustment takes place in the second and third lead/lag, which implies that, in line with empirical observations, the adjustment process displays a higher degree of price stickiness in the euro area than it does in the United Kingdom.

With respect to inflationary pressures resulting from capacity constraints, we estimate the coefficient of the output gap to be 0.032 in the euro area and 0.092 in the United Kingdom. As a result, we conclude that U.K. inflation would react more than euro area inflation to the same change in the output gap. This finding is not surprising, given the higher degree of stickiness in the euro area.[20]

The coefficient of the exchange rate is found to be larger in the case of the United Kingdom, where it is estimated at -0.030, while in the euro area it is estimated at -0.013. This result is not surprising, given that the United Kingdom is a more open economy than the euro area as a whole.

Doménech, Ledo, and Taguas (2001a) estimate a euro area Phillips curve and find the coefficient of the forward-looking parameter to be around 0.54, implying a slightly more forward-looking behaviour of inflation than estimated in our model. Smets (2000) obtains very similar results, with a forward-looking coefficient of 0.52. With respect to the output gap, Doménech, Ledo, and Taguas (2001a) estimate a coefficient of 0.062, which is almost double our finding. This result, however, is not surprising, given that the output gap estimated by Doménech, Ledo, and Taguas (2001a) appears to have a smaller amplitude than ours, thus justifying a larger coefficient in the Phillips curve.

Larsen and McKeown (2004) also estimate a reduced-form Phillips curve for the United Kingdom. They obtain a coefficient of 0.111 on the output gap, which is slightly higher than our 0.092, but in the same order of magnitude. Their coefficient on expected inflation, however, is higher than our estimates (0.79 versus our 0.5), implying more forward-lookingness.

20. Our results are in line with the findings of the OECD, who conclude that “econometric evidence [...] confirms that inflation inertia [defined as inflation declining only slowly when slack accumulates] is significantly higher in the euro area than in ‘English-speaking’ countries” such as the United Kingdom (OECD 2005).

The forecasting performance of the Phillips curve is also found to be quite satisfactory (Appendix E, Tables E3 and E4). For both countries we find that, when compared with a simple backward-looking Phillips curve, the estimated PAC version of the Phillips curve reduces the RMSE by about 30 per cent when forecasting one quarter in advance, and by about 40 to 50 per cent when forecasting eight quarters in advance. In addition, the confusion index indicates that the Phillips curve estimated with the PAC methodology can predict the direction of change in the quarterly inflation rate between 65 to 75 per cent of the time.

3.3 The monetary policy reaction function

As explained in section 2.4, our reaction function is simply estimated to fit the data, and might therefore not be optimal. This implies that our equation can be used to predict how the monetary authority *is likely to* react and not how the monetary authority *should* react. In addition, given that the ECB is still a very young institution, estimates for the euro area are based on aggregate data and do not necessarily reflect the behaviour of the central banks of the twelve euro area member countries before the advent of the euro.

In both countries, the reaction function is estimated over the period from 1990Q1 to 2004Q4. Estimation results are summarized in Appendix C (Table C5 for the U.K. reaction function and Table C6 for the euro area reaction function) and all reported coefficients are found to be significant at the 5 per cent level (based on standard *t*-test statistics). In both cases, we obtain a relatively high R^2, between 0.7 and 0.8. As shown in Appendix D, both fitted reaction functions follow actual data quite well.

All the coefficients are found to have the expected sign. Current levels of the interest rate variable (recall that the monetary stance is modelled as an interest rate gap in the euro area and as the yield curve in the United Kingdom) are related to past levels through an interest rate smoothing parameter, possibly reflecting policy-makers' aversion to moving the nominal interest rate by large steps. Indeed, McCallum and Nelson (1999) find that interest rate smoothing helps to reduce the variability of output and inflation. For the euro area, the smoothing parameter is found to be around 0.73, while in the United Kingdom the smoothing parameter is slightly higher, at around 0.82.[21] In addition, we find that the monetary authority reacts by tightening policy when expected inflation deviates from its target and (but only in the case of the United Kingdom) when the economy is in a situation of excess demand (positive output gap).

21. The root of the smoothing parameter is obtained as the combined effect of the estimated coefficients of the first and second lags of the monetary instrument. For both countries, the first lag is found to have a root bigger than one, while the effect of the second lag is negative.

The finding that the euro area monetary authority appears to react only to inflation deviations from target, while the U.K. reaction function also depends on the output gap, is in line with work by Altavilla and Landolfo (2005), who argue that "the ECB adheres to a model of 'narrow' or German central bank model, rather than to a 'broad' or Anglo-Saxon central bank framework, meaning that the ECB designs its own strategy with the sole aim of achieving price stability. In contrast, the Bank of England can pursue several (implicit) targets" (such as output and unemployment stabilization).[22] The finding that the U.K. monetary authority appears to react directly to changes in the output gap could be attributed to the lack of independence of the Bank of England over the earlier part of the estimation sample.

Our estimates indicate that the euro area monetary authority will tend to react less than the U.K. monetary authority given the same change in domestic inflation. In fact, the coefficient on the expected inflation-deviation-from-target term is found to be 0.185 for the euro area and 0.250 for the United Kingdom. In addition, but only in the case of the U.K. reaction function, the output gap is found to significantly affect the conduct of monetary policy, with an estimated coefficient of 0.074. As a result, the U.K. monetary authority appears to exhibit a more aggressive behaviour than the euro area monetary authority.

As with our research, Doménech, Ledo, and Taguas (2001a) allow for interest rate smoothing in the euro area reaction function, so that the interest rate adjusts gradually to the target level. They estimate an inflation smoothing parameter of around 0.83, in line with our estimates (0.73). With respect to the monetary authority's policy objective, Doménech, Ledo, and Taguas (2001a) evaluate a reaction function with a weight of 2 on inflation and a weight of 1 on the output gap. They also include dummy variables, to account for the effects of the exchange rate mechanism (ERM) crisis of 1992, which implied higher interest rates for reasons other than the inflation or output dynamics, and to capture the effects of the ECB period, which should coincide with a reduction of the risk premium in real interest rates.

In order to evaluate the coefficients' stability, estimates are also conducted using the whole sample (1980Q1 to 2004Q4). In the case of the United Kingdom, coefficients do not change significantly when estimating the equation over the whole sample. The only difference is associated with the output-gap coefficient, which is no longer found to be significant over the extended sample. This difference could be attributed to the absence of an inflation target, as well

22. Altavilla and Landolfo (2005) estimate a regime-dependent Taylor rule to quantify the asymmetric impact of monetary policy on the real economy. They find that the Bank of England estimated reaction function shows a higher output-gap response coefficient, supporting the belief that the Bank of England implicitly targets both inflation and output. By contrast, the ECB seems to be more focused on inflation dynamics, in line with our findings. In addition, they conclude that both the euro area and the U.K. monetary authorities react more aggressively during a recession than in periods of economic expansion.

as to the lack of independence of the Bank of England over the earlier part of the sample. In the case of the euro area, estimating the reaction function over the whole sample (rather than since 1990) leads to more significant differences than in the case of the United Kingdom. In particular, while the coefficients relative to the interest rate smoothing parameters remain very stable irrespective of the sample period, the coefficient relative to the deviations of inflation from target is no longer significant. This result is not surprising given that, during the 1980s, euro area countries were bound by the currency pegs of the exchange rate mechanism and, as a consequence, exchange rate fluctuations might have received more focus than inflation targeting. In addition, during the 1990s, the degree of macroeconomic policy coordination among euro area countries increased significantly, especially after the Maastricht Treaty was signed in 1992. Moreover, during most of the 1990s, currency re-evaluations became less frequent than during the 1980s. Consequently, the synthetic aggregate euro area reaction function should be estimated over the reduced sample (1990 onwards), when euro area countries displayed a higher degree of macroeconomic policy coordination.

When estimating the euro area reaction function, a number of other specifications were also analyzed, but not found to be significant. In particular, given the attention paid by the ECB to monetary developments, we estimated a version of the reaction function that included a measure of liquidity (such as M3 growth) among the policy objectives. However, M3 was not found to be significant, which is in line with results from Hubrich and Vlaar (2000), who analyze the role of money as a leading indicator of inflation using German and aggregate euro area data and do not find strong support for monetary targeting. Similarly, Clausen and Meier (2005) argue that broad monetary aggregates such as M3 played only a small role in the Bundesbank’s interest rate decisions.

We also tried to model the euro area reaction function in terms of the yield curve, defined as the difference between short and long interest rates. Again, we did not find the yield curve to be significant. This result is in line with findings by Berk and van Bergeijk (2000), who conclude that the information content of the yield curve with respect to future movements in inflation and real output is very limited and not useful in the Eurosystem for monetary policy purposes.

