EUROMON: De Nederlandsche Bank's Multi-Country Model*

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Abstract

The paper presents a guide to the theoretical properties of EUROMON, the Nederlandsche Bank's multi-country model for implementing policy analysis. It is written with a view to expanding Chapter 2 of the Monetary Monograph 19, which provides for a model description. EUROMON is an aggregate neo-Keynsenian model where output is described in the long run by a vertical supply curve, but is strongly affected by demand factors in the short run. At the same time, the model incorporates a wage bargaining framework which makes the long run-supply curve dependent on real factors (for example tax policies).Our future use of the model will require further strengthening of internal theoretical consistencies, including the introduction of forward looking elements. We present five indicative simulations that summarise the properties of the model
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*This paper builds on earlier work done with Silvia Sgherri when she was still at the bank and on work by Peter van Els and Marga Peeters. Views expressed are our own and do not necessarily reflect those of De Nederlandsche Bank.

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1 Introduction

EUROMON is DNB's macroeconometric multi-country model. The model has been developed in the 1990s. EUROMON is used in forecasting, in conducting policy and scenario analyses, and in counterfactual simulation exercises. In the period between 1996 and 1998, EUROMON projections were published biannually in the DNB's Quarterly Bulletin, projections reflecting a combination of model-based and judgmental information. Judgmental sources included available off-model information taken from new releases of cyclical and price indicators or from predictions based on other in-house or outside models. With the start of EMU in 1999 however, DNB has stopped publishing euro-area projections, shifting the emphasis of model uses towards topical policy and scenario analyses. The results of these analyses are regularly reported in the Quarterly Bulletin. While still therefore an important contributor to policy preparation, EUROMON is currently undergoing changes that will make it more suitable to its two main uses, policy analysis and research. The most recent changes done include an overall re-specification and re-estimation of many of the model's equations, partly in view of the advent of EMU but also in order to strengthen the long-run simulation properties of the model. This revision is an ongoing process. The present version of the model builds on the version documented in De Nederlandsche Bank (2000). In this paper we focus on the theoretical properties of the model. Therefore we will not discuss the model in full detail, and refer the reader to the publication mentioned above for further information, but rather concentrate on its main structural features.

The remainder of the paper is organised as follows, Section 2 looks closely at its theoretical properties. In Section 3 we report a few indicative simulation properties of the model. Section 4 concludes by elaborating on the future development of the model in view of the changes in the way we apply it.

2 Theoretical Properties of Euromon

Composition

EUROMON is an estimated multi-country model. The current version includes 13 individual country blocks plus a trade block that provides for international linkages. The 13 countries included are most EMU-participants - Germany, France, Italy, Spain, Netherlands, Belgium, Austria and Finland, the three EU-countries - United Kingdom, Sweden and Denmark, and finally the United States and Japan. The uses of the model (previously but also currently) necessitated an attempt to capture as many country differences as possible, beyond the country size. These are essential in the policy realm because they 1) enhance our understanding of the Euro are as a whole, 2) help us analyse the role of spillovers between the Euro area and the other large countries/regions in the world economy and, 3) provide an understanding of the ways that countries in the Euro area differ and therefore, anticipate the effects of shocks and policies. To this end, we made the following choice : country models share the same basic structure but have distinct values of model parameters and speeds of adjustment. In a few cases slightly different specifications of equations are allowed as well in order to deal with country specific institutional features. The long run properties of the model are for the moment derived only theoretically and we have not examined the long run simulation properties beyond the stability of simulations in the medium run. In terms of theoretical structures, the model is in general terms neo-Keynesian, combining a vertical supply curve in the long-run with an important role for demand factors in what determines output in the short-run. The model encompasses a wage bargaining framework which renders the long-run supply curve dependent on real factors, such as tax policies. EUROMON is an aggregate model, with no further breakdown in sectors or categories of goods and services. Country models consist of 25 behavioural equations and 50 identities[1].

General Features

The current version of the model is backward looking in nature. Expectations are thus treated implicitly, through the inclusion of lags (adaptive expectations). The rationale behind this choice was that the model was originally built to help provide short term forecasts for the main macroeconomic variables of the individual countries and the aggregate Euro area. It was important therefore, to consider macroeconomic series that were able to track the history of the variables as closely as possible. Typically, this is best done when considering autoregressive series. With the adoption of the single currency however, the process of macroeconomic forecasting is centralised at the European Central Bank and there is no urgent need to provide alternative macrocenomic forecasts for the Euro area. EUROMON is therefore now freer to help implement policy analysis. To this end, we concentrate more and more on the internal theoretical consistency of the model and less on its ability to provide accurate short-term forecasts. As the model is used more and more for policy simulation analysis we are going to proceed with rational expectations consistent specifications. The latest version of the model discussed here is the result of our first attempt to strengthen its theoretical basis and identify what remains to be done in the future to further enhance its consistency.

Specification

EUROMON has some 1000 equations in total of which 330 are estimated. The model is estimated using quarterly data over a sample period starting (if available) in 1970 up to 1999. We have applied Ordinary Least Squares in most

[1] The model is written in Troll code.

cases, to estimate single equation systems. Detailed information on individual equations and parameters can be found in De Nederlandsche Bank (2000) or by contacting the authors directly for updated information.
The model is constructed with the notion of equilibrium in mind. In other words, representing static economic theory, each equation takes the following form.

$$Y_t = c_o + \sum_{i=1}^{m} c_i X_{i,t}$$

But since the state of variables at any point in time does not necessarily reflect the state of equilibrium, we embed all equilibrium conditions into a dynamic framework and estimate the law of motion towards their equilibrium paths.

$$\Delta Y_t = c - \eta \left(Y_{t-1} - \sum_{i=i}^{m} c_i X_{i,t-1} \right) + a\,(L)\,\Delta Y_{t-1} + \sum_{i=1}^{m} \gamma_i\,(L)\,\Delta X_{i,t-1}$$

Typically therefore, behavioural equations are modelled within an Error Correction framework where the data is allowed to determine the significant timing of the series.

2.1 Aggregate Supply

Summary 1 *Aggregate supply is given by a CES production technology, with capital and labour as inputs. In the long-run output is determined by the supply of labour (largely exogenous), the equilibrium unemployment rate captured by the NAWRU, and technical progress which is measured by the development of total factor productivity. Equations for labour demand and the capital stock (non-residential) are derived from first-order conditions. Labour demand depends on output and real product wages. Non-residential private investment depends on the real user cost of capital and the capital-output ratio, in line with the CES production technology. The dynamics of investment are also affected by short-run changes in total sales and profitability.*

Labour demand and Capital Stock

We assume a CES-production function[2] for the non-government sector:

$$y_{b,t} = Ae^{\eta t + \epsilon_{y,t}} \left((1-\delta) k_{b,t-1}^{-\rho} + \delta l h_{b,t}^{-\rho} \right)^{-\frac{1}{\rho}}, \qquad \rho > -1, \qquad 0 < \delta < 1$$

where

[2] The choice of a CES rather than Cobb-Douglas production function is based on the empirical finding that the real product wage elasticity of labour demand lies between 0 and -1 and may differ between countries.

$Ae^{\eta t+\epsilon_{y,t}}$	=	total factor productivity
y_b	=	business production in real terms, value added at factor costs
k_b	=	business capital stock (excluding dwellings) in real terms
lh_b	=	business employment (in labour hours)
η	=	parameter measuring autonomous rate of technology progress
δ	=	distribution parameter
ρ	=	substitution parameter
t	=	deterministic linear trend
ϵ_y	=	technology shock, also known as the Solow-residual.

The distribution parameter δ measures the degree to which the production technology is labour intensive. Based on conventional terminology, output $y_{b,t}$ can be divided into an 'explained' part $f(k_{b,t-1}, lh_{b,t})$ and an 'unexplained' part $Ae^{\eta t+\epsilon_{y,t}}$, identified with total factor productivity. Under profit maximisation, the marginal products for labour and capital move in line with output and real factor prices. The first order conditions, provide the long-run specification of the relationship for labour demand and capital stock, respectively:

$$\log lh_{b,t} = \beta_l + \log y_{b,t} + \sigma\,(\log wh_{b,t} - \log p_{yb,t}) - (1+\sigma)\,\eta\,t \qquad (2)$$

$$\log k_{b,t-1} = \beta_k + \log y_{b,t} + \sigma\,\log ucc_t - (1+\sigma)\,\eta\,t \qquad (3)$$

with β_l and β_k constants, $\sigma = \frac{-1}{1+\rho}$ and

wh_b	=	non-government wage rate (per hour)
p_{yb}	=	price deflator value added at factor costs (index, 1990=100)
ucc	=	user cost of capital in real terms
t	=	deterministic linear trend.

Hence, in logarithms, the labour-output and capital-output ratios depend linearly on the relative factor costs and a time trend. Investment expenditure adjusts the real capital stock to its 'steady state level' in the long run. The user cost of capital in real terms ucc_t is defined at a quarterly basis as:

$$ucc_t = \frac{1}{800}(r_{l,t} + r_{s,t}) - \frac{1}{400}\dot{p}_{yb,t} + \underline{\kappa}_b + \underline{ucc}_t^{risk} \qquad (4)$$

comprising of a real interest rate, calculated as a weighted average of the long- and short-term interest rate. Further more, we incorporate both the physical capital depreciation rate $\underline{\kappa}_b$, as well as a risk premium[3], defined here as $\underline{ucc}_t^{risk}$.

