An Estimated Two-Country DSGE Model for the Euro Area and the US Economy*

Gregory de Walque, Frank Smets and Raf Wouters[†]

This draft: December 2, 2005
Work in progress

Abstract

This paper develops an open economy DSGE model with sticky prices and wages linking the euro area and the US economy. The model is estimated with Bayesian techniques using ten country-specific macroeconomic variables for each economy together with oil prices and the euro/dollar exchange rate. The introduction of a complete set of domestic and open economy shocks allows for an empirical investigation of their contribution to the business cycle fluctuations in output, trade balance and exchange rate. The spill-over effects depend crucially on the elasticity of substitution. The empirical fit results in similar probabilities for high and low values of this parameter. The restrictions that are imposed by the UIRP condition on the reaction of the model to the various shocks are not supported by the data.

1 Introduction

Over the last decade, the "New Open Economy Model" (NOEM) has become the standard model to analyze the behaviour of the exchange rate and the current account. This model is based on the optimizing behaviour of the microeconomic units, firms and households, in a monopolistic competitive environment with nominal rigidities in the price and wage setting. Consumption and investment goods are aggregate baskets of domestic and foreign goods, which are considered as imperfect substitutes. Demand is allocated between these goods in function of the real exchange rate. The current account is consistently explained by the intertemporal decisions on the one hand, that is the savings minus investment identity, and

*A previous version of the paper was presented at workshops organised by the Bundesbank, the Banque de France and the Bank of England. We would like to thank the participants for their comments and especially our discussants O. Pierrard and J. Lindé for useful suggestions.

[†]Gregory de Walque: National Bank of Belgium (gregory.dewalque@nbb.be), Frank Smets: European Central Bank, CEPR and Ghent University (frank.smets@ecb.int) and Raf Wouters: National Bank of Belgium (rafael.wouters@nbb.be). The views expressed in this paper are our own and do not necessarily reflect those of the National Bank of Belgium or the European Central Bank.

the intratemporal decisions, that is the allocation of demand depending on the relative price of the domestic and foreign goods, on the other hand. The exchange rate is determined by the uncovered interest rate parity condition. Starting from these common building blocks, many different versions have been derived in the literature. The main differences concern the assumptions on the price determination of exported and imported goods and on the nature of the international capital markets. Observed imperfect exchange rate pass-through has lead to different specifications for the price setting: producer currency pricing versus local currency pricing, homogenous pricing versus pricing to market, sticky versus flexible prices etc. Uncertainty about the international risk sharing is reflected in different assumptions on the asset market structure and the portfolio diversification opportunities. In the literature, these models have been used intensively to discuss the issue of optimal monetary policy and of international policy coordination.

Most of the work on the NOEM is highly theoretical and based on small-stylized models. Ghironi (1999), Bergin (2004), Lubik and Schorfheide (2003 and 2005), Justiniano and Preston (2004), Rabanal and Tuesta (2005) have started to estimate small scale NOEModels. However, the small dimension of these models, both for the domestic and the open economy specification, does not allow for an empirical test of all the implications of these models for a sufficiently wide range of macro-aggregates. Recently a series of larger and more realistic open and two (or multi-) country models have been constructed within central banks. Examples of such models are Laxton and Pesenti (GEM - Global Economy Model at the IMF, 2003), Erceg, Guerrieri and Gust (SIGMA at the Federal Reserve Board, 2003), Benigno and Thoenissen (Bank of England, 2002), Murchison, Rennison and Zhu (Bank of Canada, 2004), Adolfson *et al.* (Riksbank, 2004), Kortelainen (Bank of Finland, 2002). These models include extensions in the form of more realistic nominal rigidities, capital accumulation with adjustment costs, labour markets, differentiated sectors, etc.

The objective of this paper is to construct a medium-sized two-country model for the euro area and the US that is able to generate an acceptable empirical fit for a relatively wide set of macro-variables. This model should allow in subsequent work to evaluate empirically alternative specifications for the price setting behaviour, risk sharing assumptions, sectorial specifications, etc. In Smets and Wouters (2003a,b and 2005), Bayesian estimation techniques were applied to closed economy models for the euro area and the US economy. The estimation results indicated that the closed economy models produced an acceptable empirical description of the observed dynamics and that both economies were very similar both in terms of underlying shocks, structural parameters and monetary policy behaviour. In this paper, we extend this work by integrating both models through international trade in goods and assets. The dataset is extended with information from the net-trade flows, the import and consumption price inflation, the rate of depreciation and the oil price fluctuations. For the domestic block, we start from our previous work on the closed economy but we reduce the number of stochastic shocks. For the open economy block, we tried to keep the initial specification relatively simple. So we retain the assumption of producer currency pricing for exporters (no pricing to market). Following the approach in Smets and Wouters (2002), we assume that the import prices are sticky and set according to the Calvo model. This implies that the pass-through of foreign price and exchange rate fluctuations is gradual but complete in the long-run. To get a sufficiently realistic and flexible pass-through of import prices to final domestic prices, we differentiate between oil and non-oil imports and assume that these imported goods are used both in the final good and the intermediate good production. The import and export decisions are characterized by adjustment costs in order to smooth the impact of relative prices on the allocation of demand. Finally, we assume that only fixed interest rate assets are traded internationally (absence of risk sharing through portfolio diversification).

The estimation of a two-country model with imperfect international risk sharing raises some very specific issues. A first problem is related to the estimation of the intratemporal elasticity of substitution between domestic and foreign goods. The standard assumption in the traditional NOEM literature is that this elasticity is larger than one and similar in nature to the substitution elasticity between individual goods. In macroeconomic import and export equations this elasticity is typically estimated with a large uncertainty and is often quite small, sometimes even insignificantly different from zero. Schorfheide and Lubik (2005), Justiniano and Preston (2004) and Rabanal and Tuesta (2005) also estimate low values, while Adolfson *et al.* (2004) estimate a very high value. Different values for the substitution elasticity over this range have very different implications for the functioning of the two-country model (cf. Corsetti *et al.* (2003)). Furthermore, the reaction of the exchange rate to some shocks is not continuous over this range and around some critical value for the degree of substitution the exchange rate will be extremely volatile. This characteristic of the model makes the estimation outcome dependent on the starting values, as the estimated parameter for the elasticity of substitution will never succeed in crossing its critical value which is characterised by an extremely low likelihood. Therefore, we will present the estimation outcomes for two different starting values and discuss the implications for the overall model behaviour.

A second important issue that arises in a two-country model concerns the empirical validity of the uncovered interest rate parity assumption. This condition, together with the stability requirement for the net foreign asset accumulation, determines the reaction of the exchange rate and therefore also the substitution and terms-of-trade wealth effects for all domestic and foreign shocks. Empirical tests for UIRP, based on a single equation approach, have not been very supportive of the hypothesis. Also the impulse response evidence from structural VAR models typically does not confirm the theoretical jump overshooting response of the exchange rate. The simple first-order approximation for the UIRP condition that is used in our linearized model also abstracts from the existence of time-varying risk premiums that may depend on the underlying fundamental shocks. Given these empirical and theoretical arguments, it is worthwhile to test empirically the restrictions that UIRP imposes on the model. Therefore we estimate the model with and without UIRP as a diagnostic test for UIRP and its overall consequences for the functioning of the model. In the model without UIRP the exchange rate is treated simply as an exogenous process without any endogenous feedback on the rest of the model and the stability requirement that is implied by the net foreign asset accumulation is disregarded.

Based on the model estimates, we review the major implications for the domestic and open economy variables of the various shocks that are present in the model (productivity and mark-up shocks, risk premium or spending shocks, monetary policy and exchange rate risk premium shocks and price and demand shocks originating in the rest of the world). We discuss how the impact of some of the shocks differ between the models with and without UIRP and between the high and the low substitution variants. We also check whether the estimated models are able to reproduce a series of stylized facts of open economy business cycle fluctuations such as the standard deviations, autocorrelations and correlations between the exchange rate, net exports, output and demand components. Under the hypothesis that all the estimated shocks are orthogonal, the models have clearly some problems to replicate the observed international synchronisation in output and aggregate demand cycles. It remains a topic for further research to analyse how much of the observed correlation between the output of the two major economies can be explained once we allow for a positive correlation between the domestic shocks that hit the two economies. However, the models reproduce many other stylised facts and capture correctly the traditional open economy puzzle of the NOEM, i.e. the correlation between relative consumption and real exchange rate.

