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for the Euro economy**

Christian Dreger, Massimiliano Marcellino

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Christian Dreger (Corresponding author)

Institute for Economic Research Halle (IWH), Kleine Märkerstraße 8, 06108 Halle, Germany. Phone: +49-345-7753-854, Fax: +49-345-7753-825, E-Mail: cdr@iwh-halle.de.

Massimiliano Marcellino

Università Bocconi, IGIER, Via Salosco, 5, Milano 20136, Italy. Phone: +02-5836-3327, Fax: +02-5836-3302, E-Mail: massimiliano.marcellino@uni-bocconi.it.

Abstract

In this paper a structural macroeconometric model for the Eurozone is presented. In opposite to the multi country modelling approach, the model relies on aggregate data on the supra-national level. Due to nonstationarity, all equations are estimated in an 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 two simulation exercises. In particular the implications of a lower economic recovery in the US and a shock in the nominal Euro area interest rate are discussed.

1   Introduction

The aim of this paper is to build an aggregate macroeconometric model for the Euro economy as a whole instead of linking similar national models. The growing integration in Europe manifested in the European Monetary Union (EMU) promotes 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.

The Euro area modeling approach is important for several reasons. Since the introduction of the EMU in 1999, monetary policy is 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 easier. This is also true for developments affecting the Eurozone 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 member countries is neglected. For example the effects of fiscal policies can not 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 would require a more disaggregated framework, which has to be build on the linkage of several national models.

Currently a few other structural models aggregated either for the Eurozone 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 frame-

work in order to capture the nonstationarity 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 suited as a tool especially for policy and shock analysis, but is also designed to derive forecasts for Euro area aggregates. In contrast to the popular view, prediction errors are often smaller than those from time series alternatives. Most of the dataset in this study is published and updated regularly in the Monthly Bulletin of the European Central Bank (ECB), which is freely available on the Internet (www.ecb.int). All data correspond to the new European accounting system (ESA95).

The paper is organized in six sections. Section 2 reviews the general structure and the properties of the theoretical framework, while in Section 3 econometric and data issues are discussed. Section 4 provides estimation details for some equations. In particular factor demand equations, foreign trade relations and the wage price nexus are considered. In Section 5 out-of-sample forecasts are carried out, and the forecasting performance of the model is compared to time series alternatives. In section 6, two simulation exercises are discussed, namely a a slower expansion of international trade and a shock in the short term nominal interest rate. Section 7 concludes. Finally estimation and test results for all equations are put together in an appendix, which comes after the main text.

2   Model structure

The underpinning theoretical framework refers to an open economy, where markets are competitive. Agents have been aggregated into the sectors of 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 exogenous. At the present stage the behaviour in the foreign countries is also left unexplained. This implies that the economic performance in Euroland 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 have additional feedbacks on the Eurozone. However empirical evidence for the US suggests that the these impacts are small compared to the magnitude of the initial shocks, see Fair (1994).

Table 1 provides an brief overview of the model. 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 of scale, labor and capital as input factors and labor augmenting technological progress.[1] 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 must be estimated. This is done on the grounds of the time varying NAIRU concept, see Gordon (1997). Because of the persis-

tent effects in the course of European unemployment, the NAIRU is a moving average of the actual unemployment rate and exogeneous. Because of its structural determinants, the NAIRU is better investigated on microeconometric grounds.

Table 1 about here

Factor demand equations are derived from profit maximisation and are 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).

Because of the sluggishment of wage and price adjustment in the real world, the model is demand driven in the short run. Actual output (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 income life-cycle hypothesis, see Campbell and Mankiw (1991). Because disposable income is currently unavailable for the Eurozone, 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.

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[1] 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).

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. This series is explained by weighted GDP in the three major economic regions (US, Japan, Euroland) 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. 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 rate and the capacity utilization rate, respectively. The former is defined as the ratio between the unemployed and the labor force, while the latter is the ratio between actual and potential output and a proxy for the output gap.

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, Henry and Mestre (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 some target level, which can be determined by the ECB. In addition the interest rate fluctuates one to one with inflation. The interest rate on the bond market is explained by its correspon-

dence in the foreign countries and by the money market rate. The inclusion of the latter can be 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 uncovered interest parity, while the rate against the Yen is modelled conditional to the former. Due to policy behavior, UIP is more easier fulfilled for the long term interest rates (McCallum, 1994). Given the path of the consumer prices in the two foreign countries, a real exchange rate can be computed and this is utilized to explain the real effective exchange rate of the Euro.

3   Econometric methods and database

The model is build as a simultaneous equation system, where the equations are estimated separately by OLS. Alternatively, a system estimator is not be superior: if only one relation does not fit the data with sufficient accuracy, the error will spread on to the other equations as well. In order to avoid spillover effects 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, see Tödter (1992).

Due to the nonstationarity of most variables, all equations are estimated in an 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). Also the estimators are more robust even in the case of structural breaks, 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 model is estimated with quarterly and seasonal (Census X11) adjusted data. Alternatively, the ECB provides some artificial data for a long time span back to 1970, see Fagan, Henry and Mestre (2001). However in this study a much shorter sample period is employed. 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 seventies 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. Furthermore the entire region has changed: series for the unified Germany are available since 1991, and before this barrier variables rely on the western part. Given the weight of the German economy in the EMU -which is nearly one third of overall GDP- the shift will appear in the European series as well.