[3] The risk premium is calibrated to ensure that it equals $(1-\gamma_w)\frac{y_{b,t}}{k_{b,t}} - \frac{1}{800}(r_{l,t} + r_{s,t}) + \frac{1}{400}\dot{p}_{yb,t} - \underline{\kappa}_b$ on average, over the sample period, where γ_w denotes the average wage share over this sample period. This condition corresponds to the marginal productivity condition in the Cobb-Douglas case and therefore serves only as a first approximation of the premium.

We formulate the equation for investment from the way capital stocks evolve, i.e.:

$$k_{b,t} = i_b + (1 - \underline{\kappa}_b)k_{b,t-1} \tag{5}$$

where

k_b	=	business capital stock (excluding dwellings) in real terms
i_b	=	business investment in real terms
$\underline{\kappa}_b$	=	depreciation rate business capital stock.

The estimated dynamic model equations for labour demand and business investment contain the first-order conditions from the optimisation procedure as error-correction terms. Beyond these however, we also include several other factors that have empirically be proven to affect investment in the short run. First, we include lagged changes in investment to allow for persistence in the investment process. Second, we include changes in real sales, s_t, in order to capture possible accelerator effects. Third, changes in the output gap are included to capture potential business cycle effects. Fourth, the existence of any liquidity constraints is taken into account by including a measure of the liquidity position of firms, calculated as changes in the net cash flow deflated by the GDP-price. Last, we include the real change in the interest rate to capture the short run influence of change in the cost of borrowing.
Estimating the labour demand equation provides values for the long-term parameters σ and η, and the substitution parameter ρ. These estimates, denoted $\hat{\sigma}$, $\hat{\eta}$ and $\hat{\rho}$ respectively, are used in calibrating potential output as well as in estimating the business investment equation.

Potential production factors and labour supply

To determine potential output and hence the output gap, we define the stock of potential capital $k^*_{b,t}$ and potential business employment $lh^*_{b,t}$, as follows: First, $k^*_{b,t} = k_{b,t}$ on the grounds that the actual series does not fluctuate much by itself. Potential employment in the non-government sector is calculated on the basis of the NAWRU, the level of unemployment consistent with constant nominal wage inflation[4]. We have applied the technique described in Bolt and van Els (2000) which in itself uses the Elmeskov (1993) method applied at the OECD to construct a time-varying NAWRU. Potential employment is thus calculated as:

$$lh^*_{b,t} = \underline{\psi}_t \, l_{s,t}(1 - \underline{u}^N_t) - \underline{\psi}_t \, \underline{l}_{g,t} \tag{6}$$

where

[4] Torres and Martin (1990) prove that by applying the NAWRU concept in the definition of potential output, there is equilibrium consistency in the labour and goods market.

lh_b^* = potential business employment (in labour hours)
$\underline{\psi}_t$ = annual hours worked per person (in thousands per year)
l_s = total labour force (in persons)
$\underline{u}^N$ = NAWRU; non-accelerating wage rate of unemployment (in %)
$\underline{l}_g$ = government employment (in persons).

As equation 6 demonstrates, a lower (higher) natural rate of unemployment leads to higher (lower) potential business employment, for given labour supply. This reflects the increase in excess demand as the natural rate of unemployment falls. Furthermore, potential employment increases with labour supply, (either in persons ($l_{s,t}$) or more working hours per person $\underline{\psi}_t$). For a constant labour supply, a shift from employment in the government sector to the business sector also increases potential employment in businesses. In the current version of EUROMON labour supply is largely exogenous, and is assumed to grow at a constant rate over time. For specific simulation experiments, labour supply can be made to be influenced by real disposable income and discouraged or encouraged worker effects.

Potential production and output gap

Potential business production is given by

$$\log y_{b,t}^* = -\frac{1}{\hat{\rho}} \log \left((1-\hat{\delta})\ (\tilde{k}_{b,t-1}^*)^{-\hat{\rho}} + \hat{\delta}\ (\tilde{lh}_{b,t}^*)^{-\hat{\rho}} \right) + tfp_t^*, \tag{7}$$

where tfp_t^* is calculated as the HP-trend of the logarithm of actual total factor productivity. The distribution parameter δ is not invariant to units of measurement. To overcome this, we convert the factor inputs to indices, by dividing them by their sample means when measuring potential output and trend total factor productivity. They are denoted $\tilde{k}_{b,t}$ and $\tilde{lh}_{b,t}$. Parameter δ was approximated by the value of the average wage share in total production during the sample period, denoted $\hat{\delta}$. The output gap then equals

$$gap_t = 100\ \left(\log y_{b,t} - \log y_{b,t}^*\right), \tag{8}$$

The gap is used throughout the model as an indicator of cyclical tensions with respect to price determination, capital formation and imports.

2.2 Aggregate Demand

Summary 2 *The three main components of aggregate demand, private consumption, residential and government investment and inventory formation, are determined as follows: Private consumption depends on real disposable household income and real financial and non-financial wealth, with the housing and* *capital stocks measured at market value. The direct substitution effect is captured by the inclusion of the long-term interest rate in the equation. In the short-run private consumption is also affected by changes in the unemployment rate capturing the role of confidence. Residential investment is determined by real disposable household income, and by real long and short-term interest rates. Government investment is largely exogenous or constant in terms of GDP (optional). Inventory formation acts as a buffer for accommodating shocks in the short-run. Following Fair's (1984) approach, the inventory stocks-to-sales ratio returns to equilibrium in the long-run. In the short-run deviations may also be caused by changes in real interest rates.*

Consumption

Private consumption is derived from a standard model of utility optimisation, whereby households optimise their expected discounted household utility:

$$\max E_t \sum_{i=0}^{\infty} \phi U\left(C_{t+i}\right)$$

subject to a wealth accumulation constraint (human and financial). Furthermore, the optimisation procedure satisfies the no-Ponzi game condition such that the present value of consumption is equal to total wealth which is the sum of non human wealth and the present value of the stream of labour income anticipated. ϕ is the discount rate and is inversely proportional to the interest rate.

The presence of disposable income at current prices implies that a proportion of households are "liquidity constrained" in the short to medium run. The remaining households' consumptions however, is determined by both their current but also their longer run wealth position. The inclusion of the interest rate is there to capture the effects of both the initial value of non-financial wealth as well as households' propensity to consume out of their personal disposable income. The inclusion of the long-term interest rate in the equation captures the direct substitution effect between consumption and savings.

Beyond the theoretical description above there are also a number of variables that enter in the dynamic part of consumption. Changes in unemployment capture a confidence factor and is on the whole an important determinant of current consumption (consistently negative and very significant). The government financial position is also part of financial wealth in as much as the private sector is its owner. Finally, short term interest rates capture the short run effects on the consumption/savings patterns.

Private consumption is for all EUROMON-countries the main component of GDP. It is influenced by household disposable income and by real financial and non-financial net wealth. Net wealth includes the market value of domestic equity but also the market value of the housing stock. Linear homogeneity in both income and net wealth is such that a 1% increase in both income and wealth leads, *ceteris paribus*, to a 1% increase in real consumption. In the short-run private consumption is also affected by changes in the unemployment rate.

$$\log c_t = \beta_{c1} \log \frac{PDI_t}{p_{c,t}} - (1-\beta_{c1}) \log \frac{NW_{MV,t}}{p_{c,t}} - \beta_{c2}(r_{s,t} - \dot{p}_{c,t}) - \beta_{c3}(r_{l,t} - \dot{p}_{c,t}) \tag{9}$$

where

c	=	private consumption in real terms
PDI	=	personal disposable income
p_c	=	price deflator private consumption (index, 1990=100)
NW_{MV}	=	net financial wealth private sector at market values
r_s	=	nominal short-term interest rate (in %)
r_l	=	nominal long-term interest rate (in %)
$\dot{p}_c$	=	inflation (in %).

Residential Investment

In deciding the general features of the model, we have made the choice to consider residential investment as part of aggregate demand. This choice is based on two reasons, the first being that we do not view investment in housing as part of the productive process, in the sense that they are not inputs the same way machinery might be; and second we consider it to have a direct and significant impact on households' consumption. Government investment is largely exogenous or constant in terms of GDP (optional).
In a similar way to private consumption, housing investment depends on real personal disposable income and the real interest rate. The long-term interest rate captures the cost of housing investment except in the case of the UK where housing investment depends on variable mortgage rates[5]. Hence, for the UK the short-term interest rate is used as an explanatory variable.

$$\log i_{h,t} = \log \frac{PDI_t}{p_{c,t}} + \beta_{ih}\,(r_{l,t} - \dot{p}_{c,t}) \tag{10}$$

where

i_h	=	housing investment in real terms
PDI	=	personal disposable income
p_c	=	price deflator private consumption (index, 1990=100)
r_l	=	nominal long-term interest rate (in %)
$\dot{p}_c$	=	inflation (in %).

The housing stock, that plays a role in determining private sector wealth, accumulates in a similar way to non-residential capital:

$$k_{h,t} = i_h + (1-\kappa_h)\,k_{h,t-1}$$

[5] A specific feature for the UK market.

where

$k_{h,t}$	=	housing stock in real terms
i_h	=	housing investment in real terms
κ_h	=	depreciation rate of housing stock

Inventory formation

Instead of modelling inventory formation as a separate behavioural equation, we adopt Fair's (1984) approach. An equation for total final expenditures, y_{tfe}, which is the sum of total sales (determined by the sum of private consumption, investment, non-wage government spending, plus exports) and the change in inventory stocks, is postulated and estimated. Following Fair (1984) the long-run specification of the relationship for total final expenditures is

$$y_{tfe}, t = \beta_{v1}\ s_t + \beta_{v2}\ \underline{dum}_t\ t\ s_t + \beta_{v3}\ v_{t-1}. \tag{11}$$

where

y_{tfe}	=	total final expenditures in real terms
s	=	sales in real terms
v	=	inventory stock in real terms
$\underline{dum}$	=	dummy equal to 1 from 1980 or 1985 onwards, 0 otherwise
t	=	deterministic linear trend.