Starting from the impulse-responses for the different types of shocks, the joint behaviour of the domestic variables and the typical open economy variables (the exchange rate and the net trade balance) should be informative to identify the contribution of the major shocks over this period. Our approach allows to identify the major sources of the exchange rate and the trade balance developments. Past research delivered mixed results. Originally, Clarida and Gali (1995), using a small SVAR model, classified the underlying shocks to the exchange rate in terms of only three shocks: nominal, demand and supply shocks. They did not find a major role for supply shocks and nominal or monetary shocks were only important for the DEM and the JPY exchange rate. Bergin (2004) allowed explicitly for UIRP shocks that turned out to be important not only for explaining the exchange rate but also for capturing the dynamics of the current account. Our approach allows for a more detailed accounting of the underlying shocks. Shocks creating deviations from UIRP turn out to be very important for explaining the short-run volatility in the exchange rate, while fundamental shocks explain only a limited fraction of the long-run swings in the exchange rate. The trade balance is also affected by these UIRP shocks over the medium-run.

These issues will be discussed by looking at the results of the unconditional and the historical decomposition of the innovations for the most important variables. A second issue that will be discussed in this context is the importance of the different spill-over or transmission mechanisms between the two major economies. The typical domestic shocks to productivity and aggregate demand have a significant effect on the trade balance, at least over a longer horizon, but their impact on the output of the foreign economy turns out to be largely compensated by offsetting wealth effects on the domestic demand components. The historical decomposition shows that risk premium shocks tend to be systematically negative during recession periods both in the US and the euro area. A positive correlation between this type of shocks can potentially be a powerful tool to generate a common cycle.

2 Model description

The model used in this contribution links the closed economy models for the euro area and the US presented in Smets and Wouters (2005). It is a two-country model in which Rest of the World is captured by exogenous price and demand shocks. The US and euro area economies are modelled exactly symmetrically so that the following description holds for both economies. Variables appearing with an asterisk refers to the modelled foreign economy. When indexed by ROW, they refer to the non-modelled Rest of the World.

2.1 Households

In each country, there is a continuum of households indicated by index $\tau \in [0,1]$, each one supplying a differentiated labour. The instantaneous utility function of each household depends positively on consumption (C_t^τ) relative to an external habit variable (H_t) and negatively on labour supply (l_t):

$$U_t^\tau = \left(\frac{1}{1-\sigma_c}\left(C_t^\tau - H_t\right)^{1-\sigma_c}\right) \cdot \exp\left(\frac{\sigma_c - 1}{1+\sigma_l}\left(l_t^\tau\right)^{1+\sigma_l}\right) \tag{1}$$

where σ_c determines the intertemporal elasticity of substitution and σ_l the elasticity of work effort with respect to real wage. The external habit variable is assumed to be proportional to aggregate past consumption: $H_t = hC_{t-1}$. Each household τ maximises an intertemporal utility function given by :

$$E_0 \sum_{t=0}^{\infty} \beta^t \cdot U_t^\tau \tag{2}$$

with β the discount factor.

Household's total income consists of three components: labour income plus the net cash inflows from participating in state-contingent securities, the return on the capital stock diminished of the cost $\Psi(z_t^\tau)$ associated with variations in the degree of capital utilisation z_t^τ and the dividends derived from the imperfect competitive intermediate firms described in the domestic sector subsection below:

$$Y_t^\tau = \left(w_t^\tau l_t^\tau + A_t^\tau\right) + \left(r_t^k z_t K_{t-1}^\tau - \Psi(z_t^\tau) K_{t-1}^\tau\right) + Div_t^\tau \tag{3}$$

The assumption of state-contingent securities implies that households are insured against variations in household specific labour income so that the first term in the total income is equal to aggregate labour income and the marginal utility of wealth is identical across households.

Households maximise their objective function subject to an intertemporal budget constraint which is given by

$$\frac{1}{R_t^e}\frac{B_t^\tau}{P_t}+\frac{1}{R_t^{e*}}\frac{B_t^{\tau*}}{S_tP_t}=\frac{B_{t-1}^\tau}{P_t}+\frac{B_{t-1}^{\tau*}}{S_tP_t}+Y_t^\tau-C_t^\tau-I_t^\tau \tag{4}$$

with

$$\begin{aligned}
R_t^e &= \frac{R_t}{\varepsilon_t^b} \quad \text{and} \quad R_t^{e*}=\frac{R_t^*\cdot\varepsilon_t^S}{\varepsilon_t^b}\\
\varepsilon_t^b &= \rho_b\varepsilon_{t-1}^b+\eta_t^b \text{ and } \eta_t^b \text{ an i.i.d.-Normal error term}\\
\varepsilon_t^S &= \rho_S\varepsilon_{t-1}^S+\eta_t^S \text{ and } \eta_t^S \text{ an i.i.d.-Normal error term}
\end{aligned}$$

Households hold their financial wealth in the form of domestic bonds B_t and foreign bonds B_t^*. Current income and financial wealth can be used for consumption and investment in physical capital. Bonds are one period securities with a nominal rate of return R_t^e and R_t^{e*} respectively for the domestic and foreign bonds. These effective returns on domestic and foreign bonds are affected by a risk premium on bond holdings represented by the AR(1) shock ε_t^b. Beside this, we consider a risk premium on foreign bonds which take the form of a time varying shock ε_t^S and plays the role of an uncovered interest parity shock.

Maximising (2) subject to the budget constraint (4) with respect to consumption and holdings of bonds, yields the following first-order conditions:

$$E_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\cdot\frac{R_t^eP_t}{P_{t+1}}\right] = 1 \tag{5}$$

$$E_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\cdot\frac{S_t}{S_{t+1}}\frac{R_t^{e*}P_t}{P_{t+1}}\right] = 1 \tag{6}$$

where λ_t is the marginal utility of consumption, which is given by:

$$\lambda_t=(C_t-H_t)^{-\sigma_c}\cdot\exp\left(\frac{\sigma_c-1}{1+\sigma_l}(l_t^\tau)^{1+\sigma_l}\right) \tag{7}$$

Equations (5) and (6) give the uncovered interest rate parity for the determination of nominal exchange rate:

$$\frac{R_t}{\varepsilon_t^SR_t^*}=\frac{S_t}{S_{t+1}} \tag{8}$$

The labour supply and wage setting processes are modelled as in Smets and Wouters (2003a,b). Households are price-setters in the labour market and, following Calvo (1983), they can set optimally their wage with a probability $1-\xi_w$. With the complementary probability, their wage is indexed to both past inflation in the consumption price and trend inflation, with respective shares γ_w and $(1-\gamma_w)$. Optimising households choose the nominal wage $\widetilde{w}_t^\tau$ in order to maximise their intertemporal objective function (2) subject to the intertemporal budget constraint (4) and the following labour demand

$$l_t^\tau = \left(\frac{W_t^\tau}{W_t}\right)^{-\frac{1+\lambda_{w,t}}{\lambda_{w,t}}} L_t \tag{9}$$

where the aggregate labour demand and aggregate nominal wage are respectively

$$L_t = \left[\int_0^1 (l_t^\tau)^{\frac{1}{1+\lambda_{w,t}}} d\tau\right]^{1+\lambda_{w,t}} \quad \text{and} \quad W_t = \left[\int_0^1 (W_t^\tau)^{-\frac{1}{\lambda_{w,t}}} d\tau\right]^{-\lambda_{w,t}} \tag{10}$$

Shocks to the wage mark-up are assumed to follow an ARMA process around λ_w

$$\lambda_{w,t} = \lambda_w + \rho_w \lambda_{w,t-1} - \phi_w \eta_{t-1}^w + \eta_t^w \text{ with } \eta_t^w \text{ an i.i.d.-Normal error term} \tag{11}$$

The investment, capital utilisation and capital accumulation decisions by the households replicate exactly Smets and Wouters (2003a,b). Variations in the capital utilisation and in investment are assumed to incur adjustment costs. A shock $\varepsilon_t^I = \rho_I \varepsilon_{t-1}^I - \phi_I \eta_{t-1}^I + \eta_t^I$ (with η_t^I an i.i.d.-Normal error term) is introduced in the investment cost function.