Hence in the longer time period structural breaks arising from various sources are unavoidable. Thus the sample runs from 1991.1 up to 2002.4, leaving 48 observations for

estimation. The model region corresponds to the current EMU member countries.[2] Data sources are the Monthly Bulletin published regularly by the ECB and the Statistical Office for the EMU (Eurostat). Here the series are reported backwards to 1991.

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 traditional assumptions of constant returns of 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 constant growth rate of total factor productivity is about 1.5% at the annual base. Potential output is generated by taken expectations. In the analysis effective labor and capital inputs are utilized. The capital stock is determined in a recursive way where a depreciation rate of 6% per annum is assumed. Effective labor input relies on the time varying NAIRU concept, which is estimated by a bandpass filter applied to the actual unemployment rate.

The Cobb Douglas approach can be justified for several reasons. Most important empirical factor demand equations presented in table 2 are compatible with the specification. According to the first order conditions the marginal products of the input factors are equal to their real cost in the long run. This is captured by the error correction terms. They show the expected sign in both equations and the imposed restrictions are con-

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[2]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.

firmed empirically. However the adjustment to equilibrium is more pronounced in the labor as in the capital demand equation. The residual series are broadly gaussian.

Table 2 about here

Foreign trade relations are evaluated in table 3. Movements in the indices of international competitiveness have a greater impact on exports than on imports, implying a normal reaction of the current account in the long run. The effective real exchange rate of the Euro against a group of currencies (*EER*) is included in both equations.[3] Due to the implied cointegrating vector a 1 percent real appreciation of the Euro will lower exports by roughly -0.3 percent in long run equilibrium, while imports will be raised by 0.06 percent. Moreover some kind of J-curve behavior is implied in the short run, see the import equation. 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 in the import equation, respectively.

Table 3 about here

Key relations describing the evolution of prices and wages are shown in table 4. Prices for domestic goods are determined by the unit labor costs in the long run. This in turn

refers to a constant labor share as implied by the Cobb Douglas production function. In addition the money stock per unit output provides a nominal anchor to the system. Furthermore the capacity utilization has significant temporary impacts.

Table 4 about here

In equilibrium wages are determined solely by the consumer price and the labor productivity level. In the short run, temporary unemployment may have a small regressive impact on the bargaining process. Long term unemployment does not matter at all due to insider outsider effects, see for example Blanchard and Summers (1988).

5   Out-of-sample forecasts

One prominent 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 experiments. In figure 1, point forecasts for GDP growth and its main aggregates over the years are presented.

Figure 1 about here

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[3] 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.

Eventually the growth rates will converge to constants in the long run. In the steady state the ratios of consumption and investment to GDP are roughly unchanged. In addition a rising share of the foreign trade variables can be expected due to a further increase in globilization, and imports and exports will move together at the end of the forecasting horizon. Short term forecasts of real GDP growth are 0.7% in 2003 and 1.7% in 2004. The 80% confidence band around this forecast is approximately of GDP growth is roughly +/- 0.5 percentage points.

The forecasting performance of the structural model is tested against several alternatives. These include ARIMA- and VAR-models for the respective variables, threshold autoregressions (nonlinear), leading indicator and principal components (dynamic factor models). All candidates were estimated until 1997.4 and forecasts for 2 and 4 quarters ahead were computed. Then the period was extended by one quarter, and the models were re-estimated. This was done until the end of the sample was reached. The forecasts are for the growth rates, except for unemployment and interest rates where levels are used. For most variables, the structural model is able to beat the alternatives at the different horizons.

Table 5 about here

6   Standard Simulation Exercises

Given the status quo, two simulation exercises are carried out to get some further insights into the long run model properties. First, in the baseline the US economy grows at

rates of 1.5% in 2002 and 3.5% from 2003 onwards. In the alternative, a weaker expansion of 1 percentage point in 2002 and 2003 is considered. Hence a temporary growth, but a permanent level effect is evaluated. Figure 3 shows the consequences on the Euro GDP growth rate.

Figure 3 about here

A temporary slowdown in US growth translates into a negative demand shock in the foreign trade. Thus GDP growth in the Eurozone is lower under the alternative. Maximum deviations from status quo are roughly 0.2 percentage points of the overall growth rate. In levels, GDP decreases by 5 BN Euro per quarter, and 0.7 Mill people will losse their jobs in the Euro area. As US growth returns to the baseline, a partial recovery may be expected. Since the negative effect is only temporarily, an acceleration of US growth is implied in the alternative.

Next a shock in the interest rate is discussed. Specifically a decrease of 100 basis points in the short term rate is assumed, spanning two years from 2002 on and thereafter the rate goes back to the initial level. The left part of figure 3 reports the responses of real GDP growth, while the impacts on GDP inflation are on the right.

Figure 3 about here

The temporary cut in the interest rate has no long run consequences and in the short run, the stimulating effects on economic performance are not very much pronounced. Real GDP growth accelerates by little more than 0.2 percentage points. Pressures on GDP inflation are also supposed to fall in this range. Stimulating the course of the economy without inflation seems to be difficult for monetary policy in the Eurozone.

7   Conclusion

In this paper a structural macroeconometric model for the Eurozone is developed. The model relies on aggregate data obtained on the supra-national level. All equations are estimated in an error correction form using the one step procedure suggested by Stock and Watson (1993). Most relations are broadly in line with economic theory and can be justified by the means of standard specification tests. Also the validity of the aggregated approach is confirmed by several simulation exercises, which show reasonable outcomes, more or less. Here a slower expansion of the international trade and a shock in the short term nominal interest rate are discussed.