Moreover, a series of dummies were introduced in the estimations to capture the effects of specific events that might have significant impact on the conduct of monetary policy. In the case of the euro area, dummies were used to mark the ERM crisis in 1992 and the creation of the ECB in 1999. For the United Kingdom, dummies marked the adoption of an explicit inflation target in 1992 and the official declaration of independence by the Bank of England in 1997. None of these dummies was found to be significant or to significantly affect our results.

The forecasting performance of both reaction functions is less impressive than the performance observed in the case of the estimated IS or Phillips curves (Appendix E, Tables E5 and E6). For the euro area, the estimated reaction function nevertheless displays better forecasting properties than a purely autoregressive version, reducing the RMSE by about 5 to 10 per cent. However, in the case of the United Kingdom, all estimated versions of the reaction function are unable to outperform the autoregressive benchmark without being worse. Nevertheless, for the purpose of the model, we choose the estimated version of the reaction function, because it offers a richer interpretation than a simple AR specification.

4. Deterministic Shocks

This section presents the results of four shocks: a domestic demand shock, a monetary policy shock, an inflation shock, and a foreign exchange shock (Appendix F, Table F1).[23,24]

The euro area and U.K. models respond endogenously to each other, via the effect of foreign demand on the IS curve. Therefore, all of the artificial environment shocks produce a direct effect at home and an indirect effect abroad, the magnitude of which will depend on the response of domestic output to the initial shock.

Graphs F1 to F4 in Appendix F show the impulse-response functions relative to each shock. Shocks are conducted in an artificial environment over a 65-quarter time horizon, with variables starting at their steady-state values and shocking one variable at a time while holding everything else constant. All the shocks presented consist of a temporary, one-quarter shock of 1 percentage point in the variable considered, except for the exchange rate shock, which has a magnitude of 10 percentage points. These values are not intended to portray “typical” shocks of the variables analyzed, but are chosen because their standardized magnitudes are easily comparable with the literature.

All shocks are presented in the same way: in the left column we show the effects of a U.K. shock and in the right column we show the effects of a euro area shock. Each shock incorporates the

23. Although NEUQ can be used to analyze a number of other shocks, only the most notable results are reported. For example, a foreign demand shock (such as an increase in the U.S. output gap) would produce very similar dynamics to the domestic demand shock described here, with differences only in the specific magnitude of the responses, which depend on the coefficient of the U.S. output gap in each country’s IS curve. Also, since oil prices enter the model only through the Phillips curve, an oil-price shock would have a very similar dynamic to an inflation shock, only with a different magnitude.

24. Because of the aggregation bias discussed in section 3.1, shocks on potential output are very quickly reflected as a change in real output, therefore leaving the output gap virtually unchanged. As a result, a potential output shock is not simulated.

endogenous response of some key foreign macroeconomic variables. The euro area (U.K.) simulation incorporates the endogenous response of U.K. (euro area) output, inflation, and short-term interest rates. In each graph, the green line indicates the response of U.K. variables, and the black line indicates the response of euro area variables.

4.1 A temporary shock to domestic demand

The demand shock consists of a 1 percentage point increase in the quarterly growth rate of real GDP, maintained for only one quarter. Since this shock has no effect on the level or on the growth rate of potential output, it increases the output gap by 1 percentage point on impact and in the following quarter.

The environment of excess demand fuels inflationary expectations, leading to a rise in the inflation rate. The inflationary response of the two countries is very similar, with the inflation rate increasing by 0.6 of a percentage point in the United Kingdom and by 0.5 in the euro area. In both countries the peak response is reached between one and two years, the response being slower in the euro area, due to the smaller output-gap elasticity in the euro area Phillips curve. Because of the rise in inflationary expectations, and the rate of price growth deviating from its target, the monetary authority attempts to dampen the rising price pressures by tightening monetary policy. In the euro area this amounts to increasing the short-term real interest rate above its equilibrium value. In the United Kingdom, however, a tightening in monetary policy corresponds to an increase in the yield curve, which results from the short-term interest rate increasing by more than the long-term interest rate. For the purpose of this section, we assume no change in long-term interest rates; therefore, an increase in the yield curve is equivalent to a one-to-one increase in the short-term interest rates.

Despite the inflation deviation from its target being very similar in both countries, the response of the monetary authority is almost twice as large in the United Kingdom as in the euro area, with the U.K. monetary authority raising real interest rates by around 70 basis points, while in the euro area the tightening amounts to around 35 basis points. The difference is explained by the larger sensitivity of U.K. interest rates to changes in inflation and by the presence of the output gap in the U.K. reaction function. As explained in section 3.3, the U.K. monetary authority is found to pursue the dual objective of stabilizing output and inflation, while the euro area monetary authority appears to focus only on inflation deviations from target.

The increase in the cost of borrowing lowers domestic demand. As a result, the excess demand is gradually reabsorbed and the economy moves to an environment of slight excess supply. The deflationary effect stemming from the tightening output gap results in the moderation of inflationary pressures, which allows the inflation rate to return to a level compatible with the monetary authority's inflation target. The speed at which inflation returns to target is significantly different in the two countries, owing to the different lag structure of inflation. In fact, while inflation is back to target after around four years in the United Kingdom, it takes euro area inflation an additional three years to return to baseline. As inflation decreases, the monetary authority is able to gradually reduce interest rates, thus returning to a neutral stance.

The indirect effects of a demand shock abroad are very similar in both countries: a U.K. (euro area) demand shock increases the euro area (U.K.) output gap by about 0.3 of a percentage point, the effect being slower and more permanent in the euro area. In fact, while euro area GDP growth depends on the level of the U.K. output gap, the U.K. GDP growth is found to depend on the difference of the euro area output gap, implying that a foreign demand shock will be much more short lived in the United Kingdom and will depend on the persistence of the shock abroad more than on its magnitude.

Results from a demand shock in NEUQ appear broadly consistent with other works in the literature. For example, Doménech, Ledo, and Taguas (2001a) find that, in the euro area, a transitory output shock (a 1 per cent increase in output maintained for one quarter) leads immediately to output increasing by 1.5 percentage points. The stronger response of output is explained by the presence of a forward output-gap component in the IS curve. Following tightened demand conditions, the inflation rate increases, peaking at 0.5 of a percentage point after three quarters (in line with NEUQ) and leading to a monetary policy tightening corresponding to an interest rate increase of 15 basis points, which takes place after three to four quarters.

4.2 A temporary shock to short-term interest rates

The second shock we introduce into the model is a temporary increase in nominal short-term interest rates, which are increased by 100 basis points for one quarter.[25]

Given the costs implied by rapidly changing monetary policy, current interest rates depend on past levels. As a result of the lag structure present in the reaction function, the monetary authority cannot change interest rates one quarter and then fully reverse the shock the next quarter.

25. Note that the exchange rate is exogenous and financial flows are not part of the model, so that a change in interest rates is not reflected in a change in investors' preferences.

The shock depresses real activity by increasing the cost of borrowing. The response of output is broadly similar in both countries, with the output gap decreasing by just over 0.2 of a percentage point after about one year, the effect being slightly faster and more pronounced in the euro area due to the higher interest rate elasticity of the euro area IS curve. The negative output gap affects agents' inflationary expectations and the inflationary process, thereby reducing inflation by around 0.25 of a percentage point in the United Kingdom and by around 0.2 of a percentage point in the euro area, with the peak response being reached after about two years. As a result of both the inflation rate and future inflationary expectations falling below target, the monetary authority returns quickly to a more neutral monetary stance (the interest rates are back to their baseline levels within a year), and it even cuts interest rates slightly (by around 20 to 25 basis points), allowing both the output gap and the inflation rate to return to their equilibrium levels. As previously observed, the most important differences between the two country blocks is the dynamics of inflation, with euro area inflation showing significantly more persistence than U.K. inflation. In fact, while inflation is back to control in around four years in the United Kingdom, euro area inflation returns to baseline after around six years.

The impact of domestic monetary tightening on foreign output is minimal and broadly similar in both countries, amounting to the U.K. (euro area) output gap decreasing by around 0.05 of a percentage point following the higher interest rates in the euro area (United Kingdom).

A similar transitory monetary policy shock is found in Ratto et al. (2005), where interest rates are increased by 1 percentage point (100 basis points) for one quarter and are back to control within one year. The increase in the cost of borrowing lowers output, which displays a hump-shaped response, with the peak occurring in the second and third quarters after the shock. The maximum effect on output amounts to 0.4 to 0.5 of a percentage point (pp), which is around double the response of NEUQ. Prices fall on impact and the speed at which prices react to the change in interest rates is quite fast, with the peak inflation response reached in the third quarter after the shock. The maximum effect on inflation is -0.25 pp on an annualized basis (in line with our findings), but displays little persistence due to the forward-lookingness in the inflation determination. Broadly similar results are found by De Grauwe and Costa Storti (2004), where a similar monetary tightening decreases output by around 0 and -0.7 of a percentage point (with a mean of -0.33 pp) after one year, and the price level by between 0 and -0.4 of a percentage point (with a mean of -0.07 pp).