2.2 The firms and price setting

2.2.1 The domestic good sector

The *domestic* good D_t is produced by a perfectly competitive firm from a continuum of intermediate goods y_t^j which are domestically produced and indexed by j, with $j \in [0, 1]$. We follow Eichenbaum and Fisher (2004) by considering that the technology of the domestic good firm is represented by

$$\int_0^1 G\left(y_t^j / D_t\right) = 1 \tag{12}$$

with G a strictly concave and increasing function characterised by $G(1) = 1$. The domestic good firm chooses D_t and y_t^j to maximise profit. From the cost minimisation, one obtains the demand of each intermediate producer:

$$y_t^j = D_t G'^{-1}\left(\frac{P_t^j}{P_t^D} \int_0^1 G'\left(y_t^j / D_t\right) \cdot \left(y_t^j / D_t\right) dj\right) \tag{13}$$

with P_t^j the intermediate good j price and P_t^D the index of the domestically produced good. As displayed by Kimball (1995), the assumptions on $G(.)$ imply that the demand for input y_t^j is decreasing in its relative price.

Intermediate goods y_t^j are produced in a monopolistic competitive sector with a continuum of firms characterised with sticky prices. They are produced with a Cobb-Douglas technology nested in a Leontieff production function:

$$v_{j,t} = \varepsilon_t^a \cdot \widetilde{K}_{j,t}^{\alpha} \cdot L_{j,t}^{1-\alpha} \tag{14}$$

$$y_t^j = \min\left\{(1-\omega-\zeta)\cdot v_{j,t}\ ;\ \omega \cdot O_{j,t}^p\ \ ;\ \zeta \cdot M_{j,t}^p\right\} - \Phi \tag{15}$$

$$\text{with } \varepsilon_t^a = \rho_a \varepsilon_{t-1}^a + \eta_t^a \quad (\eta_t^a \text{ is i.i.d.-Normal}) \tag{16}$$

where ε_t^a is a productivity shock, $\widetilde{K}_{j,t} = z_t K_{j,t-1}$ the capital stock effectively utilised, $L_{j,t}$ an index of various types of labour hired by the firm and Φ a fixed cost introduced to ensure zero profits in steady state. Variables $O_{j,t}^p$ and $M_{j,t}^p$ are respectively the oil and non-oil imported good necessary for the production process. Parameters ω and ζ represent their respective shares.

Cost minimisation implies

$$\frac{v_{j,t}}{O_{j,t}^p} = \frac{1-\omega-\zeta}{\omega},\ \ \frac{v_{j,t}}{M_{j,t}^p} = \frac{1-\omega-\zeta}{\zeta} \quad \text{and} \quad \frac{W_t L_{j,t}}{r_{j,t}^k \widetilde{K}_{j,t}} = \frac{1-\alpha}{\alpha} \forall j \in [0,1] \tag{17}$$

and the marginal cost is given by

$$MC_t = (1-\omega-\zeta)\frac{W_t^{1-\alpha}\cdot\left(r_t^k\right)^{\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}\cdot\varepsilon_t^a} + \omega\frac{P_t^o}{S_t} + \zeta P_t^M \tag{18}$$

The real marginal cost contains the cost of capital, the real wage, the real price of oil and the price of imported goods. Because the real wage for the firm is deflated by the domestic producer price, the real marginal costs will also contain a terms of trade effect if the wage is deflated by the consumer price index. The assumption of perfect mobility of capital between firms involves that the marginal cost is identical for all firms $j \in [0,1]$.

In a Calvo pricing system with a probability $1-\xi_p$ of re-optimising prices, the objective function of the firm j is

$$\max_{\widetilde{p}_t^j} E_t \sum_{i=0}^{\infty} \left(\beta\xi_p\right)^i \Lambda_{t+i} \left(\widetilde{p}_t^j \cdot \left(\frac{P_{t-1+i}^D}{P_{t-1}^D}\right)^{\gamma_p} (\overline{\pi})^{1-\gamma_p} - MC_{t+i}\right) y_{t+i}^j \tag{19}$$

where $\beta\Lambda_t$ is the discount rate, $\overline{\pi}$ is the trend inflation and $\left(P_{t-1+i}^D/P_{t-1}^D\right)^{\gamma_p}(\overline{\pi})^{1-\gamma_p}$ is the indexation device used for the prices that are not re-optimised. After linearisation around the steady state, the first order condition for this expression becomes

$$\widehat{\pi}_t = \frac{1}{1+\beta\gamma_p}\left[\beta\widehat{\pi}_{t+1} + \gamma_p\widehat{\pi}_{t-1} + \frac{\left(1-\beta\xi_p\right)\left(1-\xi_p\right)}{\xi_p}\cdot\frac{1}{\epsilon\lambda_p+1}\cdot\widehat{mc}_t\right] + \lambda_{p,t} - \vartheta\eta_t^{pc}$$

where hats denote variables in deviation from the steady state. As explained extensively in Eichenbaum and Fisher (2004), using the generalised Kimball (1995) aggregator instead of the traditional Dixit Stiglitz one, the marginal cost is multiplied by the Calvo expression $\left(1-\beta\xi_p\right)(1-\xi_p)/\xi_p$ and a second expression $(1/(\epsilon\lambda_p+1))$. Parameter λ_p represents the firm's steady state price mark-up and parameter ϵ is the percentage change in the demand elasticity $\frac{1+\lambda_p}{\lambda_p}$ caused by a modification in the relative price of good j, evaluated at steady state. As in Smets and Wouters (2003), the price mark-up is affected by stochastic shocks. They are assumed to follow an ARMA process around λ_p

$$\lambda_{p,t} = \lambda_p + \rho_p \lambda_{p,t} - \phi_p \eta_{t-1}^p + \eta_t^p \quad \text{with } \eta_t^p \text{ an i.i.d.-Normal error term} \tag{20}$$

Measurement errors in the final good price (cf. infra) are represented by η_t^{pc} and are i.i.d.-Normally distributed.

The domestic good serves two purposes which are illustrated in the next two subsections. First, it must be combined to imported goods for the latter to be distributed in the economy. This combination is carried out within a so called "distribution sector". Second, the domestic good D_t is an input in the final good production process.

2.2.2 The distribution sector

It is often considered in the models of the NOEM that tradable goods, be they domestic or imported, reach the consumer via an intermediate distribution sector (e.g. Erceg and Levin, 1996, Burnstein *et al.*, 2001, Corsetti *et al.*, 2003). In these models, the distribution sector combines a fixed proportion of non-tradable distribution services with tradable goods to produce the final good bundle, with the effect that the law-of-one price is broken at the final good level. In our model, we do not consider a non-tradable sector. Therefore, we assume that imported goods entering the final good bundle are combined with a fixed proportion of domestic goods, representing the distribution services. Let us denote by M_t^d the imported-and-distributed good. Given the Leontieff technology assumed for this sector:

$$M_t^d = \min \left\{ \delta \cdot D_t^d \;\; ; \;\; (1-\delta) M_t^f \right\} \tag{21}$$

where δ is the share of the domestic goods used as distribution services.

2.2.3 The final good sector

The final good F_t is the composite of three goods. The first one is the domestically produced good D_t^f. The second one is the output of the distribution sector, M_t^d and the last one is oil.

