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A macroeconometric model for the Euro economy

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Abstract

In this paper a structural macroeconometric model for the Euro area is presented. In contrast to the multi-country modelling approach, the model relies on aggregate data on the supra-national level. Due to non-stationarity, all equations are estimated in error correction form. The cointegrating relations are derived jointly with the short-run dynamics, avoiding the finite sample bias of the two-step Engle Granger procedure. The validity of the aggregated approach is confirmed by out-of-sample forecasts and several simulation exercises. Several shocks are considered, and their implications for Euro area growth and inflation are examined. In particular, shocks to US growth, the nominal interest rate and the exchange rate of the Euro against the US dollar are discussed.

JEL classification: C3; C5; F01

Keywords: Euro area economy; Macroeconometric models; Policy simulation

1. Introduction

In this paper we build an aggregate macroeconometric model for the Euro area economy as a whole instead of linking similar national models. The growing integration in Europe manifested in the European Monetary Union (EMU) points to a treatment of the Euro area as a single economy. As a consequence output, employment, consumption, investment and so on are explained on the Euro area wide level. They do not result by summing up the outcomes of country specific models.

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The Euro area modelling approach is important for several reasons. Since the introduction of the EMU in 1999, monetary policy has been conducted on the supra-national level, and this enforces a better understanding of the mechanisms of the Euro economy. In addition the interactions between the major poles in the world economy – the US, Europe and Japan – can be modelled more easily. This is also true for developments affecting the region as a whole, for example, the impact of an eastern enlargement of the European Union. Moreover, it may be argued that area wide functions outperform the national ones under several statistical criteria due to an aggregation effect; see Fagan and Henry (1998) in the case of money demand. As a drawback, heterogeneity across the Euro area countries is neglected. For example, the effects of fiscal policies can hardly be analysed in such a model. Fiscal policy remains under the control of the national authorities and differs among the member states. Also, an investigation of economic convergence between the regions of the Euro area requires a more disaggregated framework, which has to be built on the linkage of several national models.

Currently a few other structural models aggregated either for the Euro area or the European Union exist; see Henry (1999), Fagan, Henry, and Mestre (2001) and Bagnai and Carlucci (2003). As usual empirical analysis is done within an error correction framework in order to capture the non-stationarity of most variables. In previous work, estimation relies on the two-step procedure suggested by Engle and Granger (1987). In contrast this paper employs more robust regression techniques. As a rule cointegrating relations are estimated jointly with the short-run dynamics in one step; see Stock and Watson (1993). This avoids the well known bias of the two-step procedure arising in finite samples. After the estimation the cointegrating relations are often restricted according to economic theory, provided that the restrictions are supported on empirical grounds.

The model is designed to derive forecasts for Euro area aggregates and, in contrast to the popular view, the resulting forecast errors are often smaller than those from time series alternatives. Moreover, the dataset used for estimation is published and updated regularly in the *Monthly Bulletin* of the European Central Bank (ECB), which is freely available on the Internet (http://www.ecb.int), so that the model can be used for real time forecasting. Actually, it is exploited to produce most of the forecasts within the European Forecasting Network (http://www.efn.uni-bocconi.int).

The model is also suited as a tool for policy and shock analysis. To illustrate this feature, we present the results of three simulation exercises that are particularly relevant in the current economic context. First, we evaluate the effects of a slowdown in the US economy. In particular, we assume a drop of 0.5 percentage points in the US GDP growth rate and show that the corresponding decline in the Euro area is about 0.15 percentage points, mostly due to lower trade with the US. Because of the linearity of the model, the effects of a positive US shock are just the opposite, and these results can be used, for example, to evaluate the effects of different hypotheses on GDP growth in the US on Euro area growth.

Second, we consider the effects of a change in monetary policy (an increase of 100 basis points in the short-run interest rate). The effects on GDP growth are rather limited, slightly larger than those on inflation. In particular, investment decisions are broadly unaffected. This outcome suggests that the opposite policy, i.e., a more expansionary monetary policy, would not lead to higher growth in the Euro area, and supports the current ECB policy choices.

Finally, we consider the effects of a 10% appreciation of the Euro against the US dollar, another current theme of policy discussions. It turns out that GDP growth in the Euro area will decline by about 0.3 percentage points after 1 year, the largest effect from shocks among those considered here. This finding supports the current concern for a steep appreciation of the Euro. On the other hand, the previous conclusion of limited effects of monetary policy changes by the ECB alone indicates that a coordinated action is required, as often discussed during the G7 meetings.

The paper is organized in six sections. Section 2 reviews the general structure and the theoretical framework, while in Section 3 econometric and data issues are discussed. Section 4 provides estimation details for some equations.[2] In particular equations for factor demand, foreign trade and wages and prices are considered. In Section 5 out-of-sample forecasts are presented, and the forecasting performance of the model is compared to time series alternatives. In Section 6, the simulation exercises are discussed. Finally, Section 7 concludes.