Altavilla and Landolfo (2005) estimate a larger response for both output and inflation stemming from a 1 per cent contractionary monetary policy shock. They find that the output gap decreases by between 0.7 and 0.4 of a percentage point in the euro area and by between 0.6 and 0.2 of a percentage point in the United Kingdom. The response of inflation lies between -0.3 and -0.8 of a percentage point for the euro area and between -0.1 and -0.8 of a percentage point for the United Kingdom.

4.3 A temporary shock to inflation

The third shock is a temporary increase in CPI inflation, which increases by 1 percentage point for one quarter. Following the shock, the inflation rate increases by 1.3 percentage points on impact in both countries, with 1 percentage point due to the shock itself and the rest due to rising inflationary expectations. Although in the following quarters inflationary expectations decrease gradually, as agents recognize the temporary nature of the shock, the decrease in inflation is only gradual, due to the presence of adjustment costs in the Phillips curve. To bring the inflation rate back to its target, the monetary authority increases interest rates by around 35 basis points in the United Kingdom and by around 25 basis points in the euro area, with the peak being reached around three quarters after the shock. This raises the cost of borrowing and therefore decreases economic activity, resulting in a small negative output gap of around -0.13 per cent two years after the initial inflationary shock. This, together with falling inflationary expectations, exerts downward pressure on the inflation rate, which slowly returns to its target (after around four years). The gradual decrease in inflation can be justified by the presence of adjustment costs in the Phillips curve, meaning that inflation will tend to be relatively persistent.

4.4 A temporary shock to the real effective exchange rate

This shock is a temporary exchange rate shock over one quarter. The real effective exchange rate appreciates by 10 per cent relative to that of its main trading partners before returning to its original value in the second quarter.

This shock can be interpreted as a temporary gain of confidence by investors in assets denominated in euro/sterling pound (a decline in the risk premium). Since this shock represents a change in investors' preferences, and not a change in economic fundamentals, monetary authorities need to reduce the interest rate to counter the effects of the appreciation of the euro/ pound sterling on domestic prices. In the model, the impact of the appreciation will be transmitted through two channels. The first, a direct effect, works over a decline in inflation in the Phillips curve and the second, an indirect effect, works over a reduction in net exports (through the IS curve) which, in turn, exerts downward pressure on domestic inflation. The effect on the economy should only be temporary, however, since monetary authorities will act to counter the shock's impact on inflation.

The temporary appreciation of the domestic currency (expressed in trade-weighted terms) induces a decline in inflation and in real GDP, with minor differences in the two countries in terms of the timing of the response due to the slight differences in the estimated lag structure. The output gap decreases by around 0.3 of a percentage point in both countries. The environment of excess supply exerts downward pressure on inflation, which, together with the deflationary effect of the appreciation, reduces CPI inflation by 0.5 of a percentage point in the United Kingdom and by 0.3 of a percentage point in the euro area. The negative inflationary effects are slightly larger in the United Kingdom due to the higher exchange rate coefficient in the U.K. Phillips curve and to the different lag structure, which affects inflationary expectations and magnifies the effect. As a result of the fall in inflation, the authorities loosen monetary policy by lowering interest rates by around 40 basis points in the United Kingdom and by around 20 basis points in the euro area.[26] As expected, the U.K. monetary authority is more reactive, due to its dual objective to maintain both price and output stability. The lower cost of borrowing stimulates economic activity and, as a result, the negative effect on output is short lived and the output gap returns to equilibrium within two years.

5. Forecasting Performance

In order to test the forecast accuracy of the NEUQ model, the new model is used to reproduce projection scenarios for the period 2002 to 2004, inclusive (Appendix G).[27] While conducting this forecasting performance exercise, no judgment or monitoring is applied to the model in order to obtain the pure response of the model. However, some caveats have to be mentioned. First, because we conduct in-sample forecasting, the model's structure already incorporates part of the information we are trying to extract. Second, we do not conduct real-time forecasting, meaning that we use the latest available data, including revisions.

Projection profiles for quarter-on-quarter GDP growth at annual rates are generated for one and four quarters ahead. The forecasting performance of the model is then evaluated against history. On average, the model seems to yield accurate GDP forecasts at the considered horizons. The mean absolute error for the United Kingdom is 0.18 one quarter ahead and 0.17 four quarters ahead, and 0.41 and 0.34, respectively, for the euro area (Table G1). For both countries, the forecasting performance of the model is significantly better than an AR model, reducing the MAE by 75 per cent.

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26. Normally, we would not expect the monetary authority to react to a temporary exchange rate shock, especially if the shock is of small magnitude, as with the one described in this section. However, the monetary authority reacts to the shock only indirectly, through its effect on expected inflation and the output gap. Moreover, this is a purely unanticipated shock and its duration is unknown to agents.

27. In this section, we evaluate the forecasting performance of the model as a whole. In section 3, we evaluated the forecasting performance of each equation individually.

6. Conclusions

In this paper, we have estimated a reduced-form forecasting model, with forward-looking properties, for the euro area and the United Kingdom. NEUQ can be used to project the future path of real output, inflation, and the monetary policy stance.

Estimation results appear to be broadly in line with the empirical literature, both in terms of each estimated equation and with respect to the model's performance as a whole. In addition, the model delivers relatively accurate projections at a variety of forecast horizons.

Simulation results suggest that persistence to shocks is greater in the euro area than it is in the United Kingdom, which is reflected both in the behaviour of output as well as in the inflation dynamics. This is in line with empirical observations of a higher degree of inertia in the euro area, possibly due to structural rigidities.

Despite its simplicity, the model exhibits good properties and forecasting performance. Nevertheless, a number of channels could be further expanded. At the moment, owing to the exogeneity of the exchange rate, an appreciation of the euro (pound) implies a contraction in euro area (U.K.) GDP, which results in a negative output gap in the United Kingdom (euro area). However, the opposite result could be obtained if the appreciation of the euro (pound) implied an increase in the competitiveness of U.K. (euro area) producers and a resulting increase in U.K. (euro area) GDP. Therefore, an endogenous exchange rate would allow us to more accurately model the foreign sector. In addition, the model could be enriched by explicitly describing the financial flows between the euro area and the United Kingdom, adding a second link between the two country blocks.

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Appendix A: Potential Output Estimation for the Euro Area

Euro area potential output is estimated by means of a *hybrid approach* as in St-Arnaud (2004) and Renisson (2003). This method is based on a variation of the multivariate filter developed by Laxton and Tetlow (1992). A structural VAR is applied to the components of output, with the aim being to separate the trend (interpreted as the supply component or equilibrium path) from the temporary factors (interpreted as the demand component). Subsequently, the equilibrium path obtained from the SVAR is used as conditional information in an HP filter, which is applied to the components of output. The minimization problem of this approach is as follows:

$$\tau = \underset{\tau}{minT} = (\tau - X)'W_X(\tau - X) + (\tau - \hat{X}_{svar})'W_{\hat{X}_{svar}}(\tau - \hat{X}_{svar}) + \lambda\tau'D'D\tau , \quad \text{(A1)}$$

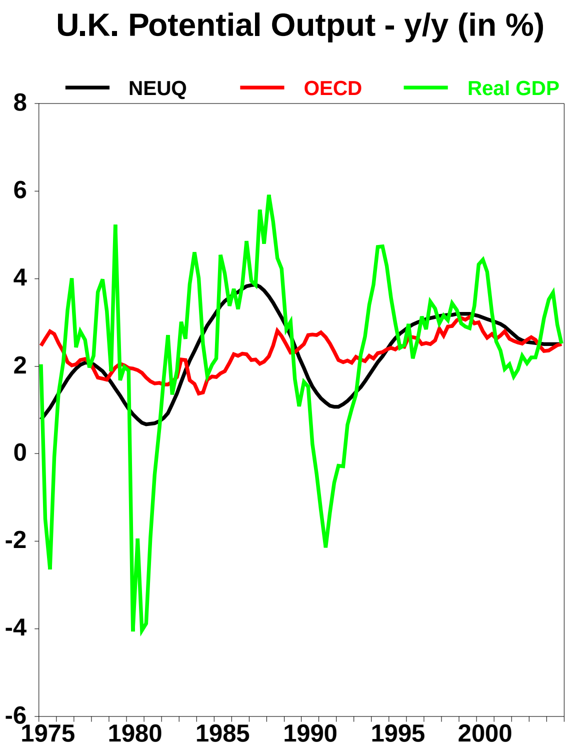
where τ is an unobserved variable, in this case potential output, X represents real GDP, and $W_{\hat{X}_{svar}}$ is the weight assigned to the equilibrium path generated by the SVAR ($\hat{X}_{svar}$). A number of specifications are analyzed and the usual criteria, including variance decomposition and the signs of impulse-response functions, are applied to select the most suitable one. The chosen specification contains the growth rate of real GDP, the seasonally adjusted consumer price inflation (based on the HICP index), the short-term real interest rate, the growth rate of U.S. real GDP, and the growth rate of the euro real effective exchange rate. The SVAR includes eight lags and is estimated on the longest sample available, from 1972Q3 to 2004Q4. Table A1 reports the variance decomposition of euro area GDP obtained from the SVAR.