The domestically produced and the imported-and-distributed inputs are combined through a CES technology. As in Erceg, Guerrieri and Gust (2003) and Laxton and Pesenti (2003), the allocation of final domestic demand between the baskets of domestic and foreign goods depends on the relative price of the two goods and is subject to a reallocation adjustment cost. This adjustment cost implies that the reallocation between domestic and imported goods will happen only gradually, depending on the perceived persistence of the relative price changes.

$$\Theta_t = \left[\mu^{\frac{\rho}{1+\rho}} \left(D_t^f \right)^{\frac{1}{1+\rho}} + (1-\mu)^{\frac{\rho}{1+\rho}} \left(\Omega_t M_t^d \right)^{\frac{1}{1+\rho}} \right]^{1+\rho} \tag{22}$$

where $\frac{1+\rho}{\rho}$ is the elasticity of substitution between domestically produced and imported goods and Ω_t reflects the adjustment cost. Parameter μ captures the preference for domestically made products. The adjustment cost is assumed to take the form

$$\Omega_t = \left[1 - \Omega \left(1 - \frac{M_t^d / D_t^f}{M_{t-1}^d / D_{t-1}^f} \right)^2 \right] \tag{23}$$

The final good F_t is then produced from the intermediate good Θ_t and oil O_t^f following a Leontieff technology with a fixed proportion θ of *oil*:

$$F_t = \min \left\{ (1-\theta) \cdot \Theta_t \ \ ; \ \ \theta \cdot O_t^f \right\} \tag{24}$$

Each firm of the final good sector maximises its expected profit using a discount rate $\beta \Lambda_t$, with $\Lambda_{t+k} = \frac{\lambda_{t+k}}{\lambda_t P_{t+k}}$ where λ_t is the marginal utility of consumption and P_t the final good price index. The producer of the final good chooses D_t^f and M_t^d in order to maximise the discounted profit

$$\max_{D_t, M_t^d} \sum_{i=0}^{\infty} \beta^i \Lambda_{t+i} \left[P_{t+i} F_{t+i} - P_{t+i}^D D_{t+i}^f - P_{t+i}^{M^d} M_{t+i}^d - P_{t+i}^o O_{t+i}^f \right]$$

where P_t^D is the price index of the domestically produced good, $P_t^{M^d}$ the price index of the imported-and-distributed good and P_t^o the oil price. Note that measurement error η_t^{pc} is introduced in the final good price index.[1]

The final good serves two main purposes. It may be used to fulfill domestic needs, i.e. privately or publicly consumed/invested, or it may be exported. The goods exported by one country simply are the goods that are imported by the two other geographical entities considered in the model. Let us denote this part of the model the trade block.

2.2.4 The trade block

As presented above, non-oil imported goods M_t enter the final good production process at two levels. First, indirectly, as they are inputs of the domestically produced intermediate goods y_t^j and second as the main input to produce the imported-and-distributed good. Therefore, total non-oil imports are given by

$$M_t = M_t^p + M_t^f \tag{25}$$

Non-oil imported goods are produced by a continuum of importing firms indexed by l, with $l \in [0, 1]$. Importers for the euro area produce an homogeneous good by combining fixed shares of the exported final goods from the two other economies, i.e. the US and

[1] This measurement error helps to reconcile the consumption price deflator with the other prices and especially the GDP deflator which is used as a proxy for the price index of the domestically produced good.

the Rest of the World. These importing firms then differentiate it, e.g. by brand naming. The differentiated good they produce is sold on the euro area market at price $p_t^{M,l}$. It is assumed that importers can set optimally their price according to a random Calvo process with probability $(1-\xi_m)$. The share ξ_m of the importers who cannot optimise their price index to the previous period inflation rate in the imported price.

Depending on the degree of nominal stickiness, the pass-through of the exchange rate will be slower or quicker. In the long run, the pass-through is complete. This assumption yields a realistic empirical description of the pass-through process. Most empirical studies indeed report only a partial pass-through in the short run, a pass-through that is also very different between countries and sectors, but in the long run the hypothesis of complete pass-through cannot be rejected in most cases (cf. for example Campa and Goldberg, 2002).

Finally, imports of the domestic economy are translated into a demand for the foreign exports via

$$X_t^* = \beta_x \cdot M_t + (1-\beta_x) \cdot M_t^{ROW*}$$

with M_t^{ROW*} the imports from the Rest of the World originating from the foreign economy. Since the imports of the Rest of the World are not observed and do not enter the model, we treat them as a demand shock affecting the exports of the economy:

$$M_t^{ROW*} \equiv \varepsilon_t^{NT*} = \rho_{NT}^* \cdot \varepsilon_{t-1}^{NT*} + \eta_t^{NT*} \quad \text{with} \quad \eta_t^{NT*} \quad \text{an i.i.d.-Normal error term}$$

When setting optimally their price, import firms face the following problem:

$$\max_{\widetilde{p}_t^{Ml}} E_t \sum_{n=0}^{\infty} (\beta\xi_m)^n \left(\frac{\lambda_{t+i}}{\lambda_t P_{t+n}^M}\right) \left(\widetilde{p}_t^{M,l} - MC_{t+n}^{M,l}\right) m_t^l \tag{26}$$

Assuming that the differentiated import goods are combined through a CES technology, we have

$$M_t = \left[\int_0^1 \left(m_{s,t}^l\right)^{\frac{1}{1+\lambda_m}} dl\right]^{1+\lambda_m} \tag{27}$$

and the demand faced by each importing firm is

$$m_t^l = M_t \cdot \left(\frac{p_t^{Ml}}{P_t^M}\right)^{-\frac{1+\lambda_m}{\lambda_m}} \tag{28}$$

$MC_t^{M,l}$ is the marginal cost of importing firm l defined as

$$MC_t^{M,l} = \beta_m \frac{P_t^*}{S_t} + (1-\beta_m) \frac{P_t^{ROW}}{S_t^{ROW}} \tag{29}$$

with S_t and S_t^{ROW} respectively the US and Rest of the World exchange rates. Variables P_t^{ROW} and S_t^{ROW} do not appear anywhere else in the model and there is no observable data to measure them. We then proxy P_t^{ROW}/S_t^{ROW} by $P_t \cdot \varepsilon_t^{PM}$ where the price index of the final good in the euro area is used to scale the AR(1) disturbance term $\varepsilon_t^{PM} = \rho_{PM} \cdot \varepsilon_{t-1}^{PM} + \eta_t^{PM}$ with η_t^{PM} an i.i.d.-Normal error term.

2.3 Balance of payments

The current account relationship determines the accumulation of foreign assets B_t^*

$$\frac{1}{R_t^{e*}}\frac{B_t^*}{S_tP_t} - \frac{B_{t-1}^*}{S_tP_t} = X_t - \frac{P_t^M}{P_t}M_t - \frac{P_t^o}{S_tP_t}O_t$$

The trade balance is the difference between the real value of exports and the real value of non-oil imports and oil inputs, with

$$O_t = O_t^f + O_t^p$$

Like non-oil imports, oil intervenes both in the final good production and the intermediary domestic good production process. The demand for oil is assumed to be proportional to total demand and total production of domestically produced intermediate good: no substitution effects are allowed. The oil price together with the non-oil import price feed immediately into the final good price without any rigidity, while both prices affect the domestic output price gradually through the marginal production cost and the Calvo price setting assumption.

2.4 Market equilibrium

The final good market is in equilibrium if the production equals the demand by domestic consumers and investors, and the import firms acting for the US and the Rest of the World economies:

$$F_t = C_t + I_t + X_t$$

Government spendings are assumed to be realized exclusively in domestic goods so aggregate demand for the intermediate good is given by

$$\begin{aligned} D_t &= D_t^d + D_t^f + G_t \\ \text{with } G_t &\equiv \varepsilon_t^g = \rho_g \varepsilon_{t-1}^g + \eta_t^g, \text{ with } \varepsilon_t^g \text{ an i.i.d.-Normal error term} \end{aligned}$$

The capital rental market is in equilibrium if the demand for capital expressed by the intermediate goods domestic producer equals the supply by the households. Equilibrium on the labour market is realized if the firm's labour demand equals the labor supply at the wage set by the households.

The interest rate is determined by an empirical reaction function describing monetary policy decisions:

$$\begin{aligned} \widehat{R}_t &= \rho \cdot \widehat{R}_{t-1} + (1-\rho)\left\{ r_\pi \cdot \widehat{\pi}_t + r_y \cdot (1-\omega-\zeta) \cdot \left(\widehat{D}_t - \widehat{D}_t^{flex}\right)\right\} \\ &\quad + r_{dy}(1-\omega-\zeta)\left\{\left(\widehat{D}_t - \widehat{D}_t^{flex}\right) - \left(\widehat{D}_{t-1} - \widehat{D}_{t-1}^{flex}\right)\right\} \end{aligned}$$

where hats denote variables in deviation from their steady state and π_t the inflation rate in the final good price index. At equilibrium in the capital market, the government debt is held by domestic or foreign investors at rate R_t^e.