Several elements underlie the Fair approach. First, it is assumed that there is some optimal ratio of the inventory stock to total sales. This ratio may be time-dependent to reflect technological changes in inventory management. Second, inventory formation depends on the discrepancy between the desired stock of inventories and the actual stock at the end of the previous period. For this reason the lagged inventory stock enters the equation. Third, it is assumed that due to costs of adjustment there is a tendency to smooth total final expenditures relative to total sales, confirmed by the estimation results. In the short-run fluctuations in inventories may also be caused by changes in real interest rates. Inventory formation then follows from

$$\Delta v_t = y_{tfe,t} - s_t \tag{12}$$

and the inventory stock itself, as the accumulation of the changes in inventory stock, i.e.

$$v_t = v_{t-1} + \Delta v_t \tag{13}$$

Foreign Trade

In defining export and import volumes, we assume that domestic and foreign goods are not perfect substitutes. This implies that the volume of exports will depend on world demand and competitiveness captured by relative export prices (competitors' export prices relative to domestic export prices). Similarly, imports depend on final demand captured by total sales and the output prices of foreign competitors relative to domestic prices.

The long-run relationship for exports of goods and services is therefore specified as follows:

$$\log x_t = \log m_t^w + \beta_x \log \frac{p_{x,t}}{p_{x,t}^w} \tag{14}$$

where

x	=	exports of goods and services in real terms
m^w	=	relevant world trade (index, 1990=100)
p_x	=	price deflator exports of goods and services (index, 1990=100)
p_x^w	=	foreign export price (index, 1990=100).

Real imports of goods and services change as sales and relative import prices vary:

$$\log m_t = \log s_t + \beta_m \log \frac{p_{m,t}}{p_{y,t}} \tag{15}$$

where

m	=	imports of goods and services in real terms
s	=	sales in real terms
p_m	=	price deflator imports of goods and services (index, 1990=100)
p_y	=	price deflator gross domestic product (index, 1990=100).

The long run sales elasticity is assumed to be 1. In the short run imports are also affected by the cyclical stance of the economy, as measured by movements in the output gap and changes in inventory formation relative to sales. Price elasticities of exports are typically smaller than 1 and price elasticities of imports are fairly low across EU-countries.

2.3 Prices and Costs

Summary 3 *The private consumption deflator is the main price variable in EUROMON. In the long-run consumer prices depend on unit labour costs, the mark-up and indirect tax rates. Oil prices have a small separate impact, reflecting the direct consumption of oil-related energy by households. Competitors' prices and cyclical indicators reflect the mark-up of prices over the costs of production. Wage formation reflects a bargaining framework according to which equilibrium wages depend on consumer and producer prices, productivity, the unemployment rate and the rates of income tax and social security premiums. Both static and dynamic homogeneity are imposed to ensure that nominal variables do not affect the equilibrium level of unemployment.*

Export and import prices

As argued by Jeanfils (2000) in an environment of monopolistic competition, domestic exporters can, up to a certain extent, decide the level of prices set. They thus set their export prices in relation to both domestic output prices as well as foreign export prices. Similarly importers allow for both the behaviour of international competitors as well as domestic prices to determine prices, in line with the 'pricing to markets' hypothesis. Export prices are homogeneous in domestic output prices and world export prices, i.e.:

$$\log p_{x,t} = \beta_{px} \ \log p_{x,t}^{w} + (1 - \beta_{px}) \ \log p_{y,t} \tag{16}$$

with

p_x	=	price deflator exports of goods and services (index, 1990=100)
p_x^w	=	weighted export price (index, 1990=100)
p_y	=	GDP deflator (index, 1990=100)

The long-run import price equation is described as follows:

$$\log p_{m,t} = \beta_{pm1} \ \log p_{m,t}^{w} + \beta_{pm2} \ \log \underline{p}_{com,t} + (1 - \beta_{pm1} - \beta_{pm2}) \ \log p_{yb,t} \tag{17}$$

with

p_m	=	price deflator imports of goods and services (index, 1990=100)
p_m^w	=	weighted import price (in national currency, index, 1990=100)
$\underline{p}_{com}$	=	commodity prices including oil (in national currency, index, 1990=100)
e_{DOL}	=	nominal exchange rate, domestic currency per USD
p_{yb}	=	GDP deflator at factor costs (index, 1990=100).

The current version of the model has pricing to markets for imports appearing only as a short-run phenomenon. This implies that in most cases $\beta_{pm1} + \beta_{pm2} = 0$ and domestic prices as well as unit labour costs affect prices only the short-run. We plan to apply this in the long run as well in our future work.

Wages and prices

EUROMON embeds a collective bargaining model of wage and price determination, in which it is possible to derive an expression for the Non-Accelerating Inflation Rate of Unemployment (NAIRU) from the core supply side. This is very similar to the process described in Layard *et al (*1992). Workers are assumed to seek a given real consumption wage that satisfies their aspirations, whereas firms are seeking to achieve a given mark-up over costs. These competing claims may not be consistent. Only when unemployment is at its equilibrium level, are competing claims reconciled and is inflation stable. The long-run wage setting in EUROMON, suppressing for convenience sake the logarithms, is given by:

$$w_b = \kappa p_c + (1 - \kappa) p_{yb} + l p_b - \gamma_{w1} u + \gamma_{w2} \underline{T}. \tag{18}$$

where w_b, p_c, p_{yb}, lp_b, are the non-government wage rate, the consumer expenditures deflator, the GDP deflator at factor cost and average labour productivity, u is the unemployment rate (in levels) and $\underline{\tau}$ is a proxy for the incidence of direct taxation on the wage rate. This equation can be interpreted as the equilibrium level for real consumption wage satisfying workers' aspirations. With respect to pricing behaviour, the consumer expenditures deflator is determined as a mark-up on import and unit labour costs, allowing for long run indirect tax effects ($\underline{\tau}_{ind}$ represents the indirect tax wedge term between consumer and producer prices.):

$$p_c = \gamma_{pc1}\,(w_b - lp_b) + (1 - \gamma_{pc1})p_m + (1 + \underline{\tau}_{ind}). \tag{19}$$

The equation representing the equilibrium level for producer prices reads as follows:

$$p_{yb} = p_c - (1 + \underline{\tau}_{ind}). \tag{20}$$

The level of unemployment which reconciles firms' and unions' real claims can thus be determined by solving for the equilibrium levels of wages and prices. Combining the import price equation and the three equations above yields the following equation for the equilibrium level of unemployment:

$$\overline{u} = \frac{1}{\gamma_{w1}} \left\{ \frac{1 - \gamma_{pc1}}{\gamma_{pc1}} (p_m - p_{yf}) + \kappa\,(1 + \underline{\tau}_{ind}) + \gamma_{w2}\underline{\tau} \right\} \tag{21}$$

There are two distinct advantages in applying this formulation. The first is that the natural rate of unemployment is now a function of the real exchange rate and tax wedge terms. This process endogenises the supply side of the model. The second advantage is that this specification can be re-arranged to solve for an explicit Phillips Curve in which in equilibrium when prices and wages are equal to their anticipated values, the actual level of unemployment is equal to this equilibrium value[6].

2.4 Government Sector

Government revenues

The government sector is treated in some detail. At the revenue-side income taxes, social security premiums, corporate taxes and indirect taxes are all modelled separately. Direct taxes on personal income are the product of an average tax rate and a tax base, consisting of the wage sum and other household income including net transfers received from the government (net of social security contributions paid to the government). Likewise, corporate taxes are the product of

[6] Although the model solves for the NAWRU implicitly, the simulations performed in actual fact make use of the natural rate derived through Elmeskov's procedure as described in the Aggregate Supply section. This is an inconsistency that we plan to amend in our future work on the model.

the corporate tax rate and a tax base which equals cash flow net of depreciation allowances and interest payments by firms. Indirect taxes are linked to private consumption.

Government expenditures

Five expenditure categories are distinguished: wages, non-wage government consumption and investment, transfers, interest payments on government debt, and other expenditures. Government employment is exogenous, whereas government wages move in line with private sector wages. Non-wage government consumption and government investment are either fixed in real terms or move in line with real GDP. Basically, government transfers are a constant fraction of GDP unless unemployment moves. If unemployment rises, transfers increase relative to GDP. Other government expenditures are constant in terms of GDP.

Fiscal solvency

In the current model version fiscal solvency is implemented by targeting the government deficit-to-GDP ratio, using personal income tax rates as instruments. However, in principle expenditure categories could be used as well for stabilising government finances in the long run.