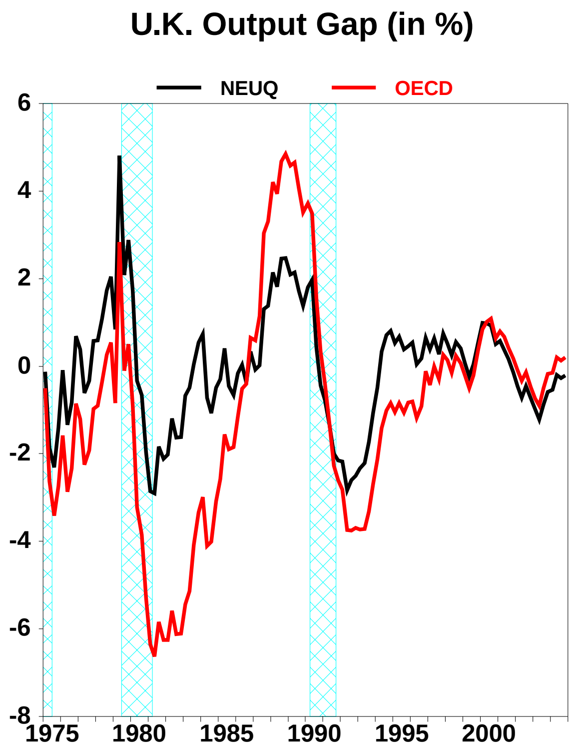
Table A1: Variance decomposition of real GDP

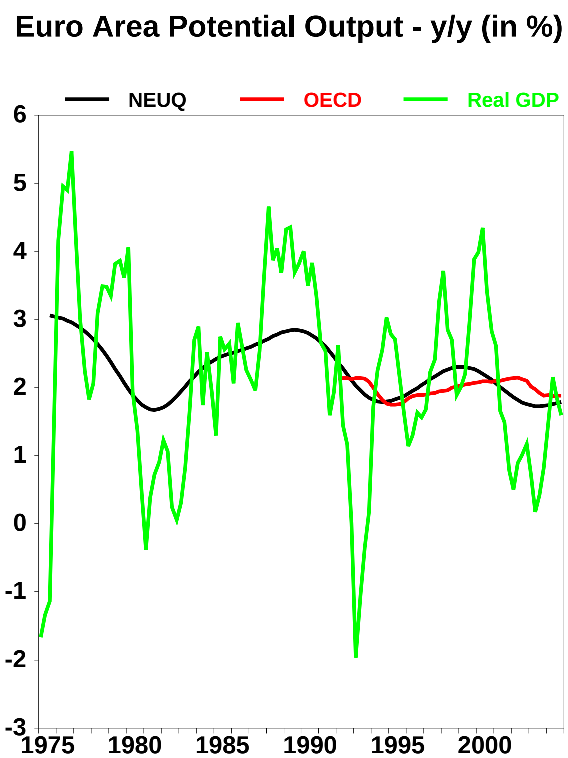
Horizon (quarters)	Supply	Demand
1	23	77
4	31	69
8	64	36
16	82	18
32	91	9
Infinity	100	0

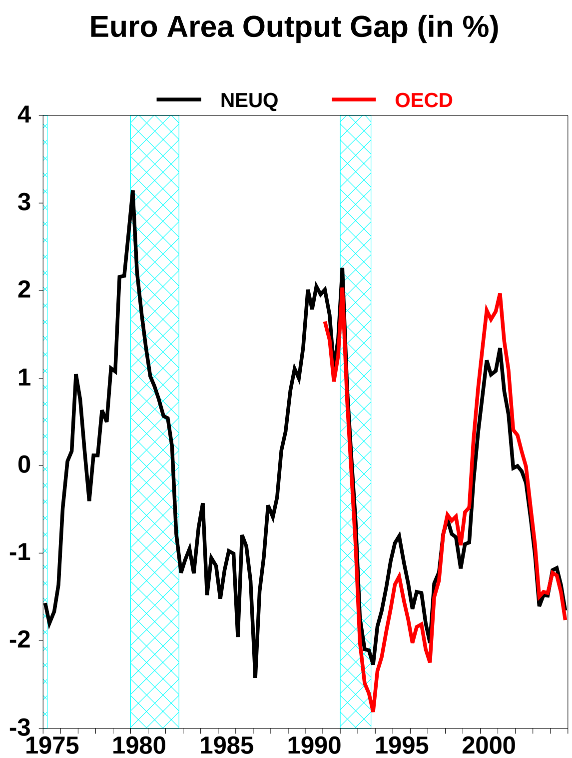
The cyclical component of GDP is relatively important. On impact, 77 per cent of the GDP variance is explained by factors related to demand, while factors related to supply account for 23 per cent. This proportion quickly changes, and two years after the shock, the majority of the GDP variance is explained by factors related to supply.

Appendix B: Potential Output Growth and Output Gap









Appendix C: Estimation Results - Tables

Table C1: Estimation results of the IS curve for the United Kingdom

Regressors	Coefficients	*t*-statistics
$dlypot\_uk_t$	0.803	21.489
$dly\_uk_{t\text{-}1}$	(1-0.803)	
$gap\ UK_{t\text{-}1}$	-0.135	-3.732
$pente\_uk_{t\text{-}2}$	-0.098	-4.398
$dgap\ EU_{t\text{-}1}$	0.5123	2.867
$dgap\ US_{t\text{-}1}$	*0.1477*[a]	
$dgap\ Asia_{t\text{-}1}$	*0.0623*[b]	
real $FX_{\ t\text{-}1}$	-0.065	-3.437
Q(1)[c]	0.579	0.447
Q(4)	4.592	0.332
R^2	0.409	

a. Calibrated coefficient (no *t*-statistics available).
b. Calibrated coefficient (no *t*-statistics available).
c. For the Ljung-Box Q-statistics, P-values are reported.

Table C2: Estimation results of the IS curve for the euro area

Regressors	Coefficients	*t*-statistics
$gap\ EU_{t\text{-}1}$	-0.074	-5.863
$R\ gap_{t\text{-}2}$	-0.091	-4.670
$gap\ UK_t$	0.114	7.669
$gap\ US_{t\text{-}1}$	0.022	2.111
$gap\ Asia_{t\text{-}1}$	0.028	2.028
real $FX_{\ t\text{-}2}$	-0.024	-4.940
Q(1)[a]	1.179	0.278
Q(4)	5.276	0.260
R^2	0.403	

a. For the Ljung-Box Q-statistics, P-values are reported.

Table C3: Estimation results of the Phillips curve for the United Kingdom

Regressors	Coefficients	*t*-statistics
G_2	0.547	12.486
G_3	0.168	5.760
B	1.00	
$gap\ UK_{t-1}$	0.0924	5.295
real FX_{t-2}	-0.030	-5.910
real WTI_{t-1}	0.003[a]	
Q(1)[b]	0.030	0.862
Q(4)	3.261	0.515
R^2	0.790	

a. Calibrated coefficient (no *t*-statistics available).
b. For the Ljung-Box Q-statistics, P-values are reported.

Table C4: Estimation results of the Phillips curve for the euro area

Regressors	Coefficients	*t*-statistics
G_2	0.748	7.325
G_3	0.340	2.849
B	1.000	
$gap\ EU_{t-1}$	0.032	2.205
real FX_{t-1}	-0.013	-1.760
real WTI_t	0.005	3.224
real WTI_{t-1}	0.003	2.447
Q(1)[a]	2.506	0.113
Q(4)	4.194	0.380
R^2	0.94013	

a. For the Ljung-Box Q-statistics, P-values are reported.

Table C5: Estimation results of the reaction function for the United Kingdom

Regressors	**Coefficients**	***t*-statistics**
yield curve UK_{t-1}	1.126	28.542
yield curve UK_{t-2}	-0.303	-8.199
$(\pi_{t+4} + \pi^*)$	0.250	2.587
gap UK_{t-1}	0.074	2.802
Q(1)[a]	0.417	0.519
Q(4)	3.311	0.507
R^2	0.872	

a. For the Ljung-Box Q-statistics, P-values are reported.