3 Estimation of the model

3.1 The structural shocks

In order to estimate the model on a series of 22 macroeconomic time series a complete set of 22 independent and well identified structural shocks are considered in the model:

1. Domestic economy shocks in the euro area and the US:

   - TFP shocks (AR(1) process);
   - investment-specific technology shocks (ARMA(1) process);
   - public expenditure shocks (AR(1) process);
   - risk premium shocks affecting consumption and investment (AR(1) process);
   - mark-up shocks in wages (ARMA(1,1) process);
   - mark-up shocks in domestic prices (ARMA(1,1) process);
   - mark-up shocks (or measurement error) in the consumption prices (i.i.d.);
   - monetary policy shocks (AR(1) process);

2. Shocks originating in the Rest of the World (all persistent AR(1) processes):

   - two demand shocks that affect exports from the US and the euro area;
   - two import price shocks driving US and euro area import prices;
   - oil price shocks;
   - uncovered interest rate parity shocks;

For the closed economy block there are some important differences compared to our earlier work. First of all the number of shocks is limited to the number of observable variables. We do no longer identify a separate labour supply shock, equity risk premium shock and inflation objective shock. The effects of these shocks have been absorbed by other shocks. In order to keep the same flexibility in the stochastic structure and a similar empirical fit some of the remaining shocks are now specified as ARMA(1,1) processes. The MA component helps to take up the short-run volatility in the series for inflation, real wages and investment. Reducing the number of shocks makes the identification less dependent on the prior assumptions. Combining shocks however also imply that the interpretation of some of them is more complicated: for instance the wage mark-up shock can also take up exogenous changes in the marginal rate of substitution between consumption and labour supply resulting from fundamental preference shifts. The absence of the inflation objective shock implies that the long-run trend in inflation is now explained by persistent inflation effects of the other shocks. It turns out that the price and especially the wage mark-up shock are responsible for this. The trade-off problems that these shocks create for monetary policy seem to produce persistent inflation effects. Finally, the shock in the discount rate of the households has been replaced with a shock to the returns on the financial assets that are held by the households. This shock may combine the impact of inefficiencies in the financial system on the one hand and time-varying risk premiums in the required returns on the other hand. This type of shock affects simultaneously consumption and investment in the same direction, a property that is helps explaining their comovement. The resulting time series of innovations for this shock has a very strong correlation in both countries with the changes in the interest rate spread between long and short rates, suggesting that the risk premium interpretation might be highly relevant.

3.2 Data and estimation method

The model presented above has been estimated with a Bayesian full information approach following the applications in Smets and Wouters (2003a,b). The 22 macroeconomic time series that are used for estimation contain ten-country specific variables plus the depreciation rate (EUR-USD) and oil price inflation.[2]

The ten country-specific series are the growth rate in real GDP, consumption, investment, real wages, the inflation rate in the GDP, consumption and import deflators, the short term interest rate, the real trade balance (expressed as a percentage of GDP) and employment (or hours worked for the US). These variables are translated to per capita data by dividing them with the population at working age.[3]

The estimation period is 1974:1-2004:4 so that the starting date is consistent with the exercise in Smets and Wouters (2005). A limited number of structural parameters which are very poorly identified by our estimation strategy are calibrated to reflect more or less the average historical values. The same values are used as in our previous closed economy exercises. All the open economy parameters are estimated, together with a constant trend growth rate and inflation rate.

3.3 Parameter estimates

The estimated structural parameters for the two domestic economy blocks (Table 1) are very similar for the US and the euro area confirming the results of Smets and Wouters (2003c). One of the few significant differences between the two economies is the magnitude of the adjustment cost in capital accumulation which is estimated to be higher in the euro area. Note also that the price stickiness (the Calvo parameter) is estimated at 0.7 for the US and 0.75 for the euro area, corresponding to an average price durations of 3.5 and 4 quarters

[2] Following Schnatz, Vijselaar and Osbat (2003), the exchange rate for the years preceding the euro has been computed as a synthetic index of the different European currencies exchange rates with respect to the US Dollar. The oil price series is the price of the UK Brent in US Dollar.

[3] For the euro area, employment is used instead of hours worked. Since this variable responds more slowly to macroeconomic shocks than hours worked, it is considered as in Smets and Wouters (2003a) that only a constant fraction of firms is able to adjust employment to the desired total labor input.

respectively. These lower estimates result from the introduction of a varying elasticity of demand in the aggregator function, following the results in Eichenbaum and Fischer (2004) when imposing $\epsilon = 33$.[4]

Table 1: Prior and posterior parameter erstimates: domestic economy behavioral parameters

	Prior Distribution			Posterior distribution					
				High Substitution Model		Low Substitution Model		Model without UIRP	
	distribution	mean	stdev	mode	90% interval	mode	90% interval	mode	90% interval
euro area									
inv. adj. cost	norm	4	1,5	8,07	6,20 / 9,54	7,77	6,34 / 9,61	7,48	5,80 / 9,29
sigma cons. util.	norm	1,5	0,375	0,84	0,77 / 0,98	1,06	0,90 / 1,30	1,07	0,96 / 1,55
sigma labor util.	norm	2	0,75	2,36	1,34 / 3,33	1,88	0,99 / 2,93	2,11	1,11 / 3,09
h	beta	0,7	0,1	0,74	0,68 / 0,79	0,72	0,66 / 0,79	0,73	0,61 / 0,77
wage mark-up	norm	0,5	0,15	0,49	0,28 / 0,71	0,50	0,25 / 0,73	0,47	0,21 / 0,70
Calvo wage	beta	0,75	0,05	0,77	0,71 / 0,83	0,76	0,71 / 0,83	0,79	0,74 / 0,85
wage index.	beta	0,5	0,15	0,32	0,15 / 0,47	0,33	0,16 / 0,50	0,33	0,17 / 0,50
Calvo price	beta	0,66	0,05	0,74	0,68 / 0,79	0,74	0,69 / 0,78	0,74	0,68 / 0,78
price index.	beta	0,5	0,15	0,21	0,09 / 0,31	0,20	0,10 / 0,30	0,21	0,09 / 0,30
Calvo employ.	beta	0,5	0,15	0,77	0,73 / 0,80	0,78	0,75 / 0,81	0,78	0,74 / 0,80
cap. util. adj. cost	norm	0,2	0,075	0,19	0,10 / 0,32	0,23	0,13 / 0,34	0,21	0,13 / 0,34
fixed cost	norm	1,25	0,125	1,35	1,22 / 1,52	1,30	1,21 / 1,46	1,34	1,23 / 1,51
US									
inv. adj. cost	norm	4	1,5	4,39	3,00 / 6,06	4,38	3,01 / 5,54	4,16	2,88 / 5,63
sigma cons. util.	norm	1,5	0,375	0,94	0,78 / 2,03	0,92	0,78 / 1,23	0,91	0,78 / 1,22
sigma labor util.	norm	2	0,75	2,72	1,64 / 3,54	2,65	1,81 / 3,80	2,94	2,23 / 3,84
h	beta	0,7	0,1	0,72	0,57 / 0,77	0,71	0,60 / 0,76	0,71	0,62 / 0,77
wage mark-up	norm	0,5	0,15	0,41	0,02 / 0,71	0,39	0,11 / 0,67	0,36	0,10 / 0,65
Calvo wage	beta	0,75	0,05	0,83	0,77 / 0,88	0,83	0,77 / 0,89	0,83	0,78 / 0,89
wage index.	beta	0,5	0,15	0,34	0,17 / 0,59	0,34	0,18 / 0,58	0,35	0,20 / 0,62
Calvo price	beta	0,66	0,05	0,70	0,63 / 0,74	0,71	0,65 / 0,76	0,69	0,64 / 0,75
price index.	beta	0,5	0,15	0,28	0,14 / 0,46	0,27	0,14 / 0,44	0,30	0,15 / 0,50
cap. util. adj. cost	norm	0,2	0,075	0,23	0,15 / 0,37	0,22	0,13 / 0,33	0,21	0,11 / 0,33
fixed cost	norm	1,25	0,125	1,46	1,36 / 1,58	1,45	1,34 / 1,57	1,43	1,33 / 1,56
Taylor rule EA									
r inflation	norm	1,5	0,25	1,62	1,31 / 1,94	1,64	1,34 / 1,92	1,72	1,43 / 1,95
r lagged int. rate	beta	0,75	0,1	0,88	0,84 / 0,92	0,89	0,85 / 0,92	0,91	0,88 / 0,93
r output gap	norm	0,125	0,05	0,08	0,04 / 0,13	0,10	0,06 / 0,15	0,10	0,06 / 0,16
r d(out. gap)	norm	0,125	0,05	0,19	0,15 / 0,25	0,21	0,16 / 0,27	0,20	0,17 / 0,26
Taylor rule US									
r inflation	norm	1,5	0,25	1,50	1,21 / 1,74	1,57	1,26 / 1,82	1,70	1,35 / 1,90
r lagged int. rate	beta	0,75	0,1	0,87	0,83 / 0,90	0,87	0,83 / 0,90	0,87	0,83 / 0,90
r output gap	norm	0,125	0,05	0,12	0,06 / 0,18	0,14	0,09 / 0,21	0,13	0,07 / 0,19
r d(out. gap)	norm	0,125	0,05	0,21	0,17 / 0,26	0,21	0,17 / 0,26	0,21	0,18 / 0,26