2.5 Monetary and Financial Sector

Summary 4 *The three-month short-term interest rate plays the role of the instrument of monetary policy. Various feedback rules, such as the Taylor-rule, are optional. The monetary and financial sector of the model further consists of behavioural equations for long-term interest rates, broad money (M3), bank loans to the private sector, and equations for exchange rates and equity and house prices. Long-term interest rates depend on short rates and potentially on other variables such as inflation and government financial balances. Various options for modelling long rates may be considered. Money demand is homogenous in income and private sector net financial wealth, and furthermore depends on short and long-term interest rates and inflation. The demand for bank loans in the long-run is determined by the condition that interest payments on bank loans develop in line with nominal income. Note that M3 and bank loans are not fully recursive. Changes in both feed into aggregate demand via the income channel of monetary transmission. This effect is however typically small. Exchange rates may be fixed in real terms, or be determined by uip or by a combination of long-term ppp and short-term uip. Equity prices depend on profitability and interest rates, and real house prices are determined by real disposable income relative to the housing stock, real interest rates and the relative price of residential investment. Equity and house prices affect private consumption via endogenous private sector net wealth measured at market value.*

Short-term interest rates

The main instrument of monetary policy in EUROMON is the three-month short-term interest rate. In the current version of the model it may be treated as an exogenous variable or may follow from a policy instrument feedback rule. Possible rules include fixed real interest rates, strict or flexible inflation targeting (Taylor rule), and money growth targeting. EMU, US, UK and Japan have an independent monetary policy. For the sake of brevity we now only focus on the Taylor rule (ignoring constants):

$$r_{s,t} = \rho r_{s,t-1} + (1-\rho)[\underline{\phi}^{IT}(\dot{p}_{c,t} - \underline{\dot{p}}^{T}) + \underline{\phi}^{gap} gap] \tag{22}$$

where

r_s	=	nominal short-term interest rate (in %)
$\underline{\phi}^{IT}$	=	weight on the inflation target in the interest rate rule
$\dot{p}_c$	=	inflation (in %)
$\underline{\dot{p}}^{T}$	=	inflation target (in %).
$\underline{\phi}^{gap}$	=	weight on output gap in the interest rate rule
gap	=	output gap (in %).
ρ	=	degree of policy smoothing

Although Denmark and Sweden are not EMU members, their policy-controlled interest rate is assumed to follow that of the euro-area.

Long-term interest rates

Long-term interest rates (10 year government bond rate)countries have converged within the European since the beginning of the 1980s. This has been the result of international capital market liberalisation and, for the more recent period, the advent of EMU. Three modelling options are available for the long-term interest rates. The first allows for an empirical explanation from short rates, inflation rates and government financial balances. The second adheres strictly to a backward looking term structure. The third allows for a forward looking term structure relationship.
OPTION 1
With reference to the first approach, the long-term interest rates in Germany (superscript DE), the UK and Japan are assumed to be determined in the long run by their US or German counterparts, the domestic short-term interest rate, the domestic inflation rate and by domestic government financial balances as a percentage of GDP, i.e.

$$r_{l,t} = \beta_{r1}\, r_{l,t}^{US} + \beta_{r2}\, r_{l,t}^{DE} + \beta_{r3}\,(r_{s,t} - \dot{p}_{c,t}) + \beta_{r4}\, \dot{p}_{c,t} + \beta_{r5}\, GFBY_t \tag{23}$$

where

r_l	= nominal long-term interest rate Germany, UK, Japan or US
r_l^{US}	= US nominal long-term interest rate (in %)
r_l^{DE}	= German nominal long-term interest rate (in %)
r_s	= nominal short-term interest rate Germany, UK, Japan or US (in %)
$\dot{p}_c$	= inflation Germany, the UK, Japan or the US (in %)
$GFBY$	= government financial balance ratio (% GDP)

The German long rate is partially explained by the US long rate in the long run, so that $\beta_{r1} \neq 0$ and $\beta_{r2} = 0$. The UK and Japanese long rates are explained by both the German and the US long rate, so $\beta_{r1} \neq 0$ and $\beta_{r2} \neq 0$. The US long rate, however, dominates world capital markets, so that for the US $\beta_{r1} = \beta_{r2} = 0$. Equations for all remaining European countries have been estimated over the sample period covering the last two decades. We attempt to explain each country's long-term interest rate differential with Germany in terms of short-term interest differentials, inflation differentials and differentials in government financial balances as a proportion of national GDP as explanatory factors, i.e.:

$$r_{l,t} - r_{l,t}^{DE} = \beta_{r6}\ (r_{s,t} - \dot{p}_{c,t} - r_{s,t}^{DE} + \dot{p}_{c,t}^{DE}) + \beta_{r7}\ (\dot{p}_{c,t} - \dot{p}_{c,t}^{DE}) + \beta_{r8}\ (GFBY_t - GFBY_t^{DE}) \tag{24}$$

OPTION 2

As a second option, long-term interest rates can be specified as a backward looking term-structure rule. This is specified, like in NiGEM, as

$$\Delta r_{l,t} = 0.8\ \Delta r_{s,t} + 0.2\ \ (r_{s,t-1} - r_{l,t-1} + 0.5)$$

OPTION 3

The long-term interest rate can also be forward looking. In this case the long rate follows the current and future three-month rate over a period of 40 quarters (i.e. 10 years) as a geometric average (see also NIESR (1998)):

$$\log\left(1 + \frac{r_{l,t}}{100}\right) = \frac{1}{40}\sum_{i=0}^{39}\log\left(1 + \frac{r_{s,t+i}}{100}\right). \tag{26}$$

Broad money

This equation is based on a standard model in which the demand for real money holdings depends in the long-run on a measure of output and a vector of returns on various assets $\tilde{R}$, i.e.

$$M^d/P = f(Y, \tilde{R}, \dot{p})$$

Beyond these, inflation enters as the opportunity cost of holding money rather than real assets and allows for explicit testing of long-run price homogeneity of money demand (see Coenen and Vega, 1999 and Fase, 1998). In practice we model the demand for broad money in the long run using the following regressors: 1) real GDP as a measure of the volume of transactions, 2) net financial wealth to reflect the portfolio role for money[7] 3) short - or long-term interest rates and inflation. The specification of the long-run relationship therefore reads:

$$\log \frac{M3_t}{p_{c,t}} = \beta_{M1} \ \log y_t + (1 - \beta_{M1}) \ \log \frac{NW_t}{p_{c,t}} + \beta_{M2} \ r_{s,t} + \beta_{M3} \ r_{l,t} + \beta_{M4} \ \dot{p}_{c,t} \tag{27}$$

where

$M3$	=	broad money
p_c	=	price deflator private consumption (index, 1990=100)
y	=	gross domestic product in real terms
NW	=	net financial wealth private sector
r_s	=	nominal short-term interest rate (in %)
r_l	=	nominal long-term interest rate (in %)
$\dot{p}_c$	=	inflation (in %).

Linear homogeneity is assumed in real GDP and real net financial wealth, implying that as they increase by 1 percent, the real money demand increases also by 1 percent. The short-term interest rate has a positive and significant effect on money demand. This is because money demand is measured in a broad sense which includes short-term savings deposits. An increase (decrease) in the short-term interest rate raises (lowers) the demand for these deposits. Long-term interest rates and inflation, on the contrary, affect money demand negatively. For some countries we also allow for the effect of the output gap in the short run to reflect potential additional cyclical effects on the demand for money (precautionary savings motive).

Bank credit to the private sector

As part of total private sector financial assets, outstanding bank credit to the private sector consists of mortgages, and of corporate and other loans to households and businesses. Credit is assumed to depend on the disposable income of households, the cash flow of firms and the level of interest rates. Here, the long-run relationship is specified as

$$\log CRD_t = \log(PDI_t - OI_t + CF_t - T_{dirb,t}) \tag{28}$$

$$- \log\{\frac{1}{1600}\sum_{i=0}^{3}(\{\underline{\omega}_{CRDB}\underline{\vartheta}_{CRDB} + (1-\underline{\omega}_{CRDB})\underline{\vartheta}_{CRDH}\}r_{l,t-i} + \{\underline{\omega}_{CRDB}(1-\underline{\vartheta}_{CRDB}) + (1-\underline{\omega}_{CRDB})(1-\underline{\vartheta}_{CRDH})\}r_{s,t-i})\} \tag{29}$$

[7] The two are constrained to have a total elasticity of one for the purposes of identifying a good fit.

where

CRD	=	bank credit to private sector
PDI	=	personal disposable income
OI	=	other household income
CF	=	cash flow
T_{dirb}	=	corporate taxes
r_l	=	nominal long-term interest rate (in %)
r_s	=	nominal short-term interest rate (in %)
$\underline{\vartheta}_{CRDB}$	=	share long-term credit in total bank credit to businesses
$\underline{\vartheta}_{CRDH}$	=	share long-term credit in total bank credit to households
$\underline{\omega}_{CRDB}$	=	share businesses in total bank credit to private sector

The assumption underlying this relationship is that total interest payments on credit as a percentage of household and business sector income is constant in the long term. The relevant interest rate is constructed as a weighted average of the long- and short-term interest rates and its long-run elasticity assumed to be -1.