2. Model structure

The underpinning theoretical framework refers to an open economy, where markets are competitive. Agents have been aggregated into the sectors of private households, firms, government and foreign countries. Within each sector individuals are assumed to be homogeneous. The model includes the goods, labor and financial asset markets, and the latter consists of money, bonds and foreign exchange. Private households and firms maximize individual utilities or profits, respectively. Because the model is not designed to evaluate fiscal policies, government is broadly treated as exogeneous. Presently, the behaviour in the foreign countries is also left unexplained. This implies that the domestic evolution does not affect the rest of the world. In reality, given the weight of the Euro area in the world economy, spillovers are expected and would have additional feedbacks. However, empirical evidence for the US suggests that these impacts are small compared to the magnitude of the initial shocks; see Fair (1994).

Table 1 provides a brief overview of the model structure. Most equations are fairly standard; see Romer (1996) for a textbook discussion. On the supply side of the goods market, potential output and factor demand are explained. Potential output stems from Cobb–Douglas production with constant returns to scale, labor and capital as input factors and labor augmenting technological progress.[3] If potential output is realized, both inputs are employed at effective levels. For the capital stock, this is assumed to be the actual level, while for the labor series the effective input is estimated on the grounds of the time varying NAIRU concept; see Gordon (1997). In the sample period, the NAIRU is derived from actual unemployment by means of smoothing techniques. Then, the unemployment gap can be obtained, which is linked to the output gap via an Okun relation. Over the forecasting period, the NAIRU is recovered from this equation. However, the model does not provide a structural interpretation of the evolution of the NAIRU, which can explain the persistence in European unemployment.

Factor demand equations are derived from profit maximization and modelled in a Hicksian way. They depend on the level of output and their own price, which is the real wage for labor and the real interest rate for capital demand. The elasticities match the restrictions of the Cobb–Douglas production function. Labor supply results from an exogeneous population under the assumption of a fixed labor participation rate. Technological progress is modelled simply as a linear time trend, which is consistent with the data; see Jones (1995a, 1995b) for the US experience.

Because of the sluggish adjustment of wages and prices in the real world, the model is demand driven in the short run. Actual GDP is equal to the sum of the demand components. Private consumption depends on disposable income in the long run, according to the stochastic permanent

[2] The whole model has about 65 equations, 30 of them are behavioural. Due to space limitations, we present only a few. However, a detailed model description is available from the authors on request.

[3] In principle other forms of technological progress are equivalent, when a Cobb–Douglas production function is assumed. However, technological progress must be labor augmenting to ensure a steady state in the neoclassical growth model; see Barro and Sala-i-Martin (1995).

Table 1
Stylized model structure

Supply side
$\mathrm{YP} = \mathrm{YP}(K, L, T)$
$L = L(Y, W/P)$
$K = (1-\delta) \times K(-1) + I$
$I = I(Y, \mathrm{IR})$
$U = \mathrm{LF} - L$
$\mathrm{O\_GAP} = (Y - \mathrm{YP})/\mathrm{YP}$
$\mathrm{U\_GAP} = U - \mathrm{UL}$
$\mathrm{U\_GAP} = \mathrm{U\_GAP}(\mathrm{O\_GAP})$
$\mathrm{PRO} = Y/L$
Demand side
$C = C(Y)$
$G = G(Y, U)$
$X = X(\mathrm{WT}, P/(E \times \mathrm{P\_F}))$
$M = M(Y, (P/(E \times \mathrm{P\_F}))$
$Y = C + I + G + X - M$
Wages, prices, interest and exchange rates
$W = W(P, \mathrm{PRO}, \mathrm{U\_GAP})$
$P = P(\mathrm{ULC}, \mathrm{O\_GAP}, \mathrm{PM}, M3)$
$\mathrm{IR} = \mathrm{IN} - \Delta P$
$E = E(\mathrm{IN}, \mathrm{IN\_F}, P, \mathrm{P\_F})$

C: private consumption; *E*: nominal exchange rate; *G*: public consumption; *I*: fixed capital formation; IN (IN_F): domestic (foreign) nominal interest rate; IR: real interest rate; *K*: capital stock; *L*: labor; LF: labor force; *M*: imports; O_GAP: output gap; *P* (P_F): domestic (foreign) price; PM: import price; PRO: labor productivity; *T*: technology; U_GAP: unemployment gap; *U*: unemployment; UL: long term unemployment (NAIRU); ULC: unit labor costs; *W*: nominal wage; WT: world trade; *X*: exports; *Y* (YP): actual (potential) GDP; δ: depreciation rate.

income life-cycle hypothesis; see Campbell and Mankiw (1991). Because disposable income is currently unavailable for the Euro area, consumption is linked to GDP. Government consumption is explained by GDP and the demand for investment in fixed capital is part of the supply block.

In the foreign trade sector exports and imports are modelled separately. Exports depend on the real exchange rate of the Euro and the level of world demand, while imports are explained by domestic demand and the real exchange rate; see Senhadji-Semlali (1998). The level of world demand is proxied by world imports. The latter is explained by weighted GDP in the three major economic regions (US, Japan and Euro area) and a linear time trend capturing the increase in globalization. Due to data availability, foreign trade variables rely on a gross concept and include intra- and extra-area flows. However, in the aggregate, intra-area trade will cancel out.

Disequilibria between supply and demand on the labor and goods market are represented by the unemployment and output gap, respectively. The former is the difference between the actual unemployment rate and the NAIRU, while the latter is the difference between actual and potential GDP, expressed as a percentage of the latter.