Compared to our previous papers, the mark-up shocks are now allowed to have a persistent component through the ARMA process (Table 2). A small fraction of the innovations does indeed have persistent effect and as a result these shocks do seem to explain successfully the long-run movements in the inflation rate (see also Ireland 2005). The stochastic structure is very similar between the two economies although there are some differences in these estimates as well. The standard error of the productivity shock turns out to be higher in the euro area. The standard error of the monetary policy shock is higher in the

[4] ϵ is the percentage change in the demand elasticity caused by a modification in the relative price of good j, evaluated at steady state.

US (the Volcker period is included), but this difference is compensated by a significant positive autocorrelation coefficient in the euro area monetary shock. There is more dispersion between the estimates of the persistence of the shock processes in the two economies but these estimates are less precise as well. In the US, the government spending shock and the shock affecting exports are relatively more persistent. In general, the typical open economy shocks (import price shocks, export demand shocks, oil prices and UIRP shocks) are all highly persistent. It is also interesting to see that all these parameters are very similar between the different model versions except for the volatility of the open economy shocks (import prices and exports) which are significantly lower for the model without UIRP. The UIRP shock has a completely different profile in the models with or without UIRP and can therefore not be compared.

Table 2: Prior and posterior parameter estimates: stochastic structure and constant trends

	Prior Distribution			Posterior distribution					
				High Substitution Model		Low Substitution Model		Model without UIRP	
	distribution	mean	stdev	mode	90% interval	mode	90% interval	mode	90% interval
Standard errors of the shocks									
euro area									
TFP	invg	0,1	2	0,78	0,60 / 0,93	0,79	0,64 / 0,94	0,77	0,60 / 0,87
risk prem.	invg	0,1	2	0,49	0,33 / 0,73	0,62	0,41 / 0,98	0,62	0,41 / 0,92
gov. spend.	invg	0,1	2	0,36	0,32 / 0,41	0,36	0,33 / 0,41	0,36	0,33 / 0,40
invest.	invg	0,1	2	0,53	0,45 / 0,60	0,57	0,49 / 0,66	0,55	0,47 / 0,63
monetary pol.	invg	0,1	2	0,16	0,14 / 0,18	0,15	0,14 / 0,18	0,15	0,14 / 0,17
price mark-up	invg	0,1	2	0,14	0,11 / 0,16	0,14	0,11 / 0,16	0,14	0,12 / 0,17
wage mark-up	invg	0,1	2	0,18	0,15 / 0,22	0,19	0,15 / 0,22	0,18	0,15 / 0,21
cons. price	invg	0,1	2	0,23	0,21 / 0,26	0,23	0,21 / 0,25	0,23	0,21 / 0,25
imp. price	invg	0,1	2	0,60	0,46 / 0,78	0,54	0,43 / 0,71	0,43	0,35 / 0,66
exp. demand	invg	1	2	2,38	2,09 / 2,82	2,35	2,00 / 2,79	2,14	1,94 / 2,71
US									
TFP	invg	0,1	2	0,44	0,40 / 0,49	0,44	0,39 / 0,50	0,44	0,39 / 0,49
risk prem.	invg	0,1	2	0,73	0,51 / 1,71	0,67	0,47 / 0,86	0,65	0,43 / 0,92
gov. spend.	invg	0,1	2	0,53	0,49 / 0,60	0,53	0,48 / 0,60	0,53	0,49 / 0,60
invest.	invg	0,1	2	0,55	0,44 / 0,70	0,55	0,44 / 0,66	0,53	0,40 / 0,65
monetary pol.	invg	0,1	2	0,24	0,22 / 0,28	0,24	0,22 / 0,28	0,24	0,22 / 0,27
price mark-up	invg	0,1	2	0,15	0,12 / 0,21	0,15	0,13 / 0,23	0,15	0,13 / 0,22
wage mark-up	invg	0,1	2	0,22	0,18 / 0,26	0,23	0,18 / 0,26	0,21	0,18 / 0,26
cons. price	invg	0,1	2	0,18	0,16 / 0,20	0,18	0,16 / 0,19	0,17	0,16 / 0,19
imp. price	invg	0,1	2	0,74	0,55 / 0,97	0,65	0,46 / 0,88	0,59	0,44 / 0,81
exp. demand	invg	1	2	1,92	1,68 / 2,25	1,90	1,67 / 2,24	1,89	1,68 / 2,18
open									
UIRP	invg	0,1	2	0,42	0,24 / 0,65	0,33	0,17 / 0,58	4,42	4,05 / 4,96
oil price	invg	0,1	2	0,09	0,08 / 0,10	0,09	0,08 / 0,10	0,09	0,08 / 0,10

Table 2 (continued): Prior and posterior parameter estimates: stochastic structure and constant trends