However macroeconometric modelling is a continous process. Therefore 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 so, 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 a more realistic export and import share. Moreover disposable income will replace GDP in the consumption equation, when the series is reported.

Other improvements are recommended on theoretical grounds. Model consistent expectations should be integrated, and this would require a pre-determination of the steady-state, for example according to the neoclassical growth model. The steady state, which is build solely on economic theory will affect the short-run dynamics. Also the framework can be extended by relations for the US and Japan in order to produce a consistent view of the development of the world economy.

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Appendix A: List of Variables

CI	=	Capital Income
CS	=	Capital Stock, 1995 prices
DB	=	Government Debt (percentage to GDP)
DEF	=	Government Deficit (percentage to GDP)
DEP	=	Depreciation Rate, 1.5% per quarter
EEN	=	Effective Exchange Rate of the Euro
EER	=	Real Effective Exchange Rate of the Euro
EMP	=	Employment (including self employment)
EMT	=	Trend Employment
EXP	=	Government Expenditure (percentage of GDP)
FDD	=	Final Demand for domestic goods
GC	=	Government Consumption, 1995 prices
HICP	=	Harmonized Index Consumer Prices, 1995=1
I	=	Gross Fixed Capital Formation
IL	=	Interest Rate, 10 Year Government Bonds
INV	=	Inventory Investment, 1995 prices
IS	=	Interest Rate, 3 Month
LF	=	Labor force
LP	=	Labor participation rate
M	=	Imports of Goods and Services, including intra area trade, 1995 prices
M3	=	Money M3
OIL	=	Oil Price, USD per Barrel
PFDD	=	Deflator Final domestic demand
PGC	=	Deflator Government Consumption, 1995=1
PI	=	Deflator Gross Fixed Capital Formation, 1995=1
PM	=	Deflator Imports, 1995=1
POP	=	Population
PPC	=	Deflator Private Consumption, 1995=1
PRO	=	Labor Productivity
PX	=	Deflator Exports, 1995=1
PY	=	Deflator GDP, 1995=1
PYF	=	Deflator GDP at factor cost, 1995=1

RAW	=	Prices raw materials, USD
REV	=	Government Revenue (percentage of GDP)
RS	=	Short term Real Interest Rate
SCR	=	Social Contributions (percentage of GDP)
SI	=	Stock Market, Eurostoxx 50
SPR	=	Social Payments (percentage of GDP)
SUBR	=	Subsidies (percentage of GDP)
TB	=	Trade Balance
TDR	=	Direct Taxes (percentage of GDP)
TIR	=	Indirect Taxes (percentage of GDP)
U	=	Unemployment rate
USD	=	Exchange Rate US Dollar per Euro
USH	=	Short run Unemployment rate
UT	=	Trend Unemployment Rate
UCC	=	User costs of capital
ULC	=	Unit labor costs
ULT	=	Trend Unit labor costs
UN	=	Unemployment
USD	=	Euro / US-Dollar Exchange rate
WI	=	Wage Income
WN	=	Compensation per Employee
WT	=	World Demand (Imports)
X	=	Exports of Goods and Services, including intra area trade, 1995 prices
Y	=	GDP, 1995 prices
YEN	=	Euro / 100 Yen Exchange Rate
YF	=	GDP, 1995 prices, at factor costs
YT	=	Trend GDP, 1995 prices

X_JP or *X_US* refer to the *X* series obtained for the Japanese or US economy, respectively. Variables *DUM*(XXX) refer to impulse dummies, which are equal to 1 in the XXX quarter and 0 otherwise.

Appendix B: Model equations

Labor Input

Δlog(*EMP*) = -0.108+0.239*Δlog(*Y*)+0.150*Δ(Δlog*Y*(-4))-0.195**EC*(-1)

              (5.58)   (1.96)   (1.91)   (5.51)

EC = log(*EMP*)-log(*Y*)+log(*W/PY*)

R2 = 0.66   DW = 2.07

Q(6) = 6.16   WHITE = 14.70   ARCH(1) = 0.57   JB = 0.46

Capital Input

log(*I/CS*(-1)) = -0.420+0.514*log(*I*(-1)/*CS*(-2))+0.457*log(*I*(-4)/*CS*(-5))

              (3.39)   (4.52)   (3.41)

+1.205*log(*CAP*)+0.314*Δlog(*X*(-2))-0.005**EC*(-1)

  (3.09)   (1.96)   (3.87)

EC = log(*CS*)-log(*Y*)+log(*UCC*)

R2 = 0.98   DW = 1.48

Q(6) = 12.34   WHITE = 19.30   ARCH(1) = 0.22   JB = 1.09

World Trade

Δlog(*WT*) = -0.570+0.004**TIME*+0.819*Δlog(*Y*)+0.158*Δlog(*Y_JP*(-2))

              (5.32)   (5.15)   (2.93)   (1.38)

+0.355*Δlog(*Y_US*)+0.424*Δlog(*Y_US*(-2))+0.340*Δlog(*WT*(-1))-0.371**EC*(-1)

  (1.43)   (1.56)   (4.69)   (5.33)