The disequilibria are important factors in explaining the short-run adjustments of wages and prices. In the long run, wage behaviour is modelled to ensure the existence of a vertical Phillips curve. Prices are determined as a mark up over unit labor costs, while the money stock serves as a nominal anchor to the system. Most important are the prices for domestic demand and imports. Other indices are explained as a linear combination of these key prices; see Fagan et al. (2001). First degree homogeneity is imposed and can be verified on empirical grounds.

The equilibrium value of the interest rate on the money market is determined by a Taylor rule which gives equal weights to the output and inflation gap; see Taylor (1993). In particular the inflation gap is the difference between actual inflation and a target level, which can be determined by the ECB. The interest rate on the bond market is explained by its correspondence in the foreign countries and by the money market rate. The inclusion of the latter is justified on the grounds of the expectations theory of the term structure; see Campbell and Shiller (1987). Thus, monetary policy has an impact on the long term nominal interest rate.

The nominal exchange rate of the Euro against the US dollar is modelled with respect to international parity conditions (PPP and UIP) in the long run, while the Euro rate against the Yen is explained conditional to the former. Due to the monetary policy behaviour, UIP is more easily fulfilled for the long term interest rates (McCallum, 1994). Given the path of the consumer prices in the foreign countries, bilateral real exchange rates are computed and utilized to explain the real effective exchange rate of the Euro.

3. Econometric methods and database

The model is built as a simultaneous equation system, where the equations are estimated separately by IV. A system estimator is not expected to be superior: if only one relation does not fit the data with sufficient accuracy, the error will spread over the other equations as well. In order to avoid spillovers the single equation analysis is preferred. However, instrumental variables are required. Otherwise estimators are inconsistent due to the presence of the endogenous right hand variables. Thus, after the OLS estimation a static simulation of the whole model is performed and one-step forecasts of the endogeneous variables are generated. The forecasts are used as instruments replacing the original series, whenever endogenous regressors occur. This procedure ensures the consistency of the estimators.

Due to the non-stationarity of most variables, all equations are estimated in error correction form. As a rule the long-run relationships are estimated jointly with the short-run dynamics as suggested by Stock and Watson (1993). This avoids the well known finite sample bias arising in the two-step procedure of Engle and Granger (1987). Moreover, the estimators are more robust even in the case of structural breaks, which is relevant for forecasting; see Kremers, Ericsson, and Dolado (1992). For the test of cointegration, the critical values of Banerjee, Dolado, and Mestre (1998) are appropriate. They depend on the deterministic part of the data generating process and on the number of variables in the cointegrating relationship. In the presence of a structural break, the number of variables has to be extended by 1, due to the low power of the standard unit root and cointegration tests; see Perron (1989) and Hassler (2001).

The ECB provides some reconstructed Euro area data for a period back to 1970; see Fagan et al. (2001). Although there were important predecessors of the EMU like the European Monetary System, a supra-national monetary policy was conducted only recently, and data from the 1970s do not match the institutional criteria. Also series prior to 1991 do not reflect the ESA95 conventions, as they correspond to an older system of national accounts. Moreover, the entire region has changed: series for the unified Germany are available since 1991, and before this period variables refer only to the western part. Given the weight of the German economy in the EMU – which is nearly 1/3 of overall GDP – the shift will appear in the European series as well. Hence, the period starting in 1970 is dominated by structural breaks arising from various sources.

Table 2
Factor demand equations

(A) Labor

$$\Delta \log(\mathrm{EMP}) = -\underset{(17.19)}{0.004} + \Delta \log(\mathrm{YT}) - \underset{(6.23)}{0.067} \times \mathrm{EC1}(-1) - \underset{(6.69)}{0.194} \times \mathrm{EC2}(-4)$$

$\mathrm{EC1} = \log(\mathrm{EMP}) - \log(\mathrm{EMPP})$

$\mathrm{EC2} = \log(\mathrm{EMP}) - \log(\mathrm{EMT})$

$\mathrm{EMPP} = \exp((\log(Y) - 0.399 - 0.003 \times T - (1 - 0.6) \times \log(\mathrm{CS}))/0.6)$

$\mathrm{EMT} = \mathrm{LF} \times (1 - \mathrm{UL})$

$R2 = 0.92$, DW = 1.95

$Q(6) = 5.13$, WHITE = 15.68, ARCH(1) = 0.13, JB = 0.21

(B) Capital

$$\log(I/\mathrm{CS}(-1)) = -\underset{(3.05)}{0.458} + \underset{(4.24)}{0.493} \times \log(I(-1)/\mathrm{CS}(-2)) + \underset{(3.79)}{0.392} \times \log(I(-2)/\mathrm{CS}(-3)) + \underset{(4.97)}{1.877} \times \Delta \log(Y) + \underset{(3.20)}{0.006} \times \mathrm{O\_GAP}(-1) - \underset{(4.23)}{1.071} \times \Delta(\mathrm{ULCR}) - \underset{(2.38)}{0.002} \times \mathrm{EC}(-3)$$

$\mathrm{EC} = \log(\mathrm{CS}) - \log(\mathrm{YT}) + \log(\mathrm{UCC})$

$R2 = 0.98$, DW = 1.88

$Q(6) = 6.34$, WHITE = 21.66, ARCH(1) = 2.75, JB = 4.52

CS: capital stock; EMP: number of employees; EMPP: potential employees (level consistent with the Cobb–Douglas production); EMT: long term employees (level consistent with the NAIRU); *I*: fixed capital formation; LF: labor force; O_GAP: output gap; UCCR: real user costs of capital; UL: long term unemployment (NAIRU); *T*: technology (time trend); *Y* (YT): actual (potential) GDP. The symbol 'Δ' denotes the first difference operator and numbers in parentheses are *t*-statistics in absolute value. *R*2 is the adjusted *R*-square and DW the Durbin Watson statistic. *Q* is the Portmanteau statistic for autocorrelation, WHITE and ARCH are tests for heteroscedasticity and JB is the Jarque Bera test for normality of the residuals.