	Prior Distribution			Posterior distribution					
				High Substitution Model		Low Substitution Model		Model without UIRP	
	distribution	mean	stdev	mode	90% interval	mode	90% interval	mode	90% interval
AR (rho) and MA (phi) parameters									
euro area									
rho TFP	beta	0,75	0,15	0,96	0,95 / 0,98	0,98	0,97 / 0,99	0,99	0,98 / 1,00
rho risk prem	beta	0,75	0,15	0,81	0,73 / 0,87	0,76	0,65 / 0,83	0,77	0,68 / 0,86
rho gov spen	beta	0,75	0,15	0,83	0,77 / 0,91	0,83	0,77 / 0,91	0,83	0,76 / 0,90
rho invest.	beta	0,75	0,15	0,92	0,87 / 1,00	0,89	0,76 / 0,96	0,90	0,82 / 1,00
phi invest.	beta	0,75	0,15	0,86	0,78 / 0,94	0,84	0,67 / 0,92	0,84	0,71 / 0,93
rho mon pol	beta	0,25	0,15	0,36	0,25 / 0,49	0,38	0,25 / 0,53	0,36	0,24 / 0,51
rho price m-up	beta	0,75	0,15	0,92	0,83 / 0,97	0,91	0,80 / 0,96	0,92	0,80 / 0,96
phi price m-up	beta	0,75	0,15	0,86	0,71 / 0,93	0,86	0,66 / 0,93	0,86	0,66 / 0,92
rho wage m-up	beta	0,75	0,15	0,98	0,96 / 0,99	0,97	0,96 / 0,98	0,98	0,96 / 0,99
phi wage m-up	beta	0,75	0,15	0,90	0,83 / 0,93	0,89	0,83 / 0,93	0,91	0,85 / 0,95
rho imp price	beta	0,75	0,15	0,99	0,97 / 1,00	0,98	0,96 / 0,99	0,99	0,96 / 1,00
rho exp demand	beta	0,75	0,15	0,90	0,86 / 0,97	0,96	0,93 / 0,98	0,89	0,87 / 0,99
US									
rho TFP	beta	0,75	0,15	0,95	0,93 / 1,00	0,96	0,92 / 0,99	0,96	0,93 / 1,00
rho risk prem	beta	0,75	0,15	0,80	0,54 / 0,87	0,83	0,78 / 0,88	0,82	0,72 / 0,90
rho gov spen	beta	0,75	0,15	0,95	0,92 / 1,00	0,95	0,91 / 1,00	0,95	0,92 / 1,00
rho invest.	beta	0,75	0,15	0,97	0,91 / 0,99	0,97	0,92 / 0,99	0,97	0,93 / 0,99
phi invest.	beta	0,75	0,15	0,82	0,63 / 0,87	0,82	0,68 / 0,88	0,81	0,63 / 0,87
rho mon pol	beta	0,25	0,15	0,06	0,01 / 0,16	0,04	0,00 / 0,12	0,04	0,00 / 0,14
rho price m-up	beta	0,75	0,15	0,84	0,72 / 0,93	0,84	0,73 / 0,93	0,84	0,74 / 0,92
phi price m-up	beta	0,75	0,15	0,78	0,60 / 0,98	0,78	0,65 / 0,99	0,78	0,75 / 0,99
rho wage m-up	beta	0,75	0,15	0,94	0,76 / 0,99	0,94	0,86 / 0,97	0,91	0,83 / 0,95
phi wage m-up	beta	0,75	0,15	0,89	0,62 / 0,97	0,90	0,75 / 0,95	0,86	0,71 / 0,91
rho imp price	beta	0,75	0,15	0,97	0,94 / 0,99	0,97	0,94 / 0,99	0,97	0,94 / 1,00
rho exp demand	beta	0,75	0,15	0,99	0,98 / 1,00	1,00	0,99 / 1,00	0,99	0,99 / 1,00
open									
rho oil price	beta	0,75	0,15	0,96	0,94 / 0,98	0,96	0,94 / 0,98	0,98	0,97 / 1,00
rho UIRP	beta	0,5	0,15	0,92	0,87 / 0,96	0,94	0,89 / 0,97	0,33	0,22 / 0,41
cpy_ea	norm	0,5	0,25	0,61	0,49 / 0,71	0,61	0,51 / 0,73	0,60	0,50 / 0,72
cpy_us	norm	0,5	0,25	0,53	0,31 / 0,68	0,52	0,31 / 0,67	0,52	0,34 / 0,66
trends euro area									
GDP price infl.	norm	0,625	0,1	0,65	0,48 / 0,79	0,67	0,53 / 0,82	0,81	0,67 / 0,92
Imp. price infl.	norm	0,625	0,1	0,62	0,46 / 0,80	0,63	0,46 / 0,78	0,45	0,36 / 0,62
Oil price infl.	norm	0	0,1	-0,01	-0,15 / 0,17	0,00	-0,15 / 0,18	0,03	-0,13 / 0,18
nom. inter. rate	norm	0,625	0,1	0,63	0,44 / 0,78	0,62	0,46 / 0,79	0,60	0,47 / 0,74
labour	norm	0	0,1	-0,07	-0,09 / -0,03	-0,08	-0,10 / -0,05	-0,07	-0,09 / -0,04
GDP	norm	0,4	0,1	0,46	0,43 / 0,49	0,48	0,44 / 0,51	0,48	0,45 / 0,52
trends US									
GDP price infl.	norm	0,625	0,1	0,75	0,65 / 0,87	0,68	0,57 / 0,79	0,68	0,53 / 0,80
Imp. price infl.	norm	0,625	0,1	0,41	0,32 / 0,52	0,44	0,33 / 0,55	0,57	0,46 / 0,72
nom. inter. rate	norm	0,625	0,1	0,62	0,50 / 0,78	0,59	0,46 / 0,71	0,62	0,49 / 0,76
labour	norm	0	0,1	0,01	-0,01 / 0,04	0,02	0,00 / 0,04	0,02	0,00 / 0,04
GDP	norm	0,4	0,1	0,44	0,41 / 0,49	0,45	0,41 / 0,49	0,43	0,38 / 0,47

The first set of parameters in the open economy block (Table 3) determines the structural characteristics of the economies: the total imports of oil makes up some 1.3% of GDP and the fraction that is immediately used in final demand (consumption, investment and exports) is a bit higher than the share that enters the production of intermediate goods. The non-oil imports are estimated at 13% of GDP for the euro area and a relatively high figure of 11% for the US. Slightly more than half of these imports enter as intermediate inputs in production. Finally the estimates of the share of domestic services in the import distribution sector differ between the model variants depending on the estimated elasticity of substitution in international trade (see the discussion below).

Table 3: Prior and posterior parameter estimates: open economy parameters

	Prior Distribution			Posterior distribution					
				High Substitution Model		Low Substitution Model		Model without UIRP	
	distribution	mean	stdev	mode	90% interval	mode	90% interval	mode	90% interval
euro area									
structural parameters									
imp. goods in D	norm	0,06	0,01	0,06	0,04 / 0,07	0,07	0,06 / 0,09	0,07	0,05 / 0,08
imp. goods in F	norm	0,06	0,01	0,07	0,06 / 0,08	0,06	0,05 / 0,07	0,07	0,06 / 0,08
delta	beta	0,7	0,1	0,86	0,77 / 0,93	0,67	0,46 / 0,82	0,76	0,58 / 0,84
oil in D	norm	0,006	0,001	0,006	0,004 / 0,007	0,007	0,005 / 0,008	0,007	0,005 / 0,008
oil in F	norm	0,006	0,001	0,007	0,005 / 0,008	0,007	0,006 / 0,008	0,007	0,006 / 0,008
beta m	beta	0,4	0,1	0,53	0,42 / 0,65	0,59	0,48 / 0,70	0,35	0,27 / 0,43
beta x	beta	0,4	0,1	0,36	0,26 / 0,50	0,18	0,10 / 0,32	0,23	0,14 / 0,40
trade parameters									
subst. elast.	norm	1,5	0,5	3,01	2,59 / 3,57	1,08	0,53 / 1,74	1,97	1,27 / 2,28
adj. cost.	norm	4	1	4,23	2,63 / 5,66	3,89	2,09 / 5,65	4,04	2,34 / 5,74
Calvo import	beta	0,75	0,05	0,61	0,54 / 0,67	0,64	0,58 / 0,70	0,68	0,58 / 0,73
imp. price index.	beta	0,5	0,15	0,18	0,07 / 0,30	0,17	0,08 / 0,30	0,17	0,08 / 0,31
US									
structural parameters									
imp. goods in D	norm	0,05	0,01	0,06	0,05 / 0,07	0,06	0,05 / 0,07	0,06	0,05 / 0,07
imp. goods in F	norm	0,05	0,01	0,05	0,04 / 0,06	0,05	0,04 / 0,06	0,05	0,04 / 0,06
delta	beta	0,7	0,1	0,73	0,58 / 0,86	0,66	0,46 / 0,83	0,69	0,50 / 0,83
oil in D	norm	0,006	0,001	0,006	0,005 / 0,007	0,006	0,005 / 0,007	0,006	0,005 / 0,007
oil in F	norm	0,006	0,001	0,007	0,006 / 0,009	0,007	0,006 / 0,009	0,007	0,006 / 0,009
beta m	beta	0,4	0,1	0,55	0,42 / 0,67	0,30	0,19 / 0,45	0,31	0,21 / 0,41
beta x	beta	0,4	0,1	0,25	0,16 / 0,33	0,39	0,25 / 0,54	0,31	0,20 / 0,45
trade parameters									
subst. elast.	norm	1,5	0,5	1,74	1,23 / 2,37	1,26	0,36 / 1,74	1,16	0,45 / 1,75
adj. cost.	norm	4	1	4,19	2,83 / 5,91	4,22	2,49 / 5,59	4,06	2,72 / 5,67
Calvo import	beta	0,75	0,05	0,66	0,58 / 0,72	0,68	0,59 / 0,75	0,70	0,61 / 0,77
imp. price index.	beta	0,5	0,15	0,09	0,04 / 0,19	0,10	0,04 / 0,19	0,09	0,04 / 0,21

The remaining open-economy parameters determine the pass-through of the foreign prices and exchange rate fluctuations and the substitution effects in the trade flows. The pass-through of the bilateral exchange rate in the total import price of the two economies is first of all governed by the weight that is assigned to the bilateral exchange rate in total imports: in the model without UIRP this weight is only 35% for US price/exchange rate in the euro area import price and 31% for the euro area price/exchange rate in the US import price. The estimates are considerable higher (up to 59%) in the model with UIRP imposed. The Calvo parameter for import prices is very similar for the two economies and for the different model versions and varies between 0.61 and 0.70: that is an average contract duration of 3 quarters for import prices. The estimated indexation in the import prices is negligible. Combined, these parameters produce a pass-through of the bilateral exchange rate that is slow on impact and limited by the share of bilateral trade in the long-run. Given the forward looking character of the Calvo specification, the pass-through will differ depending on the expected persistence of the exchange rate fluctuations. Bergin (2004) also estimates a high degree of pricing to market to fit the small pass-through effect. Our modelling approach is somewhat more flexible by differentiating between the initial and the long-run pass-through, and by accounting for the bilateral nature of the exchange rate.