EC = log(*WT*)-0.5*log(*Y_US*)-0.25*log(*Y*)-0.25*log(*Y_JP*)

R2 = 0.71   DW = 1.62

Q(6) = 4.04   WHITE = 28.67   ARCH(1) = 1.87   JB = 0.45

Private Consumption

Δlog(*PC*) = -0.168+0.894*Δlog(*Y*)-0.245*Δlog(*PC*(-1))+0.206*Δlog(*PC*(-4))

              (4.25)   (5.96)   (2.32)   (1.97)

-0.002*Δ*RS*-0.001*Δ*RS*(-3))-0.296**EC*(-1)

  (2.84)   (1.98)   (4.20)

$EC = \log(PC)\text{-}\log(Y)$

R2 = 0.68　　　　　　DW = 2.06

Q(6) = 4.92　　　　　WHITE = 17.39　　　ARCH(1) = 0.28　　JB = 0.01

Government Consumption

$\Delta\log(GC) = 0.605\text{+}0.368\text{*}\Delta\log(PC(\text{-}5))\text{-}0.409\text{*}\log(CAP(\text{-}1))\text{-}0.163\text{*}\Delta\log(GC(\text{-}3))$

　　　　　　(5.68)　　(4.38)　　　　　　　(4.92)　　　　　　　(3.29)

$\text{-}0.399\text{*}\Delta\log(GC(\text{-}8))\text{-}0.629\text{*}\log(GC(\text{-}1))\text{+}0.408\text{*}\log(Y(\text{-}1))\text{-}0.016\text{*}DUM951$

　(4.85)　　　　　　　　(5.98)　　　　　　　(5.81)　　　　　　(6.77)

R2 = 0.79　　　　　　DW = 1.92

Q(6) = 2.63　　　　　WHITE = 20.65　　　ARCH(1) = 1.52　　JB = 0.51

Inventories

$INV = 1.466\text{+}0.481\text{*}INV(\text{-}1)\text{+}0.266\text{*}\Delta INV(\text{-}2)\text{-}0.302\text{*}INV(\text{-}7))$

　　　　(2.12)　(3.76)　　　　　(1.88)　　　　　(2.39)

R2 = 0.55　　　　　　DW = 1.93

Q(6) = 4.01　　　　　WHITE = 4.11　　　ARCH(1) = 0.02　　JB = 0.39

Exports

$\Delta\log(X) = 0.303\text{*}\Delta\log(WD)\text{-}0.924\text{*}\Delta\log(PX(\text{-}4))$

　　　　　　(2.46)　　　　　　　(3.51)

$\text{-}0.633\text{*}\log(X(\text{-}1))\text{+}0.535\text{*}\log(WD(\text{-}1))\text{-}0.193\text{*}\log(EER(\text{-}1)$

　(6.77)　　　　　　(6.77)　　　　　　(7.02)

R2 = 0.79　　　　　　DW = 2.12

Q(6) = 12.48　　　　WHITE = 9.76　　　ARCH(1) = 0.06　　JB = 4.00

Imports

$\Delta\log(M) = \text{-}4.399\text{+}2.496\text{*}\Delta\log(FDD)\text{+}0.304\text{*}\log(CAP(\text{-}1))\text{-}0.076\text{*}\Delta\log(EER(\text{-}5))$

　　　　　　(3.78)　　(22.06)　　　　　(2.07)　　　　　　　(2.45)

$\text{-}0.467\text{*}\log(M(\text{-}1))\text{+}0.961\text{*}\log(FDD(\text{-}1))\text{+}0.032\text{*}\log(EER(\text{-}1))$

　(3.83)　　　　　　(3.80)　　　　　　　(1.62)

R2 = 0.95　　　　　　DW = 2.18

Q(6) = 2.81   WHITE = 12.72   ARCH(1) = 0.86   JB = 2.68

Wages

$$\Delta\log(W) = -0.982 + 0.658 \ast \Delta\log(PRO) - 0.333 \ast \Delta\log(W(-1)) + 1.115 \ast \Delta\log(PPC(-4))$$
$$\qquad (3.49) \quad (1.60) \qquad\qquad (2.38) \qquad\qquad\qquad (2.53)$$

$$-0.024 \ast \log(USH(-2)) - 0.501 EC(-1))$$
$$\ (1.08) \qquad\qquad\quad (3.01)$$

$EC = \log(W) - \log(PPC) - \log(PRO)$

R2 = 0.49   DW = 1.94

Q(6) = 3.03   WHITE = 23.79   ARCH(1) = 1.24   JB = 7.86*

Social Payments

$$\Delta\log(SP) = 0.556 - 0.177 \ast \Delta\log(UN(-2)) + 0.276 \ast \Delta\log(DEBT)$$
$$\qquad\qquad (5.88) \quad (2.56) \qquad\qquad (5.16)$$

$$-0.447 \ast \log(SP(-1)) + 0.390 \ast \log(WI(-1))) + 0.068 \ast \log(UN(-1))$$
$$\ (4.88) \qquad\qquad (4.37) \qquad\qquad (3.58)$$