To avoid these breaks, we employ a much shorter sample based on quarterly data from January 1991 to March 2003. The region corresponds to the current Euro area countries.[4] Data sources are the *Monthly Bulletin* published by the ECB and the Statistical Office for the EMU (Eurostat). All data are seasonally adjusted (Census X12).

4. Key empirical relations

According to the national accounting system the income shares of labor and capital are approximately 0.6 and 0.4. Under the assumptions of constant returns to scale and perfect competition the shares are equal to the elasticities of output with respect to inputs and restrict the evaluation of the Cobb–Douglas production function. In fact, only the deterministic part of the technology has to be estimated. As a result the growth rate of total factor productivity is about 1.3% at the annual base. Potential output is generated by taking expectations, utilizing effective labor and capital inputs. The capital stock is determined in a recursive way where a depreciation rate of 5% per annum is assumed. Effective labor input depends on the NAIRU, which is estimated by a bandpass filter applied to the actual unemployment rate.

The Cobb–Douglas approach is justified for several reasons. Most important, empirical factor demand equations can be shown to be broadly consistent with the specification. According to the first order conditions, marginal products of the input factors are equal to their real price in the long run. This property is embedded in the error correction term in the capital demand equation; see

[4] The EMU member countries are Germany, France, Italy, Netherlands, Belgium, Luxembourg, Finland, Ireland, Austria, Spain, Portugal and Greece. Currently a few variables like the labor index are only available for a subgroup of countries, most excluding Greece.

Table 3
Foreign trade relations

(A) Exports

$$\Delta \log(X) = \underset{(4.45)}{0.575} \times \Delta \log(\mathrm{WT}) + \underset{(2.06)}{0.288} \times \Delta \log(\mathrm{WT}(-1)) - \underset{(1.89)}{0.090} \times \Delta \log(\mathrm{EER}(-3)) - \underset{(2.37)}{0.214} \times \Delta \log(X(-2)) - \underset{(3.97)}{0.264} \times \log(X(-1)) + \underset{(3.97)}{0.222} \times \log(\mathrm{WT}(-1)) - \underset{(4.87)}{0.098} \times \log(\mathrm{EER}(-1)$$

$R2 = 0.75$, DW = 1.82

$Q(6) = 4.43$, WHITE = 16.55, ARCH(1) = 0.15, JB = 0.40

(B) Imports

$$\Delta \log(M) = -\underset{(4.33)}{4.173} + \underset{(23.39)}{2.596} \times \Delta \log(\mathrm{FDD}) + \underset{(2.95)}{0.355} \times \log(\mathrm{CAP}(-1)) - \underset{(2.17)}{0.056} \times \Delta \log(\mathrm{EER}(-5)) - \underset{(4.34)}{0.453} \times \log(M(-1)) + \underset{(4.33)}{0.919} \times \log(\mathrm{FDD}(-1)) + \underset{(2.70)}{0.043} \times \log(\mathrm{EER}(-1))$$

$R2 = 0.93$, DW = 1.97

$Q(6) = 3.94$, WHITE = 13.49, ARCH(1) = 0.70, JB = 1.79

CAP: capacity utilization rate; EER: real effective exchange rate of the Euro, measured at consumer prices; FDD: final demand for domestic goods; *M*: imports of goods and services; WT: world trade; *X*: exports of goods and services. The symbol 'Δ' denotes the first difference operator and numbers in parentheses are *t*-statistics in absolute value. *R*2 is the adjusted *R*-square and DW the Durbin Watson statistic. *Q* is the Portmanteau statistic for autocorrelation, WHITE and ARCH are tests for heteroscedasticity and JB is the Jarque Bera test for normality of the residuals.

Table 2. In the labor demand equation, however, the error correction mechanism is put differently. In fact, it is splitted into two components. The first one ensures that labor input is consistent with a level implied by the production technology. The other mechanism enforces the variable to be in line with the NAIRU. The equality of labor productivity and the real wage serves as a long-run condition in the wage and price system.

Foreign trade relations are discussed in Table 3. Movements in the indices of international competitiveness are measured by the real effective exchange rate of the Euro against a group of currencies.[5] They are more important for exports than for imports. Due to the implied cointegrating vector, a 1% real appreciation of the Euro will reduce exports by roughly −0.3% in the long run, while imports are expected to rise by 0.1%. In both equations the bulk of the explanation stems from aggregate demand variables reflecting the performance of the world and domestic economy. For example, the long-run elasticities are approximately 0.9 in the export and 2.0 in the import equation, respectively.