Exchange rates

Different options are available with respect to the exchange rate. We distinguish three options here, those being fixed real exchange rates, a combination of uip and long-run ppp (backward looking), and forward looking uip. The exchange rates of the euro, the pound sterling and the yen vis-á-vis the dollar are accordingly modelled as follows:

Fixed real	$\Delta \log e_{DOL,t} = \Delta \log p_{c,t} - \Delta \log p_{c,t}^{US}$
UIP/PPP	$\log e_{DOL,t} = \beta_{e0} + \beta_{e1} \log e_{DOL,t-1} + (1-\beta_{e1}) \log(p_{c,t}/p_{c,t}^{US}) - (r_{s,t} - r_{s,t}^{US}) + \beta_{e1} (r_{s,t-1} - r_{s,t-1}^{US})$
UIP-forward	$\log e_{DOL,t} = \log e_{DOL,t+1} - \frac{1}{4} \log\left(1 + \frac{r_{s,t}}{100}\right) + \frac{1}{4} \log\left(1 + \frac{r_{s,t}^{US}}{100}\right)$

where

e_{DOL}	= nominal exchange rate, domestic currency per USD
$\dot{p}_c$	= inflation (in %)
$\dot{p}_c^{US}$	= inflation US (in %)
r_s	= nominal short-term interest rate (in %)
r_s^{US}	= nominal short-term interest rate US (in %).

Equity prices

The equity price for each country in EUROMON is explained by a long-run relationship combining the GDP-deflator, the labour income share measured as the share of private sector wages in gross value added of businesses at factor costs, and the nominal long-term interest rate. So,

$$\log p_{eq,t} = \log p_{y,t} + \beta_{eq1}\, lis_t + \beta_{eq2}\, r_{l,t} \tag{30}$$

where

p_{eq}	=	equity price (index, 1990=100)
p_y	=	price deflator gross domestic product (index, 1990=100)
lis	=	business labour income share
r_l	=	nominal long-term interest rate (in %).

The equity price is imposed to be homogeneous in the GDP-deflator $p_{y,t}$, to avoid price level shifts affecting real equity returns in the long run. The labour income share lis_t is assumed to affect the equity price negatively. The higher the labour income share the lower the profitability in the business sector. If profitability decreases, equity prices fall, so $\beta_{eq1} < 0$. The long-term interest rate serves as a proxy for the required yield on equity with a negative impact on equity prices, so $\beta_{eq2} < 0$. Equity prices across EMU-countries and the US have displayed a strikingly similar pattern. For this reason the estimated effects in the long-run relationship have been assumed to be equal across countries by imposing cross-equation restrictions on parameters β_{eq1} and β_{eq2}. Short-term effects and adjustment speeds towards the long-term relationship may however differ across countries.

House prices

The market for houses is characterized by an inelastic supply curve and house prices are mainly influenced by demand factors. A the main determinant of financing opportunities, personal disposable income is the an important determinant of house prices. Furthermore, equity prices are used as a short-run indicator of private wealth and provide an alternative measure of purchasing power. Mortgage opportunities are dependent on both the short-term as well as the long-term interest rates.

On the supply side, there are two important determinants; first, the housing stock which naturally determines house prices and second, the deflator of residential investment which proxies the costs of building new houses and therefore reflects the opportunity cost for the prices of existing houses. In the short-run the unemployment rate serves as a confidence variable.

The long run specification of the real house price is determined by real personal disposable income, real long-term interest rates and the relative construction cost price. It is assumed that all long run variables exhibit a mean reverting behaviour. Personal disposable income is divided by the housing stock, to reflect the assumption that a constant proportion of the income is spent on houses in the long run. Any remaining trends in the data are captured by including a time trend. Apart from a constant, time trend and (seasonal) dummies, the long run house price equation reads as follows:

$$\log(p_{h,t}/p_{c,t}) = \log \frac{PDI_t/p_{c,t}}{k_{h,t-1}} + \beta_{ph1}\ (r_{l,t} - \dot{p}_{c,t}) + \beta_{ph2}\ \log(p_{ih,t}/p_{c,t}) \quad (31)$$

where

p_h	=	house price
p_c	=	price deflator private consumption (index, 1990=100)
p_{ih}	=	price deflator residential investment (index, 1990=100)
k_h	=	housing stock in real terms
PDI	=	personal disposable income
r_l	=	nominal long-term interest rate (in %)
$\dot{p}_c$	=	inflation (in %).

Monetary transmission

The transmission of monetary policy to the real economy operates through various channels. In the short-run prices and output are affected by the exchange rate responses as they affect import prices and competitiveness. In the medium term cost-of-capital effects and direct substitution effects on the investment categories and on private consumption, respectively, dominate the impact of monetary policy on output. A fourth channel of transmission is the wealth channel, which operates mainly through endogenous responses of house and equity prices. Finally, the income channel already mentioned, refers to changes in the net investment income flows received (or paid) by households, when interest rates change. This decomposition of monetary transmission is fairly standard in central bank models (see van Els et al, 2001). The wealth channel is however, somewhat special as it includes an endogenous asset price channel.

3 Simulation properties

EUROMON's system properties are analysed by conducting five simulation experiments:

- A two-year 100 basis points increase in the euro area short-term interest rate
- A permanent 1% GDP increase in government consumption of goods and services
- A permanent 1% increase in non-euro area world demand
- A five-year 1% appreciation of the euro vis-à-vis all other currencies
- A permanent 10% increase in oil prices

The results of these experiments for the aggregate euro area are presented in Tables 1 through 5 below. The main results are summarised as follows. The two-year 100 basis points increase in short-term interest rates triggers moderate aggregate effects on output and prices in the euro area. In the short-run, the appreciation of the exchange rate affects the competitiveness of euro-area producers adversely, leading to a drop of (net) exports. Higher interest rates also reduce private consumption. Weaker demand and higher user cost of capital reduce investment. Negative international spillovers also contribute to the size of the output loss, which amounts to approximately 0.25%. In the short-run domestic prices decline because of lower import prices. The reduction in unit labour costs in the medium term in response to higher unemployment fosters some further price decreases.

The permanent 1% GDP increase in government expenditures on goods and services is followed by a drop in unemployment and positive accelerator effects on investment. The rise in output and, as from year 2, inflation is followed by higher (real) short-term and long-term interest rates. As the fiscal solvency rule is imposed, tax rates increase to counteract the increase in the government deficit. This leads to a reduction in private consumption and investment from year 3 onwards. In the medium term, prices rises are fairly large and partly pushed by higher wage demands because of increases in income tax rates.

The effects of a permanent 1% increase in non-euro area world demand on euro area GDP are quite small, which reflects the relatively closed character of the euro area economy. Initially, the shock boils down to a 0.45% increase in total relevant world demand for the euro area. However, as world demand is endogenous for individual countries, there is a slight increase in the output effects over time due to international spillovers. Wages and prices are somewhat higher, induced by a small decrease in the unemployment rate.

The 1% appreciation of the euro lowers real GDP by almost 0.1%. Lower foreign prices feed gradually into domestic prices and wages, with consumer prices down by 0.4% after five years.

A permanent 10% rise in oil prices leads to higher consumer prices and thus to a drop in real disposable income and consumer spending. In year 5, GDP is close to 0.2% lower than base and consumer prices are 0.9% higher. This general price response not only reflects the direct effect of higher oil-related energy prices, but also includes indirect second-round effects via wage formation and international spillovers.

4 Future Research

There are a number of issues that we would like to improve in the current structure of EUROMON in order to improve its theoretical cohesiveness but also make it more appropriate to the ways that the model is used. We mention a few in order to cast some light on the direction that we would like to see the model take. First, we would like to strengthen the long run simulation properties of the model by further improving its theoretical consistency. An important element of this refers to solving for the equilibrium unemployment rate explicitly as mentioned in the text and use this variable rather than the exogenous NAWRU (à la Elmeskov) as an input to the supply side of the model. Second, strengthening the theoretical consistency will provide the basis for including forward looking elements such as model consistent expectations regarding future inflation, interest rates and exchange rates, and household income/wealth. Third, we plan to improve the modelling of international linkages by incorporating information on trade linkages with country blocks that are not currently included in the model. A fourth element is to reconsider the modelling of import prices by including pricing to market not only as a short-term phenomenon, as is now the case for most countries, but also in the long-term equilibrium relationship for import prices and test for its statistical significance.

The current version of the model has two distinct features that we would like to maintain in future versions of the model. The first refers to the endogeneity of the equilibrium unemployment rate [8]. In principle this feature is very helpful in exploring the effects on wage and price formation of structural reforms in labour and product markets. This feature is not very common in other macroeconomic policy models, which mainly rely on Phillips curve models of inflation. The other feature relates to the endogeneity of asset prices in the model and the modelling of private sector financial wealth measured at market value as a channel of monetary policy transmission.

With reference to the first of the two, we expect to follow the approach to modelling the equilibrium unemployment rate laid out by Broer, Draper and Huizinga (2000). This approach entails combining an optimising firm model with a wage bargaining framework. The firm model is used to derive equilibrium relationships which describe labour demand, non-residential investment and the deflator of private sector output at factor cost (price setting). We will assume a CES production technology and imperfectly competitive goods markets, so that output prices are set as a mark-up over marginal cost, whereas labour and capital demand depend on labour and capital costs relative to the total costs of production [9]. Wages will be derived from a union bargaining framework of the 'right-to-manage' variety (Nickell and Andrews, 1983). This implies that gross wages depend on output prices, the level of unemployment, the replacement rate, labour productivity and the wedge between product and consumption wages. This wedge consists of the effects of direct and indirect

[8] Although this feature is not fully exploited in the current model version.

[9] Because cross-equaton restrictions these equations should preferably be estimated simultaneously.