R2 = 0.69   DW = 1.73

Q(6) = 5.96   WHITE = 18.93   ARCH(1) = 0.03   JB = 0.93

Final Domestic Demand Deflator

$$\Delta\log(PFDD) = 0.244 \ast \log(CAP(-1)) + 0.156 \ast \Delta\log(PM(-1)) + 0.128 \ast \Delta\log(ULT(-4))$$
$$\qquad\qquad (2.38) \qquad\qquad (3.90) \qquad\qquad\qquad (2.91)$$

$$-0.016 \ast EC1(-4) - 0.047 \ast EC2(-1)$$
$$\ (2.10) \qquad\qquad (2.17)$$

$EC1 = \log(PFDD) - \log(ULT); EC2 = \log(PFDD) - \log(M3Y)$

R2 = 0.61   DW = 1.87

Q(6) = 3.49   WHITE = 20.66   ARCH(1) = 0.98   JB = 0.52

GDP Deflator

$$\Delta\log(PY) = 1.305 \ast \Delta\log(PFDD) - 0.320 \ast \Delta\log(PM) - 0.163 \ast EC(-1)$$
$$\qquad\qquad (116.04) \qquad\qquad (55.02) \qquad\qquad (3.48)$$

$EC = \log(PY) - 1.333 \ast \log(PFDD) + 0.333 \ast \log(PM)$

R2 = 0.99   DW = 2.05

Q(6) = 4.62   WHITE = 27.71*   ARCH(1) = 3.55   JB = 4.31

Private Consumption Deflator

$$\Delta\log(PPC) = 0.002 + 1.024 * \Delta\log(PFDD) - 0.149 * \Delta\log(PM(-1)) - 0.340 * PPC(-1))$$
$$\quad\quad\quad\quad\quad (4.75)\quad (12.78)\quad\quad\quad\quad\quad (5.40)\quad\quad\quad\quad\quad (3.50)$$
$$+ 0.455 * \log(PFDD(-1)) - 0.070 * \log(PM(-1))$$
$$\quad (3.35)\quad\quad\quad\quad\quad\quad (2.60)$$

R2 = 0.88   DW = 1.94

Q(6) = 7.77   WHITE = 17.46   ARCH(1) = 0.11   JB = 1.67

Harmonized Index of Consumer Prices

$$\Delta\log(HICP) = 0.086 * \Delta\log(PM) + 0.558 * \Delta\log(HICP(-4)) - 0.414 * \Delta\log(PPC(-1))$$
$$\quad\quad\quad\quad (2.38)\quad\quad\quad\quad (4.63)\quad\quad\quad\quad\quad\quad (3.74)$$
$$-0.359 * \Delta\log(PPC(-4)) + 0.348 * \Delta\log(PFDD(-4)) - 0.217 * \log(HICP(-1)/PFDD(-1))$$
$$\quad (3.77)\quad\quad\quad\quad\quad\quad (3.17)\quad\quad\quad\quad\quad\quad (4.45)$$

R2 = 0.70   DW = 2.31

Q(6) = 6.48   WHITE = 30.29   ARCH(1) = 0.00   JB = 4.31

Government Consumption Deflator

$$\Delta\log(PGC) = 0.746 * \Delta\log(PFDD) + 0.540 * \Delta\log(PM) - 0.230 * \log(PGC(-4))$$
$$\quad\quad\quad\quad\quad (5.21)\quad\quad\quad\quad\quad (4.15)\quad\quad\quad\quad (2.08)$$
$$-0.175 * \log(PGC(-1)/PFDD(-1))$$
$$\quad (2.22)$$

R2 = 0.42   DW = 1.48

Q(6) = 2.87   WHITE = 9.39   ARCH(1) = 4.76*   JB = 3.83

Investment Deflator

$$\Delta\log(PI) = 1.162 * \Delta\log(PFDD) + 0.202 * \Delta\log(PM) - 0.189 * \Delta\log(PI(-3))$$
$$\quad\quad\quad\quad (7.74)\quad\quad\quad\quad\quad (3.14)\quad\quad\quad\quad (2.00)$$
$$-0.324 * \log(PI(-1)) + 0.187 * \log(PFDD(-1)) + 0.131 * \log(PM(-1))$$
$$\quad (3.01)\quad\quad\quad\quad\quad (2.64)\quad\quad\quad\quad\quad\quad (2.64)$$

R2 = 0.71   DW = 1.51

Q(6) = 4.61   WHITE = 25.78*   ARCH(1) = 0.06   JB = 1.01

Export Deflator

Δlog(*PX*) = -0.002+0.307*Δlog(*PM*)+0.632*Δlog(*PFDD*

                (3.04)   (6.37)   (4.92)

-0.276*log(*PX*(-1))+0.129*log(*PFDD*(-1))-0.120*log(*PM*(-1)

  (3.13)   (3.14)   (2.62)

R2 = 0.84   DW = 1.82

Q(6) = 7.63   WHITE = 21.49   ARCH(1) = 0.06   JB = 0.92

Import Deflator

Δlog(*PM*) = 0.004+0.921*Δlog(*PX*)+0.056*Δlog(*RAW*)-0.466*log(*PM*(-1))

               (3.29)   (7.69)   (6.94)   (4.46)

+0.348*log(*PX*(-1))+0.047*log(*RAW*(-1))

  (4.26)   (4.59)

R2 = 0.90   DW = 2.36

Q(6) = 8.42   WHITE = 8.42   ARCH(1) = 0.58   JB = 4.76

Prices Raw Materials

Δlog(*RAW*) = -0.242+0.114*Δlog(*RAW*(-2))+0.586*Δlog(*OIL_EU*)

                (1.84)   (2.24)   (22.98)