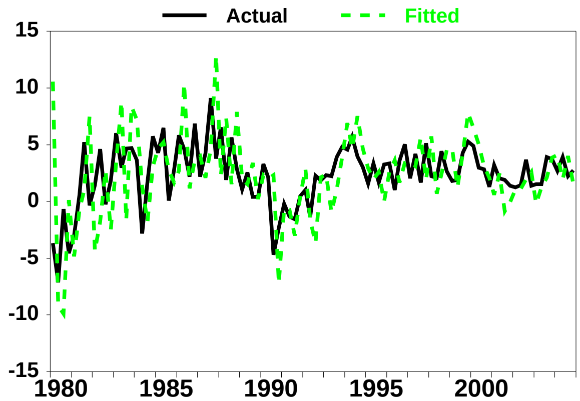
Table C6: Estimation results of the reaction function for the euro area

Regressors	**Coefficients**	***t*-statistics**
R gap EU_{t-1}	1.061	11.256
R gap EU_{t-2}	-0.328	-3.331
$(\pi_{t+4} - \pi^*)$	0.185	2.345
Q(1)[a]	0.273	0.601
Q(4)	8.714	0.069
R^2	0.734	

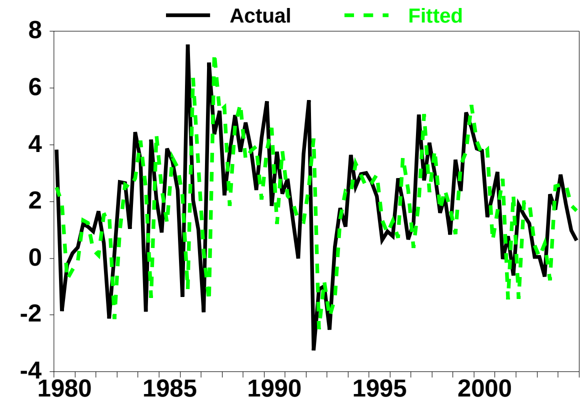
a. For the Ljung-Box Q-statistics, P-values are reported.

Appendix D: Estimation Results - Graphs

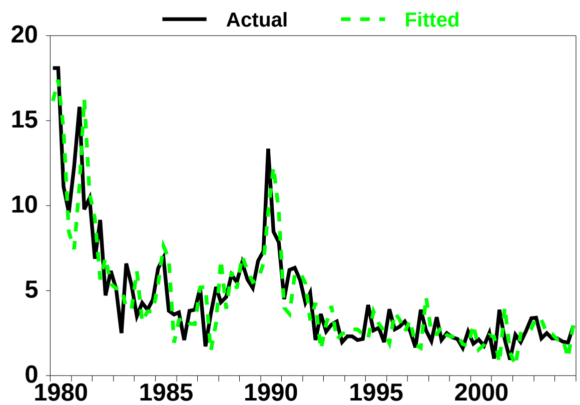
U.K. GDP (q/q at a.r. in %)



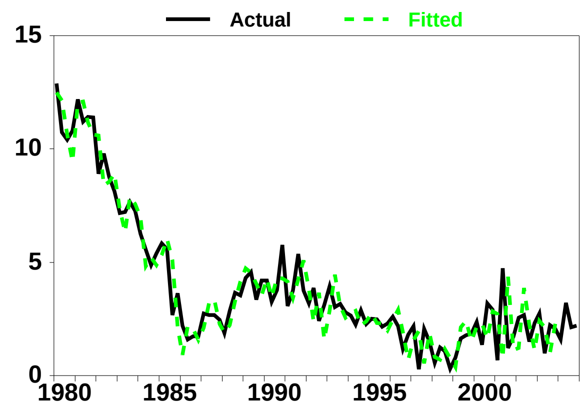
Euro Area GDP (q/q at a.r. in %)



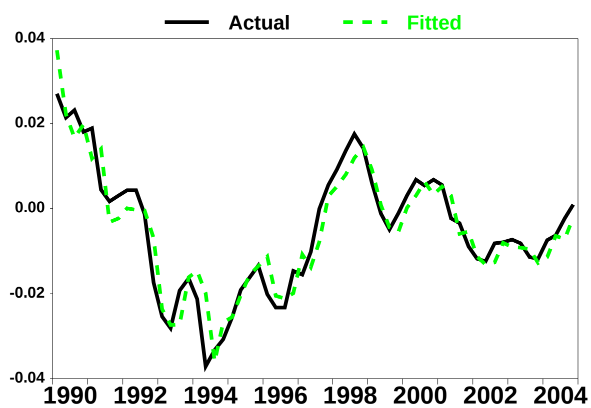
U.K. Inflation (q/q at a.r. in %)



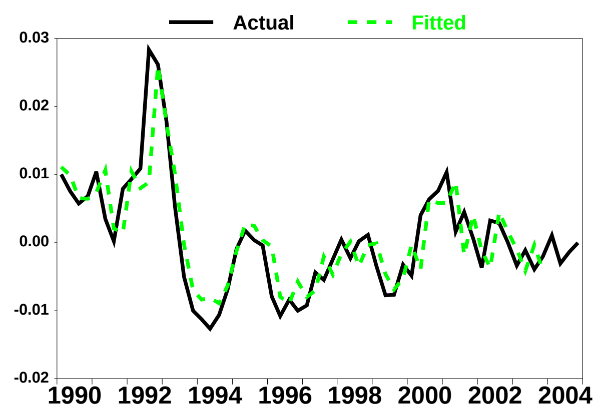
Euro Area Inflation (q/q at a.r. in %)



U.K. Yield Curve (in %)



Euro Area Interest Rate Gap (in %)



Appendix E: Forecasting Performance of the Equations

Table E1: Forecasting performance - U.K. IS curve

Horizons	h=1	h=2	h=3	h=4	h=5	h=6	h=7	h=8	h=9	h=10	h=11	h=12
RMSE	0.0035	0.0036	0.0036	0.0036	0.0036	0.0036	0.0033	0.0030	0.0030	0.0031	0.0031	0.0031
MAE	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0025	0.0024	0.0024	0.0024	0.0025	0.0025
U of Theil[a]	0.8292	0.7786	0.7432	0.7184	0.7473	0.7374	0.6616	0.6195	0.6007	0.6090	0.6140	0.6055
Confusion index	0.3548	0.3500	0.3103	0.3036	0.2963	0.3077	0.2800	0.2708	0.2826	0.2955	0.3095	0.3000
MSE decomposition[b]												
bias proportion	0.0168	0.0212	0.0165	0.0146	0.0135	0.0080	0.0016	0.0106	0.0135	0.0126	0.0135	0.0139
variance proportion	0.0656	0.0753	0.0691	0.0665	0.0658	0.0580	0.0149	0.0656	0.0947	0.0984	0.1197	0.1495
covariance proportion	0.9176	0.9035	0.9144	0.9189	0.9207	0.9340	0.9835	0.9238	0.8918	0.8890	0.8668	0.8366

a. Use the RMSE of an AR model instead of the RMSE of a naïve model.
b. As in Clements and Hendry (1998).

Table E2: Forecasting performance - EU IS curve

Horizons	h=1	h=2	h=3	h=4	h=5	h=6	h=7	h=8	h=9	h=10	h=11	h=12
RMSE	0.0036	0.0037	0.0037	0.0037	0.0037	0.0038	0.0038	0.0037	0.0036	0.0038	0.0038	0.0038
MAE	0.0029	0.0029	0.0029	0.0029	0.0029	0.0030	0.0030	0.0028	0.0028	0.0030	0.0030	0.0030
U of Theil[a]	0.8470	0.8033	0.7629	0.7366	0.7773	0.7931	0.7632	0.7453	0.7051	0.7512	0.7554	0.7390
Confusion index	0.5397	0.5738	0.5085	0.5263	0.5636	0.5849	0.5490	0.5510	0.5106	0.6000	0.5349	0.4634
MSE decomposition[b]												
bias proportion	0.0005	0.0003	0.0002	0.0008	0.0006	0.0001	0.0014	0.0018	0.0038	0.0041	0.0057	0.0091
variance proportion	0.0196	0.0207	0.0217	0.0190	0.0209	0.0423	0.0279	0.0066	0.0022	0.0084	0.0045	0.0105
covariance proportion	0.9799	0.9790	0.9781	0.9802	0.9785	0.9576	0.9706	0.9916	0.9939	0.9875	0.9898	0.9804

a. Use the RMSE of an AR model instead of the RMSE of a naïve model.
b. As in Clements and Hendry (1998).