Key relations describing the evolution of wages and prices are shown in Table 4, where the results for the harmonized index of consumer prices are reported. In both equations, the restriction of a constant labor share as implied by the Cobb–Douglas production function is embedded as a long-run restriction. This requires that wages move in line with productivity and prices, while prices are determined via unit labor costs.

In addition, the money stock per unit output provides a nominal anchor to the system. Gap variables are important in the short run. Long term unemployment does not have an impact on the wage bargaining process in the Euro area because of insider outsider effects; see, for example, Blanchard and Summers (1988).

[5] The effective exchange rate of the Euro is a weighted average of bilateral Euro exchange rates where weights are based on manufactured goods trade. The real exchange rate is computed by the means of consumer prices.

Table 4
Price and wage system

(A) Wages

$$\Delta \log(W) = \underset{(3.79)}{-0.584} + \underset{(2.44)}{0.351} \times \Delta \log(\mathrm{PPC}) - \underset{(3.26)}{0.427} \times \Delta \log(W(-1)) - \underset{(1.77)}{0.234} \times \mathrm{U\_GAP}(-3) - \underset{(3.83)}{0.290} \times \mathrm{EC}(-1))$$

$\mathrm{EC} = \log(W) - \log(\mathrm{PPC}) - \log(\mathrm{PRO})$

$R2 = 0.55$, DW=1.82

$Q(6) = 7.36$, WHITE = 9.47, ARCH(1) = 0.01, JB = 0.96

(B) Prices (harmonized index of consumer prices)

$$\Delta \log(\mathrm{HICP}) = \underset{(3.06)}{0.001} \times \mathrm{O\_GAP}(-3) + \underset{(5.78)}{0.090} \times \Delta \log(\mathrm{PM}) + \underset{(3.78)}{0.128} \times \Delta \log(\mathrm{PM}(-2)) + \underset{(8.90)}{0.554} \times \Delta \log(\mathrm{HICP}(-3)) - \underset{(3.71)}{0.045} \times \mathrm{EC1}(-4) - \underset{(4.08)}{0.011} \times \mathrm{EC2}(-1) - \underset{(4.33)}{0.005} \times \mathrm{D002}$$

$\mathrm{EC1} = \log(\mathrm{HICP}) - \log(\mathrm{ULC})$, $\mathrm{EC2} = \log(\mathrm{HICP}) - \log(M3Y)$

$R2 = 0.81$, DW = 2.40

$Q(6) = 4.58$, WHITE = 17.06, ARCH(1) = 0.79, JB = 0.06

HICP: harmonized index of consumer prices; O_GAP: output gap; PM: price of imports; PPC: consumer price deflator; PRO: labor productivity; *M3Y*: money stock *M*3 per unit output; U_GAP: unemployment gap; ULC: unit labor costs; *W*: labor cost index. D002 is an impulse dummy for February 2000 (introduction of the Euro), Δ the first difference operator and numbers in parentheses are *t*-statistics in absolute value. *R*2 is the adjusted *R*-square and DW the Durbin Watson statistic. *Q* is the Portmanteau statistic for autocorrelation, WHITE and ARCH are tests for heteroscedasticity and JB is the Jarque Bera test for normality of the residuals.

5. Out-of-sample forecasts

One application of macroeconometric models is to generate forecasts of the endogeneous variables. They also identify the status quo, which is the baseline scenario for simulation. Fig. 1 presents the current forecasts for the year-on-year GDP growth rates. To address the uncertainty around the forecasts, intervals are reported for several confidence levels. They are based on stochastic simulation.

Based on the information up to March 2003, short term forecasts of annual GDP growth are about 0.5% in 2003, 1.5% in 2004 and 2.0% in 2005. Hence, the Euro area gradually recovers from the recent downturn. The point forecasts turned out to be quite accurate especially in the first two

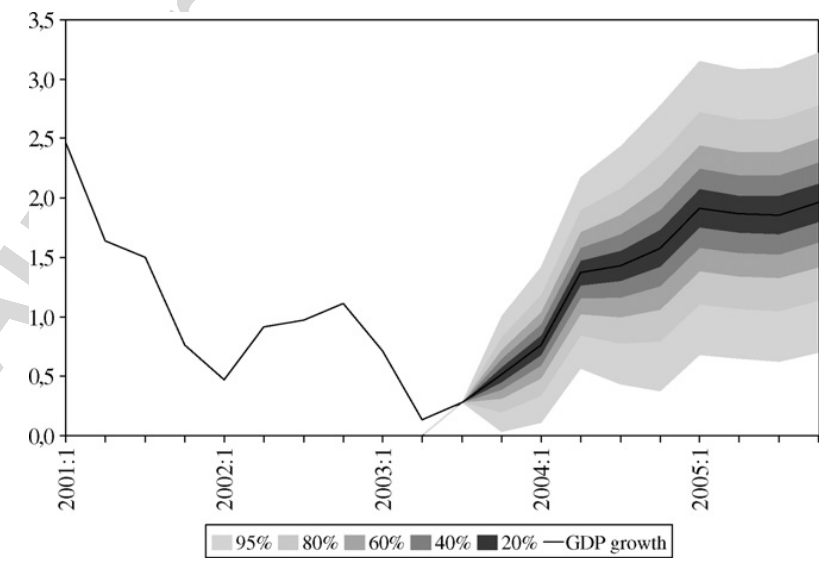

Fig. 1. Year-on-year GDP growth rates. Percentage change over the same period of the previous year.