-0.128*log(*RAW*(-1))+0.084*log(*OIL_EU*(-1))

  (1.93)   (2.28)

R2 = 0.94   DW = 1.51

Q(6) = 7.97   WHITE = 10.30   ARCH(1) = 0.00   JB = 2.64

Long term Interest Rate

ΔIL = 0574*ΔIL_US+0.250*ΔIS_US(-1)-0.323*ΔIS

        (5.61)   (2.27)   (3.13)

-0.157**IL*(-1)+0.104**IS_US*(-1)+0.072**IS*(-1)

  (2.45)   (2.20)   (1.98)

R2 = 0.64   DW = 1.65

Q(6) = 2.32   WHITE = 19.05   ARCH(1) = 0.30   JB = 0.79

Effective Exchange Rate of the Euro

$\Delta\log(EEN) = 0.470*\Delta\log(USD)+0.164*\Delta\log(YEN)$

$\qquad\qquad$ (12.55) $\qquad\qquad$ (5.70)

R2 = 0.89   DW = 1.68

Q(6) = 6.59   WHITE = 14.61   ARCH(1) = 0.06   JB = 80.70*

Real Effective Exchange Rate of the Euro

$\Delta\log(EER) = 0.457*\Delta\log(EER\_US)+0.170*\Delta\log(EER\_YEN)$

$\qquad\qquad$ (12.40) $\qquad\qquad\qquad$ (6.00)

R2 = 0.89   DW = 1.67

Q(6) = 4.42   WHITE = 22.65*   ARCH(1) = 0.01   JB = 85.81*

Absolute t-values in parantheses. A * indicates the significance of the respective test statistic at least on the 5% level.

Table 1: Structure of the Euro model

Supply Side

$YP = YP(K, L, T)$	YP = Potential Output, T = Technology
$L = L(Y, W/P)$	L = Labor
$K = (1-\delta)*K(-1)+I$	K = Capital Stock, δ = depreciation rate
$I = I(Y, IR)$	I = Investment
$U = LF-L$	U = Unemployment, LF = Labor force
$CAP = Y/YP$	CAP = Capacity Utilization Rate
$\Lambda = Y/L$	Λ = Labor Productivity

Demand Side

$C = C(Y)$	C = Consumption
$X = X(WD, P/EP^*)$	X = Exports, WD = World Demand
$M = M(Y, P/EP^*)$	M = Imports, P^* = Foreign Price Index
$Y = C+I+G+X-M$	Y = Actual Output (GDP), G = Government

Wages, Prices, Interest and Exchange Rates

$W = W(P, \Lambda, U)$	W=Nominal Wage
$P = P(ULC, CAP, PM, M3)$	P = Price Index, PM = Import Price
$ULC = WIN / Y$	ULC = Unit Labor Costs
$WIN = W*L$	WIN = Compensation to Employees
$IR = IN-\Delta P$	IR ,IN = Real, Nominal Interest Rate
$E = E(IN, IN^*)$	E = Exchange Rate, IN^* = Foreign Interest Rate

Table 2: Factor demand equations

A. *Labor*

$$\Delta\log(EMP) = -0.108+0.239*\Delta\log(Y)+0.150*\Delta(\Delta\log Y(-4))-0.195*EC(-1)$$

(5.58)   (1.96)   (1.91)   (5.51)

$$EC = \log(EMP)-\log(Y)+\log(W/PYF)$$

R2 = 0.66   DW = 2.07

Q(6) = 6.16   WHITE = 14.70   ARCH(1) = 0.57   JB = 0.46

B. *Capital*

$$\log(I/CS(-1)) = -0.420+0.514*\log(I(-1)/CS(-2))+0.457*\log(I(-4)/CS(-5))$$

(3.39)   (4.52)   (3.41)

$$+1.205*\log(CAP)+0.314*\Delta\log(X(-2))-0.005*EC(-1)$$

(3.09)   (1.96)   (3.87)

$$EC = \log(CS)-\log(Y)+\log(UCC)$$

R2 = 0.98   DW = 1.48

Q(6) = 12.34   WHITE = 19.30   ARCH(1) = 0.22   JB = 1.09

EMP = employees in persons, *W/PY* = nominal wage divided by GDP deflator, *Y* = GDP, *I* = investment in fixed capital, *CAP* = capacity utilization rate, *CS* = capital stock, *UCC* = user costs of capital and *EC* = error correction term of the respective equation. Δ is the first difference operator and numbers in parantheses are t-statistics in absolute value. R2 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 3: Foreign trade relations

A. *Exports*

$\Delta\log(X) = 0.303*\Delta\log(WD)-0.924*\Delta\log(PX(-4))$

         (2.46)   (3.51)

$-0.633*\log(X(-1))+0.535*\log(WD(-1))-0.193*\log(EER(-1)$

  (6.77)   (6.77)   (7.02)

R2 = 0.79   DW = 2.12

Q(6) = 12.48   WHITE = 9.76   ARCH(1) = 0.06   JB = 4.00

B. *Imports*

$\Delta\log(M) = -4.399+2.496*\Delta\log(FDD)+0.304*\log(CAP(-1))-0.076*\Delta\log(EER(-5))$

            (3.78)   (22.06)   (2.07)   (2.45)

$-0.467*\log(M(-1))+0.961*\log(FDD(-1))+0.032*\log(EER(-1))$

  (3.83)   (3.80)   (1.62)