Table E3: Forecasting performance - U.K. Phillips curve

Horizons	h=1	h=2	h=3	h=4	h=5	h=6	h=7	h=8	h=9	h=10	h=11	h=12
RMSE	0.0035	0.0032	0.0030	0.0027	0.0026	0.0026	0.0023	0.0024	0.0023	0.0022	0.0022	0.0021
MAE	0.0023	0.0021	0.0021	0.0020	0.0018	0.0019	0.0018	0.0018	0.0018	0.0017	0.0018	0.0017
U of Theil[a]	1.1540	0.9390	0.8151	0.7583	0.7006	0.6775	0.5264	0.4951	0.4565	0.4371	0.4261	0.4124
Confusion index	0.6000	0.5000	0.5000	0.5370	0.4808	0.4800	0.5625	0.4565	0.5455	0.5238	0.5750	0.5789
MSE decomposition[b]												
bias proportion	0.0011	0.0006	0.0079	0.0134	0.0248	0.0461	0.0228	0.0368	0.0425	0.0596	0.0528	0.0476
variance proportion	0.1781	0.0379	0.0156	0.0004	0.0093	0.0384	0.0242	0.0552	0.1088	0.0357	0.0351	0.0964
covariance proportion	0.8208	0.9615	0.9766	0.9862	0.9659	0.9155	0.9530	0.9080	0.8487	0.9047	0.9122	0.8560

a. Use the RMSE of a backward-looking model instead of the RMSE of a naïve model.
b. As in Clements and Hendry (1998).

Table E4: Forecasting performance - EU Phillips curve

Horizons	h=1	h=2	h=3	h=4	h=5	h=6	h=7	h=8	h=9	h=10	h=11	h=12
RMSE	0.0016	0.0016	0.0017	0.0018	0.0018	0.0018	0.0019	0.0018	0.0018	0.0019	0.0019	0.0019
MAE	0.0012	0.0012	0.0013	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014
U of Theil[a]	0.6957	0.6957	0.6800	0.5455	0.5143	0.4737	0.4524	0.4000	0.3750	0.3800	0.3585	0.3519
Confusion index	0.2623	0.2373	0.2632	0.2727	0.2642	0.2549	0.3061	0.2979	0.3111	0.3256	0.3171	0.3077
MSE decomposition[b]												
bias proportion	0.0021	0.003	0.0024	0.003	0.003	0.0026	0.0027	0.0008	0.0007	0.0001	0	0.0001
variance proportion	0.0804	0.0899	0.1302	0.1514	0.1577	0.1663	0.1706	0.1411	0.1647	0.1553	0.1457	0.1642
covariance proportion	0.9175	0.9072	0.8675	0.8456	0.8393	0.8311	0.8267	0.8582	0.8347	0.8447	0.8543	0.8356

a. Use the RMSE of a backward-looking model instead of the RMSE of a naïve model.
b. As in Clements and Hendry (1998).

Table E5: Forecasting performance - U.K. reaction function

Horizons	h=1	h=2	h=3	h=4	h=5	h=6	h=7	h=8	h=9	h=10	h=11	h=12
RMSE	0.0053	0.0087	0.0111	0.0122	0.0124	0.0134	0.0146	0.0153	0.0157	0.0156	0.0161	0.0178
MAE	0.0039	0.0069	0.0092	0.0098	0.0096	0.0097	0.0099	0.0106	0.0109	0.0107	0.0111	0.0119
U of Theil[a]	0.9636	0.9775	1.0091	1.0252	1.0420	1.0984	1.1496	1.1769	1.1805	1.1729	1.1838	1.2806
Confusion index	0.3115	0.4237	0.5614	0.5818	0.4906	0.549	0.449	0.4894	0.4222	0.3488	0.3659	0.4103
MSE decomposition[b]												
bias proportion	0.0000	0.0001	0.0005	0.0022	0.0068	0.0092	0.0103	0.0127	0.0151	0.0196	0.0183	0.0146
variance proportion	0.0241	0.0578	0.0993	0.1409	0.1942	0.2477	0.2968	0.3425	0.3709	0.3836	0.4004	0.4728
covariance proportion	0.9759	0.9421	0.9002	0.8569	0.7989	0.7431	0.6929	0.6448	0.6141	0.5968	0.5813	0.5126

a. Use the RMSE of an AR model instead of the RMSE of a naïve model.
b. As in Clements and Hendry (1998).

Table E6: Forecasting performance - EU reaction function

Horizons	h=1	h=2	h=3	h=4	h=5	h=6	h=7	h=8	h=9	h=10	h=11	h=12
RMSE	0.0053	0.0087	0.0111	0.0122	0.0124	0.0134	0.0146	0.0153	0.0157	0.0156	0.0161	0.0178
MAE	0.0039	0.0069	0.0092	0.0098	0.0096	0.0097	0.0099	0.0106	0.0109	0.0107	0.0111	0.0119
U of Theil[a]	1.2045	1.3385	1.5000	1.4699	1.4762	1.5952	1.7381	1.8214	1.8690	1.8795	1.9398	2.1190
Confusion index	0.3115	0.4237	0.5614	0.5818	0.4906	0.549	0.449	0.4894	0.4222	0.3488	0.3659	0.4103
MSE decomposition[b]												
bias proportion	0	0.0001	0.0005	0.0022	0.0068	0.0092	0.0103	0.0127	0.0151	0.0196	0.0183	0.0146
variance proportion	0.0241	0.0578	0.0993	0.1409	0.1942	0.2477	0.2968	0.3425	0.3709	0.3836	0.4004	0.4728
covariance proportion	0.9759	0.9421	0.9002	0.8569	0.7989	0.7431	0.6929	0.6448	0.6141	0.5968	0.5813	0.5126

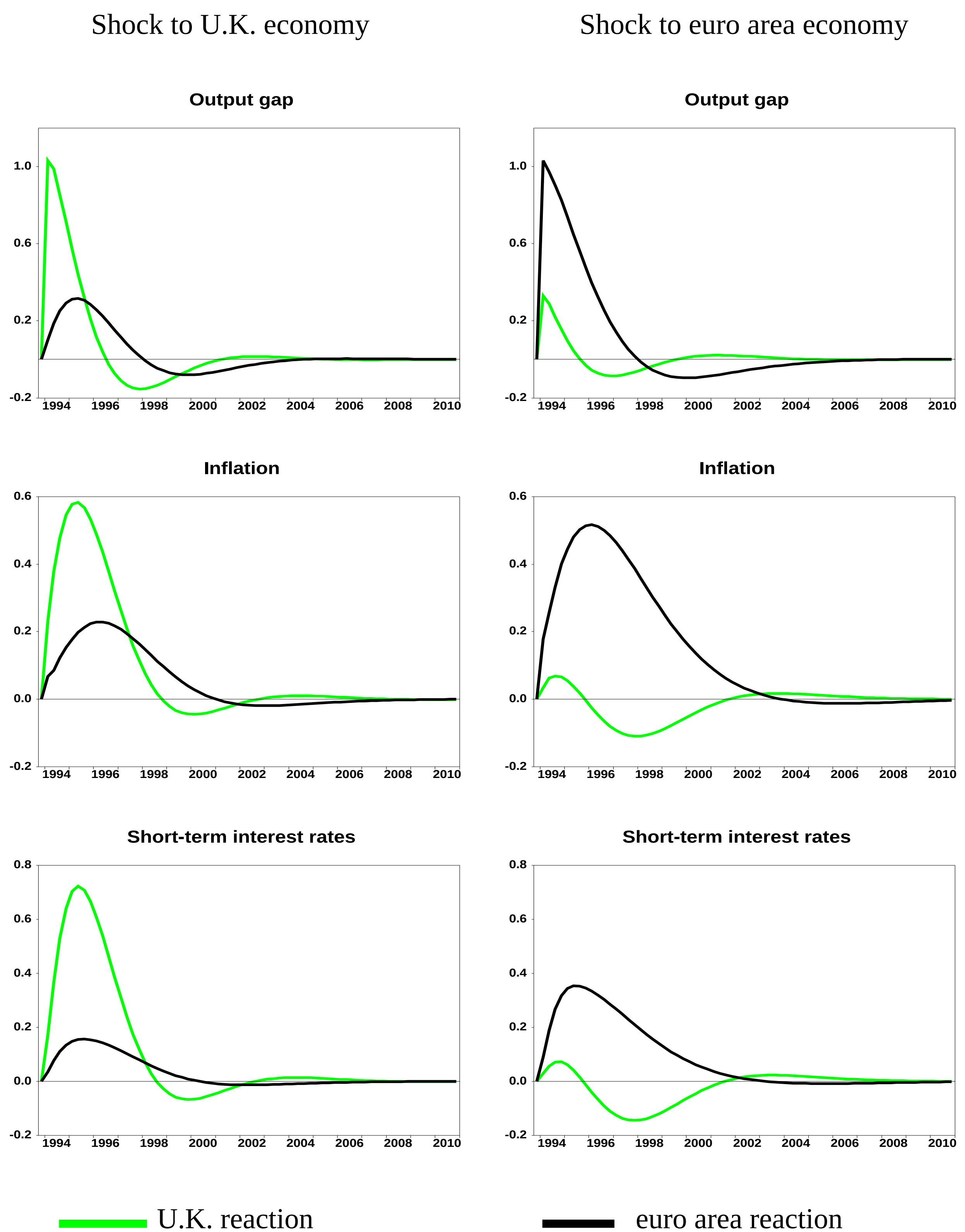
a. Use the RMSE of an AR model instead of the RMSE of a naïve model.
b. As in Clements and Hendry (1998).