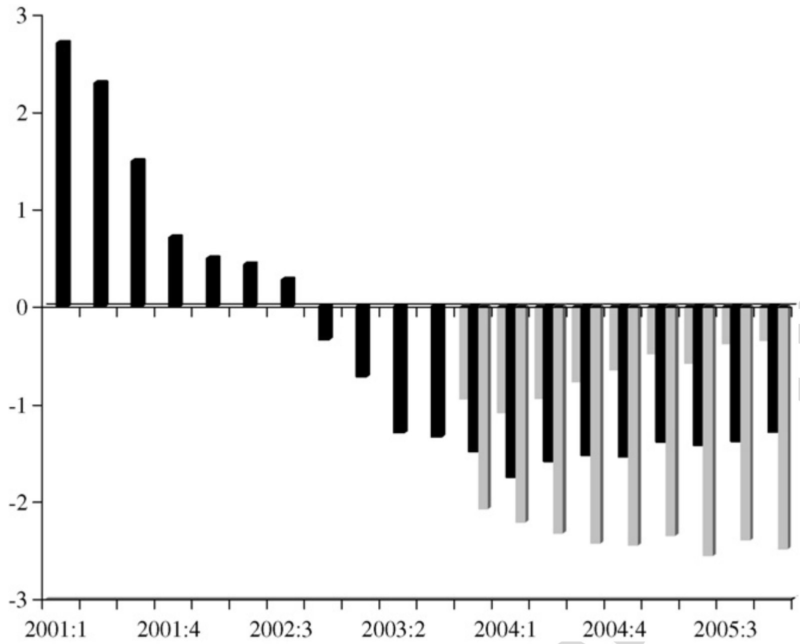

Fig. 2. Development of the output gap. Output gap in percent of potential GDP, 80% confidence intervals.

years, as actual growth was 0.7% in 2003 and 1.8% in 2004. The forecast error is slightly larger in 2005 (actual 1.5%), but not significant. The 80% band around this forecast is approximately ±0.5 percentage points. The interval is rather small, as large structural breaks do not occur in the sample period.

The cyclical evolution of the economy is captured by means of the output gap; see Fig. 2. This measure will narrow slowly from January 2004 onwards, but is still significant and in the range of 1.2% of potential GDP at the end of 2005. At the 80% level of confidence, no inflationary pressure is expected from the demand side over the forecasting period. But, the dampening effect of demand on inflation subsequently disappears.

Due to the implied long-run restrictions in the model, the growth rates will converge to constants in the steady state. Hence, the ratios of consumption and investment to GDP will be roughly unchanged. However, a rising share of the foreign trade variables is expected due to a further increase in globalization, where the current account is on balance in the long run.

The forecasting performance of the model can be evaluated against several alternatives (Table 5). These include ARIMA- and VAR-models for the respective variables, threshold autoregressions (non-linear), leading indicator and dynamic factor models. All candidates were estimated until March 1997 and forecasts for two and four quarters ahead were computed. Then the period was extended by one quarter, and all models were re-estimated. This process was repeated until the end of the sample was reached. For most variables, the macroeconometric model (structural) is able to beat the alternatives at the different forecasting horizons.

The good performance of the structural model is likely caused by its careful econometric specification and, in particular, by the fact that economic theory is used in strict connection with time series techniques to model both the long-run relationships and the short-run dynamics.

6. Simulation exercises

The most prominent application for macroeconometric models is to give policy advice. In order to quantify the implications of certain economic developments, a structural model is required,