Table 1 Effects two-year 100 basis points increase in short-term interest rates

	2001	2002	2003	2004	2005
Prices	Levels, percentage deviations from baseline				
HICP	-0.02	-0.07	-0.16	-0.26	-0.38
GDP Deflator	-0.02	-0.06	-0.14	-0.24	-0.35
Unit labour costs	0.06	-0.01	-0.21	-0.34	-0.46
Compensation per employee	-0.02	-0.17	-0.34	-0.47	-0.60
Productivity	-0.08	-0.16	-0.13	-0.12	-0.14
Export deflator	-0.12	-0.15	-0.09	-0.12	-0.19
Import deflator	-0.31	-0.36	-0.15	-0.09	-0.07
GDP and Components	Levels, percentage deviations from baseline				
GDP	-0.10	-0.25	-0.23	-0.22	-0.25
Private consumption	-0.02	-0.11	-0.10	-0.09	-0.11
Investment	-0.16	-0.70	-0.87	-0.81	-0.85
Government consumption	-0.05	-0.16	-0.20	-0.21	-0.23
Exports	-0.14	-0.19	-0.21	-0.29	-0.33
Imports	-0.02	-0.20	-0.41	-0.46	-0.49
Contributions to GDP	Percentage of GDP, absolute deviations from baseline				
Domestic demand	-0.06	-0.25	-0.29	-0.27	-0.29
Inventories	0.00	0.00	0.00	-0.01	-0.01
Trade balance	-0.05	0.00	0.07	0.06	0.05
Labour market	Levels, percentage deviations from baseline				
Total employment	-0.03	-0.11	-0.11	-0.10	-0.11
Unemployment rate *	0.02	0.08	0.08	0.07	0.08
Household Accounts	Levels, percentage devaiations from basline				
Real disposable income	-0.01	-0.11	-0.17	-0.18	-0.20
Fiscal Ratios	Percentage of GDP, absolute deviations from baseline				
Budget deficit	0.16	0.23	0.09	0.06	0.06
Government debt	0.25	0.63	0.76	0.89	1.05
Financial Variables	Percentage points, absolute deviations from baseline				
Short-term interest rates	1.00	1.00	0.00	0.00	0.00
Long-term interest rates	0.17	0.06	0.00	0.00	0.00
Foreign Demand	Levels, percentage deviations from baseline				
World demand	-0.01	-0.15	-0.32	-0.39	-0.42
Foreign Prices	Levels, percentage deviations from baseline				
Effective exchange rate	1.28	0.48	-0.02	-0.01	0.02
Foreign prices (euro)	-0.79	-0.32	-0.02	-0.04	-0.07
Oil prices (US $)	0.00	0.00	0.00	0.00	0.00

* percentage points

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Figure 1:

Table 2 Effects of 1% GDP increase in non-wage government consumption; aggregate effects on euro area*

	2001	2002	2003	2004	2005
Prices	Levels, percentage deviations from baseline				
HICP	-0.14	-0.10	0.31	0.98	1.84
GDP Deflator	-0.08	-0.11	0.22	0.83	1.65
Unit labour costs	-0.70	0.08	0.79	1.74	2.77
Compensation per employee	0.11	0.74	1.47	2.36	3.32
Productivity	0.81	0.65	0.68	0.63	0.57
Export deflator	-0.04	-0.17	-0.09	0.21	0.74
Import deflator	-0.01	-0.09	-0.20	-0.30	-0.26
GDP and Components	Levels, percentage deviations from baseline				
GDP	1.09	1.16	1.15	1.02	0.84
Private consumption	0.16	0.27	0.17	-0.08	-0.38
Investment	0.58	1.17	1.15	0.84	0.39
Government consumption	5.36	5.63	5.78	5.91	5.99
Exports	0.06	0.64	1.19	1.49	1.56
Imports	0.61	2.01	2.53	2.65	2.42
Contributions to GDP	Percentage of GDP, absolute deviations from baseline				
Domestic demand	1.30	1.56	1.53	1.34	1.07
Inventories	-0.03	0.07	0.00	0.06	0.05
Trade balance	-0.19	-0.47	-0.45	-0.38	-0.28
Labour market	Levels, percentage deviations from baseline				
Total employment	0.38	0.56	0.48	0.36	0.19
Unemployment rate (%-points)	-0.28	-0.41	-0.35	-0.26	-0.14
Household Accounts	Levels, percentage devaiations from basline				
Real disposable income	0.58	0.75	0.41	-0.03	-0.56
Fiscal Ratios	Percentage of GDP, absolute deviations from baseline				
Budget deficit	0.93	0.85	0.83	0.90	0.98
Government debt	0.17	1.00	1.60	2.13	2.64
Financial Variables	Percentage points, absolute deviations from baseline				
Short-term interest rates	0.17	0.38	0.80	1.19	1.47
Long-term interest rates	0.14	0.34	0.72	1.10	1.40
Foreign Demand	Levels, percentage deviations from baseline				
World demand	0.40	1.34	1.76	1.90	1.77
Foreign Prices	Levels, percentage deviations from baseline				
Effective exchange rate	0.14	0.31	0.58	0.74	0.73
Foreign prices (euro)	-0.10	-0.26	-0.38	-0.32	-0.03
Oil prices (US $)	0.00	0.00	0.00	0.00	0.00

* In EUROMON the euro area is represented by Austria, Belgium, Finland, France, Germany, Italy, the Netherlands and Spain.

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Figure 2:

Table 3 Effects of a permanent 1% increase in non-euro area world demand; aggregate effects on euro area*

	2001	2002	2003	2004	2005
Prices	Levels, percentage deviations from baseline				
HICP	0.00	-0.01	0.01	0.06	0.13
GDP Deflator	0.00	-0.01	0.01	0.05	0.11
Unit labour costs	-0.05	-0.03	0.04	0.11	0.20
Compensation per employee	0.01	0.06	0.14	0.22	0.32
Productivity	0.05	0.09	0.10	0.11	0.11
Export deflator	0.00	-0.01	-0.02	-0.01	0.02
Import deflator	0.00	-0.01	-0.02	-0.04	-0.05
GDP and Components	Levels, percentage deviations from baseline				
GDP	0.07	0.15	0.17	0.19	0.20
Private consumption	0.01	0.04	0.06	0.06	0.07
Investment	-0.16	-0.70	-0.88	-0.83	-0.88
Government consumption	0.04	0.10	0.14	0.16	0.18
Exports	0.17	0.39	0.53	0.63	0.70
Imports	0.02	0.20	0.36	0.45	0.49
Contributions to GDP	Percentage of GDP, absolute deviations from baseline				
Domestic demand	-0.06	-0.25	-0.31	-0.31	-0.36
Inventories	0.00	0.00	0.00	-0.01	-0.01
Trade balance	-0.05	0.00	0.07	0.06	0.06
Labour market	Levels, percentage deviations from baseline				
Total employment	0.02	0.07	0.08	0.09	0.09
Unemployment rate (%-points)	-0.02	-0.05	-0.06	-0.06	-0.07
Household Accounts	Levels, percentage devaiations from basline				
Real disposable income	0.03	0.11	0.16	0.18	0.18
Fiscal Ratios	Percentage of GDP, absolute deviations from baseline				
Budget deficit	0.00	0.00	0.02	0.04	0.06
Government debt	-0.05	-0.10	-0.11	-0.11	-0.11
Financial Variables	Percentage points, absolute deviations from baseline				
Short-term interest rates	0.01	0.04	0.08	0.13	0.17
Long-term interest rates	0.01	0.04	0.07	0.12	0.16
Foreign Demand	Levels, percentage deviations from baseline				
World demand	0.45	0.57	0.68	0.75	0.78
Foreign Prices	Levels, percentage deviations from baseline				
Effective exchange rate	0.01	0.03	0.06	0.08	0.09
Foreign prices (euro)	0.00	-0.02	-0.04	-0.05	-0.04
Oil prices (US $)	0.00	0.00	0.00	0.00	0.00

* In EUROMON the euro area is represented by Austria, Belgium, Finland, France, Germany, Italy, the Netherlands and Spain.

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Figure 3:

Table 4 Effects of five-year 1% appreciation of euro vis-à-vis all other currencies; aggregate effects on euro area*

	2001	2002	2003	2004	2005
Prices	Levels, percentage deviations from baseline				
HICP	-0.01	-0.06	-0.15	-0.26	-0.38
GDP Deflator	-0.01	-0.05	-0.13	-0.23	-0.35
Unit labour costs	0.02	-0.04	-0.15	-0.28	-0.41
Compensation per employee	-0.01	-0.09	-0.19	-0.30	-0.41
Productivity	-0.03	-0.04	-0.04	-0.02	0.00
Export deflator	-0.08	-0.15	-0.19	-0.26	-0.33
Import deflator	-0.18	-0.33	-0.39	-0.43	-0.47
GDP and Components	Levels, percentage deviations from baseline				
GDP	-0.04	-0.08	-0.07	-0.04	-0.02
Private consumption	0.00	-0.01	0.00	0.03	0.05
Investment	-0.01	-0.08	-0.07	-0.02	0.04
Government consumption	-0.02	-0.05	-0.06	-0.05	-0.04
Exports	-0.09	-0.15	-0.17	-0.18	-0.17
Imports	0.00	-0.04	-0.08	-0.07	-0.04
Contributions to GDP	Percentage of GDP, absolute deviations from baseline				
Domestic demand	-0.01	-0.03	-0.03	0.00	0.03
Inventories	0.00	0.00	0.00	0.00	0.00
Trade balance	-0.03	-0.04	-0.04	-0.04	-0.05
Labour market	Levels, percentage deviations from baseline				
Total employment	-0.01	-0.04	-0.03	-0.02	-0.01
Unemployment rate (%-points)	0.01	0.03	0.03	0.02	0.01
Household Accounts	Levels, percentage devaiations from basline				
Real disposable income	-0.02	-0.05	-0.04	0.00	0.05
Fiscal Ratios	Percentage of GDP, absolute deviations from baseline				
Budget deficit	0.00	-0.01	-0.03	-0.05	-0.07
Government debt	0.04	0.09	0.11	0.12	0.12
Financial Variables	Percentage points, absolute deviations from baseline				
Short-term interest rates	-0.01	-0.06	-0.12	-0.16	-0.18
Long-term interest rates	-0.01	-0.05	-0.10	-0.15	-0.17
Foreign Demand	Levels, percentage deviations from baseline				
World demand	0.00	-0.02	-0.04	-0.04	-0.03
Foreign Prices	Levels, percentage deviations from baseline				
Effective exchange rate	1.00	1.00	1.00	1.00	1.00
Foreign prices (euro)	-0.52	-0.53	-0.54	-0.56	-0.59
Oil prices (US $)	0.00	0.00	0.00	0.00	0.00

* In EUROMON the euro area is represented by Austria, Belgium, Finland, France, Germany, Italy, the Netherlands and Spain.