Appendix F: Model Shocks

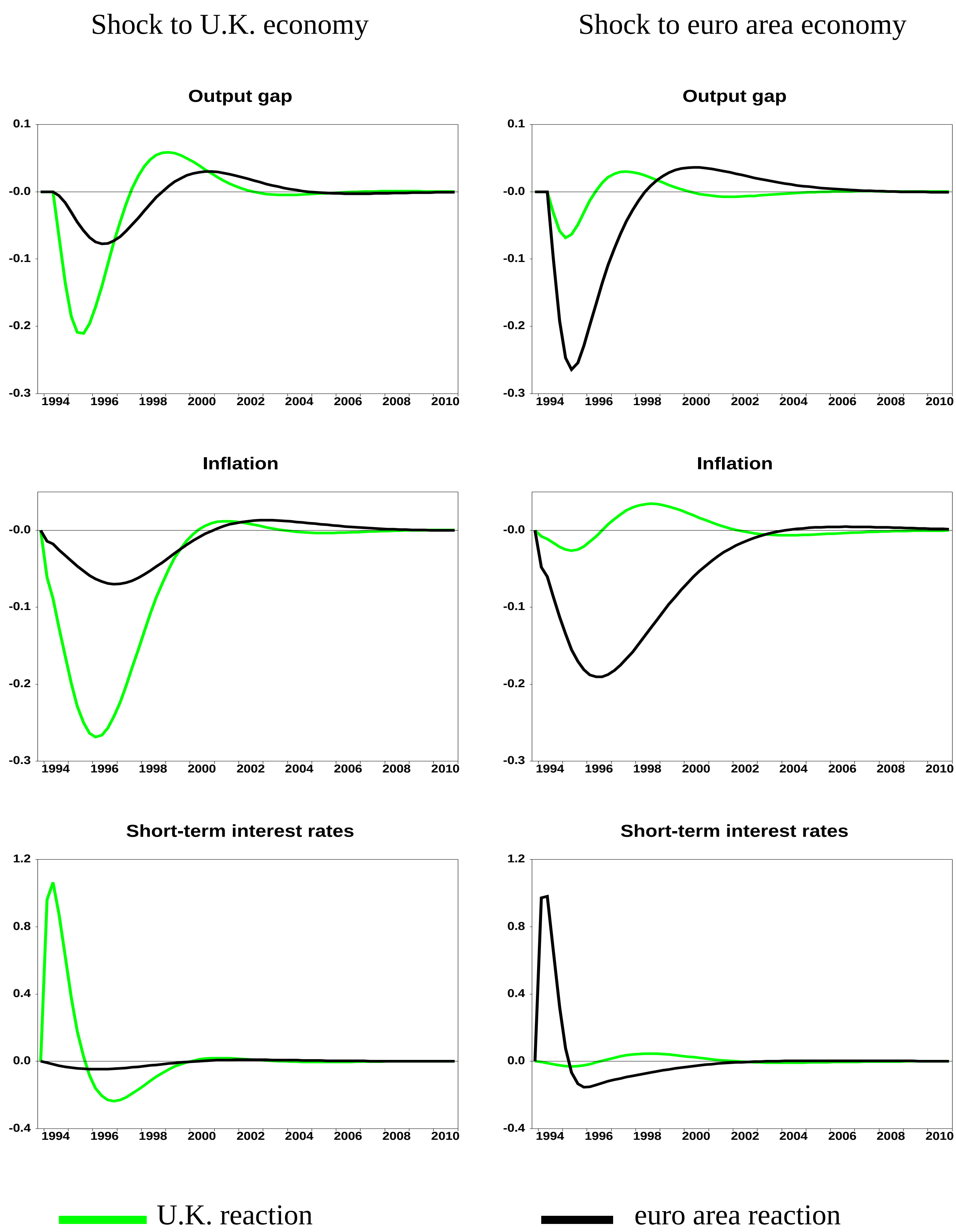
Table F1: Shocks' details

Shock	Description	Details
1. Domestic demand	A 1-quarter transitory increase in the levels of consumption and investment at the same time.	Shock to consumption and investment: Q1: 1.00 per cent; i.e., the levels of consumption and investment increase by 1 per cent at the 1-quarter horizon.
2. Short-term interest rate	A 1-quarter transitory increase in the short-term interest rate.	Shock to short-term interest rate: Q1: 100 basis points
3. Consumer price inflation	A 1-quarter transitory increase in the level of CPI inflation.	Shock to CPI inflation: Q1: 1.00 percentage point
4. Real effective exchange rate appreciation	A 1-quarter temporary decrease in the risk premium on the exchange rate (an appreciation).	Shock to exchange rate: Q1: 1.00 per cent