Table 5
Out-of-sample forecast comparison

	Y	*C*	*G*	*I*	*X*	*M*	ULC	IS	IL	PY	HICP	*W*	WT	EER	MR
Two-step ahead forecast comparison															
RMSE															
Structural	0.34	0.59	0.23	1.05	1.55	1.82	0.44	0.40	0.41	0.27	0.34	0.47	1.11	2.16	1.47
ARIMA	0.49	0.45	0.58	1.53	2.47	2.17	0.77	0.52	0.63	0.28	0.57	0.41	1.04	4.85	1.54
Non-linear	0.50	0.75	0.26	1.20	2.48	2.34	0.39	0.68	0.76	0.24	NA	0.67	1.28	3.02	2.13
VAR	0.74	0.92	0.55	1.32	2.38	2.33	0.61	1.19	0.66	0.31	1.46	0.66	NA	5.82	1.70
Factor (best)	0.54	0.52	0.30	1.46	2.72	2.26	0.45	0.59	0.61	0.15	NA	0.67	1.65	4.62	1.38
Leading indicators	0.71	0.78	0.49	2.48	3.77	3.96	0.89	3.13	1.34	0.50	0.61	0.81	3.03	7.95	1.81
MAE															
Structural	0.29	0.45	0.20	0.88	1.11	1.35	0.38	0.33	0.36	0.22	0.28	0.42	0.87	1.75	1.01
ARIMA	0.42	0.41	0.51	1.38	2.25	1.80	0.66	0.44	0.55	0.23	0.46	0.36	0.86	4.26	1.16
Non-linear	0.39	0.64	0.20	1.08	1.97	1.81	0.31	0.55	0.65	0.19	NA	0.53	1.10	2.65	1.59
VAR	0.63	0.81	0.46	1.06	2.11	1.85	0.45	0.81	0.56	0.26	1.12	0.58	NA	4.86	1.36
Factor (best)	0.45	0.41	0.24	1.01	2.12	1.96	0.37	0.49	0.52	0.13	NA	0.56	1.52	3.33	1.00
Leading indicators	0.57	0.63	0.38	2.08	3.09	3.21	0.82	2.80	1.23	0.42	0.52	0.68	2.65	6.64	1.36
Four-step ahead forecast comparison															
RMSE															
Structural	0.59	0.83	0.20	1.90	2.39	2.36	0.72	0.55	0.54	0.48	0.64	0.78	2.10	2.64	2.66
ARIMA	1.12	0.68	0.89	2.63	4.17	3.92	1.55	0.99	1.22	0.75	1.01	0.54	2.44	6.33	3.18
Non-linear	1.07	1.26	0.43	2.43	3.85	3.38	0.47	1.34	1.67	0.49	NA	0.88	3.40	6.49	4.00
VAR	1.34	1.79	0.82	3.37	4.03	3.94	1.06	2.65	1.44	0.75	2.66	1.25	NA	6.38	2.91
Factor (best)	0.80	1.00	0.52	2.88	4.18	3.17	0.38	1.17	1.27	0.40	NA	0.59	3.90	4.87	2.29
Leading indicators	1.77	1.13	0.67	2.95	7.68	8.23	1.06	2.23	2.12	0.42	0.88	0.56	6.84	8.47	3.77
MAE															
Structural	0.51	0.78	0.15	1.56	1.85	1.78	0.55	0.47	0.43	0.39	0.49	0.68	1.76	2.06	2.05
ARIMA	0.94	0.53	0.84	2.42	3.83	2.64	1.37	0.79	1.05	0.64	0.84	0.44	1.90	5.36	2.56
Non-linear	0.71	0.87	0.30	1.84	3.04	2.41	0.35	0.87	1.21	0.35	NA	0.63	2.49	5.03	2.80
VAR	1.08	1.64	0.73	2.86	3.40	3.34	0.86	2.09	1.03	0.64	2.14	1.10	NA	5.72	2.40
Factor (best)	0.77	1.04	0.46	2.24	5.52	2.97	0.29	1.33	1.05	0.33	NA	0.46	3.45	4.30	1.86
Leading indicators	1.42	1.00	0.57	2.27	6.63	7.65	0.81	1.82	2.00	0.34	0.76	0.47	5.89	7.30	3.39

Forecast comparison corresponds to a slightly different (older) version of the model. *C*: private consumption; EER: real effective exchange rate of the Euro; *G*: public consumption; HICP: harmonized index of consumer prices; *I*: fixed capital formation; IL (IS): long (short) term nominal interest rate; *M*: imports; MR: real money; PY: GDP deflator; ULC: unit labor costs; *W*: nominal wage; WT: world trade; *X*: exports; *Y*: actual GDP. RMSE: root mean square error; MAE: mean absolute error. Alternative forecasting methods are discussed in detail in the Spring 2002 report of the European Forecasting Network (EFN), which is available from the EFN website (http://www.efn.uni-bocconi.it).

while pure time series alternatives are not appropriate. Therefore, as anticipated in Section 1, we now consider the effects of different shocks on the Euro area economy.

Three different exercises are provided. First, a slowdown of the US economy is investigated. In particular, the US GDP growth rate is assumed to drop about 0.5 percentage points in the first year of the simulation period. Next, a rise of the Euro area nominal interest rate of 100 base points is discussed. Finally, the Euro will appreciate by 10% against the US dollar. The interest and exchange rate shocks are permanent. The US growth shock is temporary for the growth rate, but permanent in the level of GDP. The impacts of these shocks on Euro area GDP growth and inflation are presented in Fig. 3. Results are derived by simulation. Here, the baseline is compared to an alternative, which is identified by each of the specific shocks outlined above.