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Figure 4:

Table 5 Effects of permanent 10% increase in oil prices; aggregate effects on euro area*

	2001	2002	2003	2004	2005
Prices	Levels, percentage deviations from baseline				
HICP	0.08	0.23	0.43	0.67	0.91
GDP Deflator	0.05	0.19	0.38	0.61	0.84
Unit labour costs	0.01	0.17	0.41	0.65	0.88
Compensation per employee	0.00	0.14	0.35	0.55	0.75
Productivity	-0.01	-0.03	-0.06	-0.10	-0.13
Export deflator	0.01	0.07	0.19	0.35	0.54
Import deflator	0.40	0.70	0.76	0.82	0.91
GDP and Components	Levels, percentage deviations from baseline				
GDP	-0.01	-0.02	-0.06	-0.12	-0.18
Private consumption	-0.02	-0.04	-0.09	-0.16	-0.23
Investment	0.00	0.03	-0.02	-0.13	-0.26
Government consumption	-0.03	-0.04	-0.05	-0.09	-0.13
Exports	0.00	0.01	-0.01	-0.07	-0.16
Imports	0.00	-0.01	-0.04	-0.14	-0.27
Contributions to GDP	Percentage of GDP, absolute deviations from baseline				
Domestic demand	-0.01	-0.03	-0.07	-0.14	-0.21
Inventories	0.00	0.00	0.00	0.00	0.00
Trade balance	0.00	0.01	0.01	0.02	0.03
Labour market	Levels, percentage deviations from baseline				
Total employment	0.01	0.02	0.01	-0.03	-0.07
Unemployment rate (%-points)	-0.01	-0.02	-0.01	0.02	0.05
Household Accounts	Levels, percentage devaiations from basline				
Real disposable income	-0.07	-0.11	-0.14	-0.23	-0.34
Fiscal Ratios	Percentage of GDP, absolute deviations from baseline				
Budget deficit	0.00	0.02	0.05	0.08	0.11
Government debt	-0.03	-0.11	-0.18	-0.21	-0.23
Financial Variables	Percentage points, absolute deviations from baseline				
Short-term interest rates	0.03	0.12	0.21	0.26	0.27
Long-term interest rates	0.02	0.11	0.19	0.25	0.27
Foreign Demand	Levels, percentage deviations from baseline				
World demand	0.00	-0.02	-0.08	-0.17	-0.28
Foreign Prices	Levels, percentage deviations from baseline				
Effective exchange rate	-0.02	-0.02	0.05	0.08	0.07
Foreign prices (euro)	0.03	0.14	0.24	0.39	0.58
Oil prices (US $)	10.00	10.00	10.00	10.00	10.00

* In EUROMON the euro area is represented by Austria, Belgium, Finland, France, Germany, Italy, the Netherlands and Spain.

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Figure 5:

taxes and the terms of trade. Combining the firm and wage models implies that equilibrium unemployment is determined by the wedge, the replacement rate, the mark-up and the relative cost of capital (see Broer, Draper and Huizinga (2000) for an empirical application to the Netherlands).
The current version of EUROMON does incorporate some of the elements of this approach (see Section 2). However, in the current version price setting and factor demand are not derived from the same firm problem explicitly and hence are not modelled simultaneously. For lack of time series data on the replacement rate in most countries, this potentially important explanatory factor of wages has not been included in the empirical analysis up to now. Finally, in the current version of EUROMON the consumption deflator is the central price variable in the model. For theoretical reasons however, it should be the output deflator at factor costs which should acquire the role of the central price equation in the model. Partly as a result of these imperfections the implicit equilibrium unemployment rate is only affected by elements of the wedge in the current EUROMON version. As structural policies are and will continue to be an important aspect of policy in Europe, we consider a proper modelling of the impact of such policies on the supply side of the economy, a key issue in the success of future model uses.

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APPENDICES

A A stylised representation of the economy

Monetary submodel

i	Net financial wealth private sector	ΔNW	=	$CB + \Delta D$
i	Net financial wealth private sector at market value	NW_{MV}	=	$NW + E_{MV} + \underline{\theta}_h \, \frac{1}{100} \, \underline{p}_h \, k_h$
i	Market value domestic equity	E_{MV}	=	$\frac{1}{100} \, \underline{\theta}_q \, p_{eq} \, k_b$
b	Broad money	$M3$	=	$f(p_c, y, NW_{MV}, r_s, r_l, \dot{p}_c, gap)$
i	Private sector holdings of non-government bonds	B_{ps}	=	$TA - M3 - D_{ps} - NFA$
i	Private sector holdings of government debt	$\Delta \log D_{ps}$	=	$\Delta \log D + \underline{D}_{ps}^{mres}$
i	Net foreign assets owned by the private sector	ΔNFA	=	$CB + \underline{NFA}^{mres}$
i	Total private sector financial assets	TA	=	$CRD + NW + \underline{NW}^{mres}$
b	Bank credit to private sector	CRD	=	$f(PDI, CF, T_{dirb}, r_l, r_s, p_y, i_b, i_h, v, Y)$
i	Personal disposable income	PDI	=	$COM + OI + TR - T_{ssc} - T_{dirp}$
i	Total wage compensation	COM	=	$w_b \, l_b + w_g \, \underline{l}_g$
c	Other household income	OI	=	$\frac{1}{400}\{(2 + \frac{1}{20} \sum_{-3}^{0} r_s) \, \underline{\omega}_{M3} \frac{1}{4} \sum_{-4}^{-1} M3$
				$+(\underline{\vartheta}_{DPS} \frac{1}{4} \sum_{-3}^{0} r_l + (1 - \underline{\vartheta}_{DPS}) \frac{1}{4} \sum_{-3}^{0} r_s) \frac{1}{4} \sum_{-4}^{-1} D$
				$+\frac{1}{4} \sum_{-3}^{0} \underline{r}_{eq} \frac{1}{4} \sum_{-4}^{-1} E_{MV}$
				$-\{\underline{\vartheta}_{CRDH}(\frac{1}{4} \sum_{-3}^{0} r_l + \underline{\mu}_l)$
				$+(1 - \underline{\vartheta}_{CRDH})(\frac{1}{4} \sum_{-3}^{0} r_s + \underline{\mu}_s)\} \, \underline{\omega}_{CRDH} \frac{1}{4} \sum_{-4}^{-1} CRD\}$
				$+\frac{1}{4} \sum_{-3}^{0} NX_{PI}$
i	Cash flow	CF	=	$Y - COM - T_{ind}$

Financial submodel

o	Nominal short-term interest rate	Δr_s	=	rulebased
		r_s	=	interest rate rule for EMU, UK, JP, US
o/b	Nominal long-term interest rate	r_l	=	empirical or term structure equations
o	Nominal US exchange rate	e_{DOL}	=	various options, EMU, UK, JP
i	Nominal DM exchange rate	e_{DM}	=	$\frac{e_{DOL}}{e_{DOL}^{DE}}$ for UK, JP, US
b	Equity price	p_{eq}	=	$f(p_y, r_l, lis)$
i	Price deflator government bonds	$\frac{p_{gb}}{100}$	=	$\{(1 + \frac{r_{gd}}{100})^{\frac{1}{365}} - 1\} \frac{(1+\frac{r_L}{100})^{\underline{DUR}} - 1}{\{(1+\frac{R_L}{100})^{\frac{1}{365}} - 1\}(1+\frac{R_L}{100})^{\underline{DUR}}}$
				$+ \frac{1}{(1+\frac{r_L}{100})^{\underline{DUR}}}$