R2 = 0.95   DW = 2.18

Q(6) = 2.81   WHITE = 12.72   ARCH(1) = 0.86   JB = 2.68

X = Exports of goods and services, *WD* = World Demand, *EER* = real effective exchange rate of the Euro, consumer prices, *M* = Imports of goods and services, *FDD* = Final demand for domestic goods, *PX* = price of exports. Δ is the first difference operator and numbers in parantheses are t-statistics in absolute value. R2 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 4: Price and wage system

A. *Prices* (*Final Domestic Demand*)

$\Delta\log(PFDD) = 0.244*\log(CAP(-1)) + 0.156*\Delta\log(PM(-1)) + 0.128*\Delta\log(ULT(-4))$

                 (2.38)   (3.90)   (2.91)

$-0.016*EC1(-4) - 0.047*EC2(-1)$

 (2.10)   (2.17)

$EC1 = \log(PFDD) - \log(ULT); \quad EC2 = \log(PFDD) - \log(M3Y)$

R2 = 0.61   DW = 1.87

Q(6) = 3.49   WHITE = 20.66   ARCH(1) = 0.98   JB = 0.52

B. *Wages (Labor Costs)*

$\Delta\log(W) = -0.982 + 0.658*\Delta\log(PRO) - 0.333*\Delta\log(W(-1)) + 1.115*\Delta\log(PPC(-4))$

               (3.49) (1.60)   (2.38)   (2.53)

$-0.024*\log(USH(-2)) - 0.501 EC(-1))$

 (1.08)   (3.01)

$EC = \log(W) - \log(PPC) - \log(PRO)$

R2 = 0.49   DW = 1.94

Q(6) = 3.03   WHITE = 23.79   ARCH(1) = 1.24   JB = 7.86*

PYF = GDP Deflator at factor cost, CAP = capacity utilization rate, $M3Y$ = Money Stock M3 per unit output, ULT = Trend Unit Labor Costs, PM = price of imports. Δ is the first difference operator and numbers in parantheses are t-statistics in absolute value. R2 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 5

2-step ahead forecast comparison

RMSE	Y	PC	GC	I	X	M	INV	U	ULC	IS	IL	PY	HICP	W	WT	EER	EEN	M3R
STRUCTURAL	0.34	0.59	0.23	1.05	1.55	1.82	3.16	1.47E-03	0.44	0.40	0.41	0.27	0.34	0.47	1.11	2.16	2.08	1.47
ARIMA	0.49	0.45	0.58	1.53	2.47	2.17	3.69	2.00E-03	0.77	0.52	0.63	0.28	0.57	0.41	1.04	4.85	5.00	1.54
NON-LINEAR	0.50	0.75	0.26	1.20	2.48	2.34	2.56	6.46E-03	0.39	0.68	0.76	0.24	NA	0.67	1.28	3.02	4.07	2.13
VAR	0.74	0.92	0.55	1.32	2.38	2.33	NA	4.87E-03	0.61	1.19	0.66	0.31	1.46	0.66	NA	5.82	6.08	1.70
FACTOR (Best)	0.54	0.52	0.30	1.46	2.72	2.26	2.65	NA	0.45	0.59	0.61	0.15	NA	0.67	1.65	4.62	4.70	1.38
LEADING INDICATORS	0.71	0.78	0.49	2.48	3.77	3.96	4.46	1.41E-02	0.89	3.13	1.34	0.50	0.61	0.81	3.03	7.95	8.28	1.81

MAE	Y	PC	GC	I	X	M	INV	U	ULC	IS	IL	PY	HICP	W	WT	EER	EEN	M3R
STRUCTURAL	0.29	0.45	0.20	0.88	1.11	1.35	2.72	1.14E-03	0.38	0.33	0.36	0.22	0.28	0.42	0.87	1.75	1.80	1.01
ARIMA	0.42	0.41	0.51	1.38	2.25	1.80	2.93	1.84E-03	0.66	0.44	0.55	0.23	0.46	0.36	0.86	4.26	4.43	1.16
NON-LINEAR	0.39	0.64	0.20	1.08	1.97	1.81	2.12	6.37E-03	0.31	0.55	0.65	0.19	NA	0.53	1.10	2.65	3.27	1.59
VAR	0.63	0.81	0.46	1.06	2.11	1.85	NA	3.91E-03	0.45	0.81	0.56	0.26	1.12	0.58	NA	4.86	4.94	1.36
FACTOR (Best)	0.45	0.41	0.24	1.01	2.12	1.96	2.07	NA	0.37	0.49	0.52	0.13	NA	0.56	1.52	3.33	3.46	1.00
LEADING INDICATORS	0.57	0.63	0.38	2.08	3.09	3.21	3.97	1.09E-02	0.82	2.80	1.23	0.42	0.52	0.68	2.65	6.64	6.82	1.36