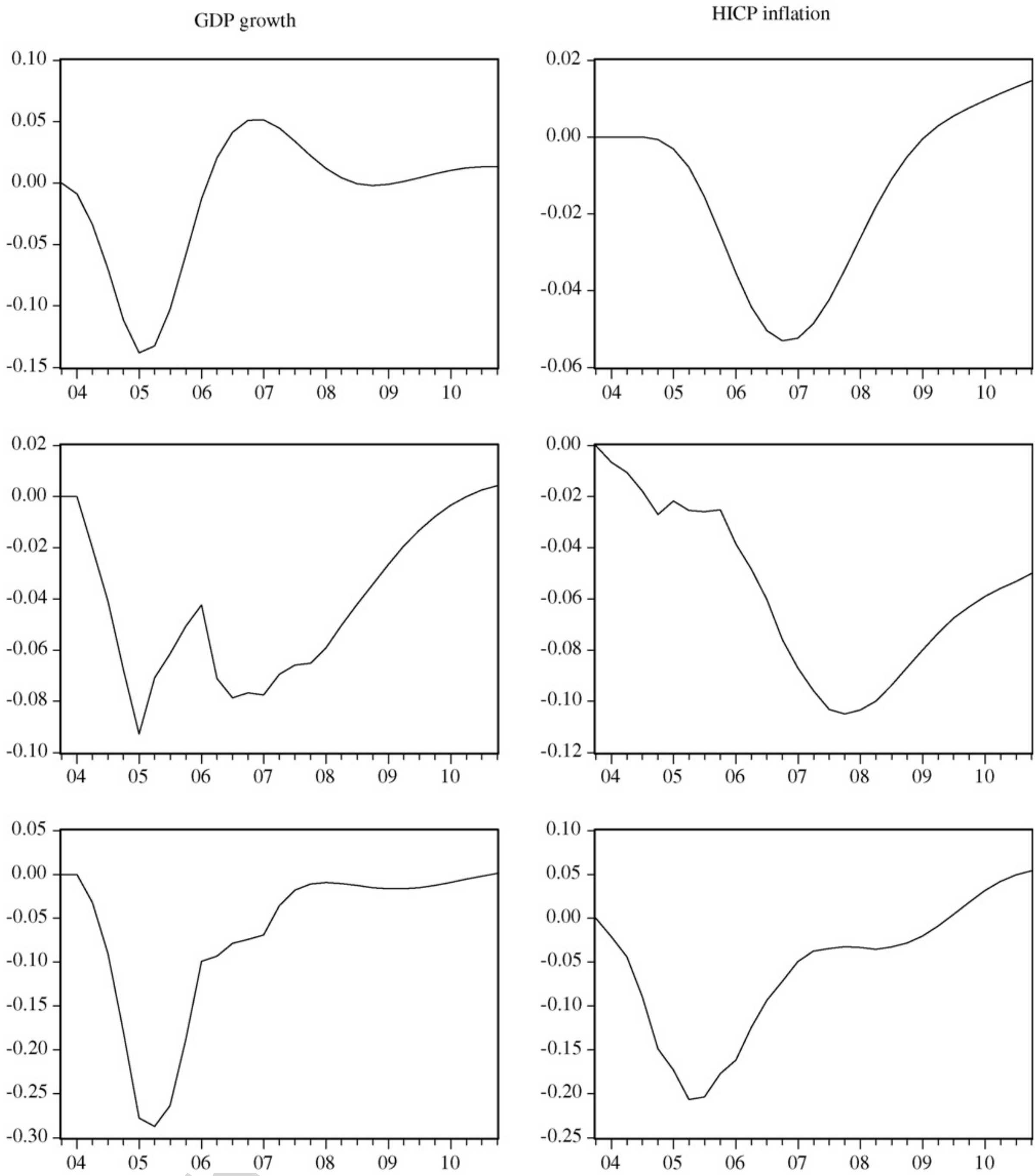

Fig. 3. GDP growth and HICP inflation responses to various shocks. *Upper panel*: US growth shock; *middle panel*: interest rate shock; *lower panel*: exchange rate shock; figure shows differences to the baseline.

A temporary slowdown in US growth translates into a negative demand shock in the foreign trade. Hence, GDP growth in the Euro area is lower under the alternative. Maximum deviations from the status quo are 0.15 percentage points of the overall growth rate; see the upper panel in Fig. 3. Due to the short-run dynamics embedded in the model, wages, inflation and interest rates will be lower than in the baseline, thereby supporting some rebound in the medium run. Based on this result, the US slowdown of 2001/2002 cannot fully explain the recent downturn in the Euro area.

The middle panel of Fig. 3 holds the responses of GDP growth and inflation in response to the interest rate shock. As expected, an increase in the interest rate will temporarily reduce GDP growth and inflation. However, the effects seem to be quite limited. In particular, the responses of investment are very low. One interpretation is that actual monetary policy is performed rather optimally. Then, relatively small changes will not have large impacts on the course of the economy.

Finally, the lower panel of the figure shows the reactions to an appreciation of the Euro. Although real income is supported by lowering inflation rates, the overall effect is negative. Due to decreasing exports and increasing imports, Euro area GDP growth will decline by around 0.3 percentage points after 1 year. The effect is rather large, especially when compared to the other shocks.

7. Conclusion

In this paper a structural macroeconometric model for the Euro area is presented. All equations are estimated in error correction form using the one-step procedure suggested by Stock and Watson (1993). Most relations are broadly in line with economic theory and provide a congruent statistical representation for the variables, on the basis of standard specification tests. Also, the validity of the aggregate approach is confirmed by the good forecasting performance and the reasonable and interesting outcome of several simulation exercises.

However, macroeconometric modelling is a continuous process. Hence, the current stage of model building should not be taken as the final version. The availability of Euro area data will improve in the future and therefore a re-specification of some equations will be on the agenda. For example, the actual foreign trade figures include extra- and intra-area flows. A valid specification will rule out the latter series, leading to more realistic export and import shares. Moreover, disposable income should replace GDP in the consumption equation, when the series is reported.

Other improvements are recommended on theoretical grounds. Model consistent expectations should be integrated, which are based on the long-run equilibrium. Such an extension would alleviate the Lucas critique regarding the validity of the policy simulation exercise. Moreover, the framework can be extended by including relations for the US and Japan in order to produce a consistent view of the development of the world economy.

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