Graph F1: Results from a Domestic Demand Shock

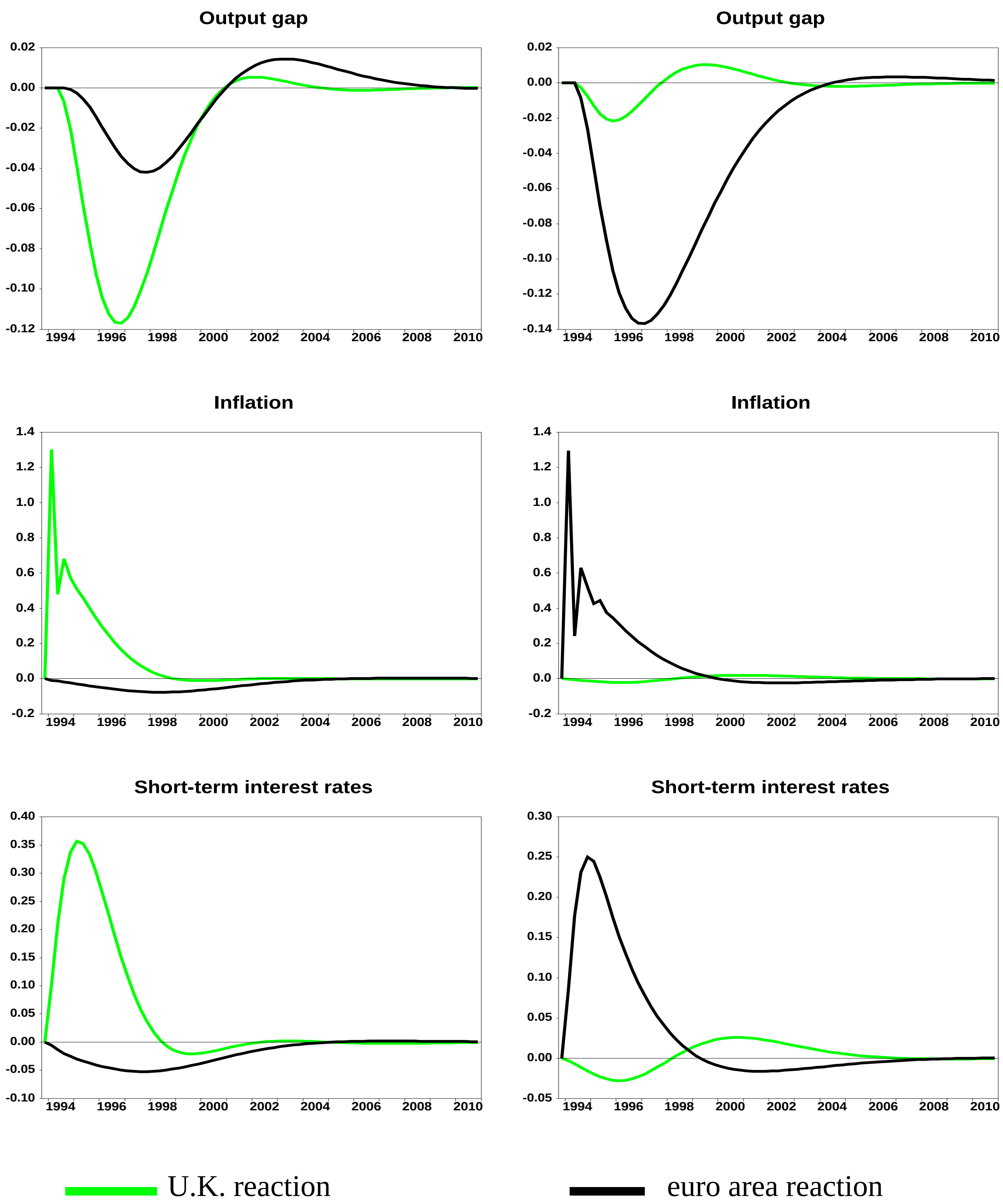


Graph F2: Results from an Interest Rate Shock



Graph F3: Results from an Inflation Shock

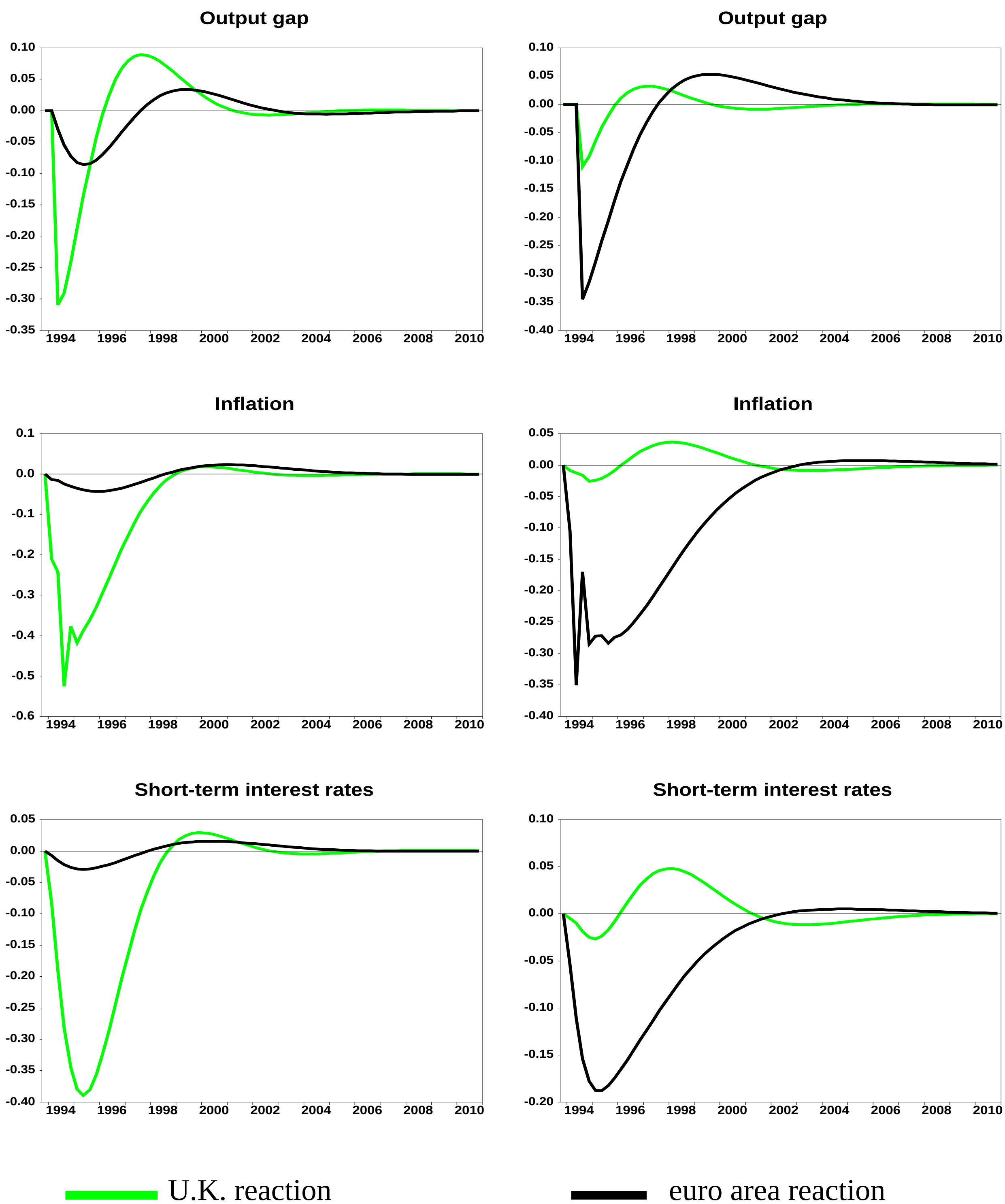
Shock to U.K. economy | Shock to euro area economy



Graph F4: Results from an Exchange Rate Shock

Shock to U.K. economy

Shock to euro area economy



Appendix G: Forecasting Performance of the Model

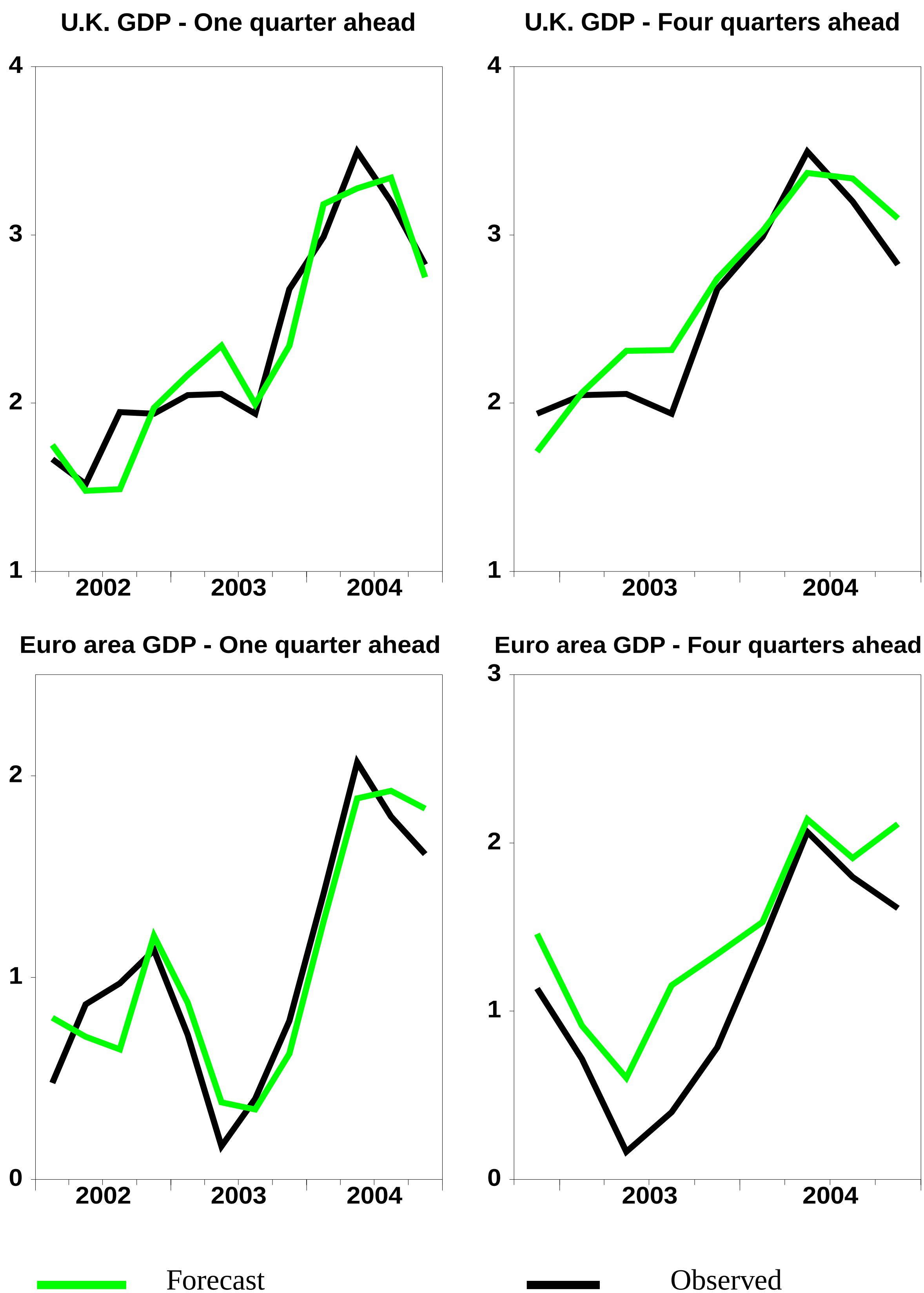


Table G1: Forecasting accuracy - GDP

Indicators	United Kingdom		Euro area	
	1 quarter	**4 quarters**	**1 quarter**	**4 quarters**
RMSE - model	0.213	0.204	0.196	0.178
MAE - model	0.178	0.167	0.408	0.342
RMSE - AR[a]	1.090	0.981	1.119	1.314
MAE - AR	0.906	0.816	0.909	1.102

a. Statistic from an AR model

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