4-step ahead forecast comparison

RMSE	Y	PC	GC	I	X	M	INV	U	ULC	IS	IL	PY	HICP	W	WT	EER	EEN	M3R
STRUCTURAL	0.59	0.83	0.20	1.90	2.39	2.36	3.50	2.01E-03	0.72	0.55	0.54	0.48	0.64	0.78	2.10	2.64	2.82	2.66
ARIMA	1.12	0.68	0.89	2.63	4.17	3.92	2.99	4.68E-03	1.55	0.99	1.22	0.75	1.01	0.54	2.44	6.33	6.87	3.18
NON-LINEAR	1.07	1.26	0.43	2.43	3.85	3.38	2.40	1.19E-02	0.47	1.34	1.67	0.49	NA	0.88	3.40	6.49	6.79	4.00
VAR	1.34	1.79	0.82	3.37	4.03	3.94	NA	7.80E-03	1.06	2.65	1.44	0.75	2.66	1.25	NA	6.38	7.03	2.91
FACTOR (Best)	0.80	1.00	0.52	2.88	4.18	3.17	3.37	NA	0.38	1.17	1.27	0.40	NA	0.59	3.90	4.87	5.29	2.29
LEADING INDICATORS	1.77	1.13	0.67	2.95	7.68	8.23	6.14	1.41E-02	1.06	2.23	2.12	0.42	0.88	0.56	6.84	8.47	7.78	3.77

MAE	Y	PC	GC	I	X	M	INV	U	ULC	IS	IL	PY	HICP	W	WT	EER	EEN	M3R
STRUCTURAL	0.51	0.78	0.15	1.56	1.85	1.78	2.99	1.39E-03	0.55	0.47	0.43	0.39	0.49	0.68	1.76	2.06	2.59	2.05
ARIMA	0.94	0.53	0.84	2.42	3.83	2.64	2.46	4.27E-03	1.37	0.79	1.05	0.64	0.84	0.44	1.90	5.36	5.83	2.56
NON-LINEAR	0.71	0.87	0.30	1.84	3.04	2.41	1.60	1.00E-02	0.35	0.87	1.21	0.35	NA	0.63	2.49	5.03	5.24	2.80
VAR	1.08	1.64	0.73	2.86	3.40	3.34	NA	4.90E-03	0.86	2.09	1.03	0.64	2.14	1.10	NA	5.72	6.44	2.40
FACTOR (Best)	0.77	1.04	0.46	2.24	5.52	2.97	3.11	NA	0.29	1.33	1.05	0.33	NA	0.46	3.45	4.30	4.58	1.86
LEADING INDICATORS	1.42	1.00	0.57	2.27	6.63	7.65	5.15	1.25E-02	0.81	1.82	2.00	0.34	0.76	0.47	5.89	7.30	6.60	3.39

RMSE=Root Mean Square Error. MAE=Mean Absolute Error. The alternative forecasting methods considered are discussed in detail in the Spring 2002 report (extended version) of the European Forecasting Network (EFN), which is available from the EFN website (www.efn.uni-bocconi.it). Variables are described in the appendix of this paper.
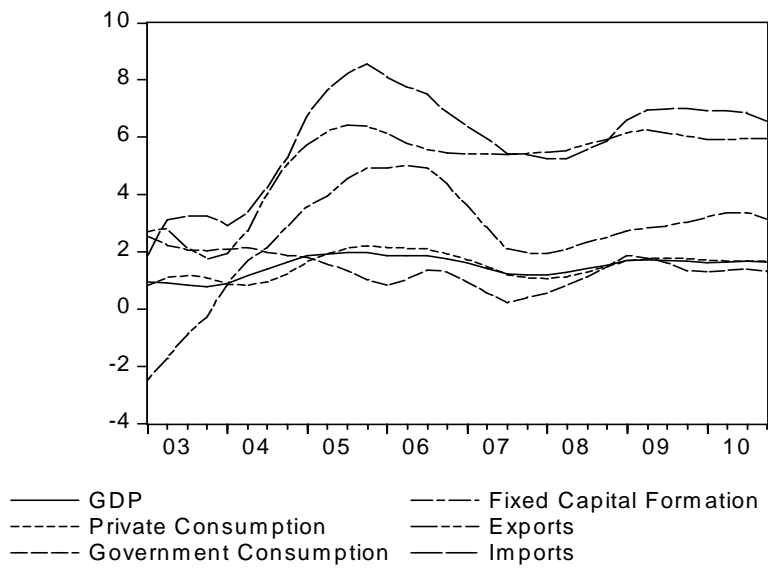
Figure 1: Growth rates of GDP components

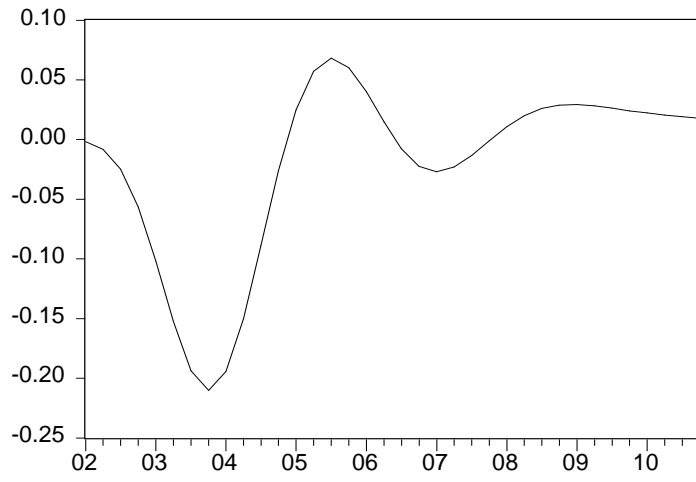Figure 2: GDP growth in response to a US growth shock

Figure 3: GDP growth (left) and inflation (right) in response to an interest rate shock