Labour market and physical capital stock

b	Business employment	lh_b	=	$f(y_b, wh_b - p_b)$
b	Business investment	i_b	=	$f(k_b, y_b, \frac{ucc}{\underline{\mu}_{ucc}}, s, gap, r_l - \dot{p}_c, r_s - \dot{p}_c, \frac{CF-T_{dirb}}{p_y})$
i	User cost of capital	ucc	=	$\frac{1}{800}(r_l + r_s) - \frac{1}{400}\dot{p}_{yb} + \underline{\kappa}_b + \underline{ucc}^{risk}$
i	Business capital stock	k_b	=	$i_b + (1 - \underline{\kappa}_b)\, k_{b-1}$
i	Potential business employment	lh_b^*	=	$\underline{\psi}\, l_s\, (1 - \underline{u}^N) - \underline{\psi}\, \underline{l}_g + \underline{lh}_b^{*,mres}$
b	Total labour force	$\Delta \log l_s$	=	l_s
c	Potential business production	y_b^*	=	$-\frac{1}{\hat{\rho}} \log\{(1-\hat{\delta})\tilde{k}_{b,t-1}^{-\hat{\rho}} + \hat{\delta}(l\tilde{h}_{b,t}^*)\}^{-\hat{\rho}} + tfp_t^*$
i	Output gap	gap	=	$100\,(\log y_b - \log y_b^*)$
i	Business production	y_b	=	$y - 100\,\frac{w_g\, l_g + T_{ind}}{p_{gc}} CHECK!!!$
i	Unemployment rate	u	=	$100\,\frac{l_s - l_b - l_g}{l_s}$
i	Business employment (in persons)	l_b	=	$\frac{1}{\underline{\psi}}\, lh_b$
i	Business labour productivity (per employee)	lp_b	=	$\frac{y - 100\frac{w_g\, l_g}{p_{gc}}}{l_b}$
i	Business labour productivity (per hour)	lhp_b	=	$\frac{y - 100\frac{w_g\, l_g}{p_{gc}}}{lh_b}$

National income

i	Gross domestic product	y	=	$c + i_b + i_h + g_c + g_i + x - m + \Delta v$
b	Private consumption	c	=	$f(\frac{PDI}{p_c}, \frac{NW_{MV}}{p_c}, r_s - \dot{p_c}, r_l - \dot{p_c}, \Delta u, GFBY)$
b	Housing investment	i_h	=	$f(\frac{PDI}{p_c}, r_l - \dot{p}_c)$
i	Housing stock	k_h	=	$i_h + (1 - \underline{\kappa}_h)\, k_{h-1}$
b	Government consumption	$g_c - 100\,\frac{w_g\, l_g}{p_{gc}}$	=	$f(y)$
b	Government investment	g_i	=	$f(y)$
i	Change in inventories	Δv	=	$y_{tfe} - s$
i	Inventory stock	v	=	$v_{-1} + \Delta v$
i	Sales	s	=	$c + i_b + i_h + g_c - 100\,\frac{w_g\, l_g}{p_{gc}} + g_i + x$
b	Total final expenditures	y_{tfe}	=	$f(s, v_{-1}, r_s - \dot{p}_c)$
i	Gross domestic product	Y	=	$\frac{1}{100}\, p_y\, y$

Foreign trade

i	Current account balance	CB	=	$\frac{1}{100}(p_x\ x - p_m\ m) + NX_{PI} + NX_{TR}$
b	Exports of goods and services	x	=	$f(\frac{p_x}{p_x^w}, m^w)$
b	Imports of goods and services	m	=	$f(\frac{p_m}{p_y}, s, gap, \frac{\Delta v}{s})$
b	Net exports primary income	NX_{PI}	=	$f(r_l^w, NFA)$
b	Net exports transfers	$100\,\frac{NX_{TR}}{Y}$	=	constant

Wages and prices

b	Non-government wage rate (per employee)	w_b	$=$	$f(p_c, p_{yb}, lp_b, \underline{\tau}_{dir} + \underline{\tau}_{ssc}, u)$
i	Non-government wage rate (per hour)	w_{hb}	$=$	$\frac{1}{\underline{\psi}}\ w_b$
b	Government wage rate (per employee)	w_g	$=$	$f(w_b)$
i	Unit labour costs	ulc	$=$	$\frac{w_b\, l_b}{y - 100 \frac{w_g\, \underline{l}_g}{p_{gc}}}$
i	Business labour income share	lis	$=$	$100\, \frac{w_b\, l_b}{Y - w_g\, \underline{l}_g - T_{ind}}$
b	Price deflator private consumption	p_c	$=$	$f(ulc, p_m, \underline{\tau}_{ind}, gap)$
b	Price deflator government consumption	p_{gc}	$=$	$f(p_y)$
b	Price deflator government investment	p_{gi}	$=$	$f(p_y)$
b	Price deflator exports of goods and services	p_x	$=$	$f(p^w_x, p_y)$
b	Price deflator imports of goods and services	p_m	$=$	$f(p^w_m, \underline{p}_{oil}, \underline{p}_{com}, e_{DOL}, p_{yb})$
i	Price deflator gross domestic product	Δp_y	$=$	$\frac{s-x+m}{s} \Delta p_c + \frac{x}{s} \Delta x - \frac{m}{s} \Delta m CHECK$
i	Inflation	$\dot{p}_c$	$=$	$100\, \Delta_4 \log p_c CHECK$

Public sector

i	Gross financial balance	GFB	$=$	$T_{dir} + T_{ind} + T_{ssc} - \frac{1}{400} \{(1 - \underline{\vartheta}_{DPS}) r_s + \underline{\vartheta}_{DPS} r_l\} D_{-1}$
				$G_c - G_i - TR - OGE + \underline{GFB}^{mres}$
i	Government debt	ΔD	$=$	$-GFB + \underline{D}^{mres}$
i	Direct taxes	T_{dir}	$=$	$T_{dirp} + T_{dirb} + \underline{T}^{mres}_{dir}$
i	Direct taxes on personal income	T_{dirp}	$=$	$\underline{\tau}_{dirp}(COM + OI + TR - T_{ssc}) + \underline{T}^{mres}_{dirp}$
i	Corporate taxes	T_{dirb}	$=$	$\underline{\tau}_{dirb}\{CF - \underline{DEP}$
			-	$\frac{1}{400}\, (\underline{\vartheta}_{CRDB} r_l + (1 - \underline{\vartheta}_{CRDB}) r_s)\, \underline{\omega}_{CRDB}\, CRD\} + \underline{T}^{mres}_{dirb}$
i	Indirect taxes	T_{ind}	$=$	$\underline{\tau}_{ind}\, p_c\, c + \underline{T}^{mres}_{ind}$
i	Social security contributions	T_{ssc}	$=$	$\underline{\tau}_{ssc}(COM + TR) + \underline{T}^{mres}_{ssc}$
i	Government consumption	G_c	$=$	$\frac{1}{100}\, p_{gc}\, g_c$
i	Government investment	G_i	$=$	$\frac{1}{100}\, p_{gi}\, g_i$
b	Transfers	$\frac{TR}{Y}$	$=$	$f(u, \frac{w_g}{p_y}, \frac{p_c}{p_y})$
b	Net other government expenditures	OGE	$=$	$f(Y)$

Weighted variables

i	Relevant world trade	$\frac{\Delta m^w}{m^w}$	=	$\sum_{j=1}^{13} \underline{ew}_j \frac{\Delta m_j}{m_{j,-1}}$
i	Weighted export price	p_x^w	=	$\frac{e_{DM}}{\underline{e}_{DM}(90)} \sum_{j=1}^{13} \underline{cw}_j p_{x,j} \frac{\underline{e}_{DM,j}(90)}{e_{DM,j}} / \sum_{j=1}^{13} \underline{cw}_j$
i	Weighted import price	p_m^w	=	$\frac{e_{DM}}{\underline{e}_{DM}(90)} \sum_{j=1}^{13} \underline{iw}_j p_{x,j} \frac{\underline{e}_{DM,j}(90)}{e_{DM,j}}$
i	Effective exchange rate	e_{fex}	=	$100 \frac{\underline{e}_{DM}(90)}{e_{DM}} \sum_{j=1}^{13} \underline{cw}_j \frac{e_{DM,j}}{\underline{e}_{DM,j}(90)} / \sum_{j=1}^{13} \underline{cw}_j$

Additional

i	Current balance ratio	CBY	=	$100 \frac{CB}{Y}$
i	Government debt ratio	DY	=	$100 \frac{D}{\sum_{-3}^{0} Y}$
i	Government financial balance ratio	$GFBY$	=	$100 \frac{\sum_{-3}^{0} GFB}{\sum_{-3}^{0} Y}$

World variables

i	World nominal long-term interest rate	r_l^w	=	$\sum_{j=1}^{13} r_{l,j} \underline{\zeta}_{yw} (I_{\{j \neq DE,ES,FR,IT,JP\}} + 1000\, I_{\{j=DE,ES,FR,IT,JP\}})$

Eurozone variables referred to in Chapter 2

i	Broad money eurozone	$M3^{EMU}$	=	$\sum_{j=1}^{13} \frac{M3_j}{\underline{e}_{DM,j}(90)} (I_{\{j=AU,BE,FI,NL\}} + 1000\, I_{\{j=DE,ES,FR,IT\}})$
i	Inflation eurozone	$\dot{p}_c^{EMU}$	=	$\sum_{j=1}^{13} \dot{p}_{c,j} \underline{\zeta}_{yEMU} (I_{\{j=AU,BE,FI,NL\}} + 1000\, I_{\{j=DE,ES,FR,IT\}})$
i	Gross domestic product eurozone	Y^{EMU}	=	$\sum_{j=1}^{13} \frac{Y_j}{\underline{e}_{DM,j}(90)} (I_{\{j=AU,BE,FI,NL\}} + 1000\, I_{\{j=DE,ES,FR,IT\}})$
i	Output gap eurozone	gap^{EMU}	=	$\sum_{j=1}^{13} gap_j \underline{\zeta}_{yEMU} (I_{\{j=AU,BE,FI,NL\}} + 1000\, I_{\{j=DE,ES,FR,IT\}})$

Explanatory note first column:

b	=	behavioural equation
i	=	identity
c	=	calibrated or constructed
o	=	option