The elasticity of substitution between domestic and foreign goods is a crucial parameter for the open economy block. The existing empirical evidence on this parameter yields mixed results: at the micro level evidence points in favour of a high substitution elasticity, while at the macro level the typical estimates are sometimes far below one. Ruhl (2003) argues that this elasticity might be much higher for permanent relative price shocks (typical for the trade liberalisation type of studies) than for temporal shocks (due to cyclical macroeconomic adjustments). In our setup, following Corsetti *et al.* (2003), the value of the elasticity of substitution is further influenced by the estimated share of the domestic services in the import distribution sector. This domestic service component implies that the effective trade elasticities are lower than the estimated elasticity of substitution between domestic and foreign goods. In the model without UIRP, the elasticity of substitution is estimated at 1.97 for the euro area and 1.16 for the US.

In the model with UIRP this parameter has important implications that exceeds its role for the trade elasticity as it will also determine the reaction of the exchange rate to the various exogenous shocks. Because of the discontinuous and extreme reaction of the exchange rate around some critical value for this parameter, an iterative optimisation procedure will never succeed to cross this critical point. To overcome this problem, we consider in our estimation two different starting values for the substitution elasticity, one above the critical value and one below. The marginal likelihood value of the two models will give an indication of what parameter value is preferred by the data. The model with high elasticities converges to an estimate of 3.01 for the euro area and 1.74 for the US. At the same time the share of domestic services is estimated to be very small so that the effective trade elasticities are close to the high substitution parameter. As we will explain more in detail in the next section, these high elasticities are necessary to make the expenditure switching effect sufficiently large to guarantee long-run stability for the foreign asset accumulation and to moderate the systematic reaction of the exchange rate to the exogenous shocks. The optimal estimates in the low elasticity region are 1.08 for the euro area and 1.24 for the US. In this region of the parameter space, values far below the critical value are preferred so that the terms-of-trade wealth effects dominate the smaller substitution effects in order to secure stability with moderate exchange rate volatilities.

Finally, the estimates for the trade reallocation adjustment costs are estimated close to the prior (with mean 4), illustrating the lack of strong information in the data about this parameter. The imports of one country determine the exports of the other country again after taken into account that the bilateral trade is only a share of the total export and import: the weights are estimated between 20 and 30%.

3.4 Marginal likelihood of the three model versions

The two models with a high and a low elasticity of substitution have a very similar marginal likelihood (2358.99 versus 2355.27). The low elasticity model does marginally better than the model with a high elasticity. It is difficult to compare the marginal likelihood of these DSGE models with a-theoretical models given the high number of variables that are considered here. Preliminary comparisons seem to suggest that the marginal likelihood of the structural models outperform the joint marginal likelihood of univariate autoregressive equations or the joint marginal likelihood of separate BVAR models for blocks of the variables. These last results also suggest that the explanatory power for the typical closed economy variables is certainly not deteriorated by considering them in a larger open economy context.

The marginal likelihood of the model without UIRP is significantly higher than the marginal likelihood of the models with UIRP (2314.03). The main difference is that the exchange rate is treated as exogenous in the model without UIRP while the models with UIRP imply a systematic response of the exchange rate to the various exogenous shocks. With UIRP the equilibrium exchange rate will also depend on the stability requirement imposed by the net foreign asset accumulation. Without UIRP this stability condition is not imposed on the model dynamics and the net foreign assets equation is dropped. The systematic response of the exchange rate in the models with UIRP differ according to the parameter region for the elasticity of substitution, but none of the two versions seem to be supported strongly by the data.

The estimated model is further evaluated in the following sections by showing the plausibility of the structural impulse response functions for the different shocks and by analysing the implied decomposition of the historical data and the variance decomposition of the forecast errors. We will also check the capability of the models to reproduce a list of stylised facts that are traditionally considered in the NOEM literature.

4 Impulse response functions for the shocks

We discuss the impulse response functions for the two versions of the model with UIRP and a higher and a lower degree of substitution. Some of the impulse response functions are relatively insensitive to this parameter but for other shocks these functions are fundamentally altered at least as far as the open economy variables are concerned: the supply shocks (both productivity and mark-up shocks) are more sensitive while the demand shocks are less affected.

4.1 Domestic supply and demand shocks

In the model we identify two types of productivity shocks: transitory level shocks to total factor productivity (TFP) that are modelled as a highly persistent AR(1) process and transitory shocks to the investment-specific technology that lead to changes in the relative price of investment goods and that is modelled as an ARMA(1,1) process with a small persistent component. In the following discussion, we concentrate the discussion on the shocks that affect the euro area economy.

4.1.1 Level shocks in TFP (see Graph 1)

The TFP shock expands temporarily the production frontier of the economy and lowers the marginal cost of production. Firms lower their prices, but given the stickiness this will happen only gradually over time. Real wages and real income increase and consumption will follow with a slight delay given the habit persistence in preferences. Higher expected returns on capital stimulate investment. Employment or hours worked temporally decrease. The exact impulse response for this typical productivity shock depends on a number of important parameters in the model. We know from the discussion on the effects of a productivity shock on employment in the closed economy context, that the impact of a productivity shock depends crucially on how accommodating monetary policy reacts to the shock, on how quick domestic demand and prices respond and on the expected path of future productivity. The same parameters also have an impact on the open economy implications of a productivity shock. However in an open economy context, another crucial parameter for the productivity shock is the degree of substitution between domestic and foreign goods.

First, we will consider the case with a high substitution elasticity. In this model the productivity shock results in an important depreciation of the exchange rate. The basic argument is that the supply of the domestic good is increased so that the price of this good relative to the foreign good has to decline relative to foreign good price in order for demand to shift towards the domestic good. This means that the domestic economy will undergo a deterioration in the terms-of-trade. The initial depreciation in the exchange rate raise the retail import prices only gradually given the price stickiness in the importing sector. The stickiness in the domestic prices also implies that the domestic and export prices only gradually fall following the decrease in the marginal cost. As these relative price adjustments take time and because there are important adjustment costs in the reallocation of demand between domestic and foreign goods, exports and imports respond slowly to the relative price as well. The result is a strong deficit in the current account mainly because of the positive income effect on imports but also because of the terms-of-trade deterioration that dominates the substitution effect in net exports. This deficit continues for several years and is stabilized finally through a positive real trade balance caused by the high long term trade elasticities.

The important deterioration of the terms-of-trade also limits the expansion of domestic demand and especially consumption compared to the closed economy model. The terms-of-trade deterioration for the domestic economy and the terms-of-trade gain for the US economy result in a sharing of the wealth effects between the two economies. The outcome is a modest expansion in consumption expenditures in the US. On the other hand, the depreciation of the euro and the resulting loss in competitiveness implies that production will expand less than domestic demand in the US economy.

A very different picture occurs when we consider the version of the model with a lower elasticity of substitution. Corsetti *et al.* (2003) recently discussed the importance of the intratemporal substitution parameter to understand the exchange rate reaction following a productivity shock. For a high elasticity of substitution, the exchange rate reaction will remain modest because the resulting expenditure switching effects are large. Relatively minor exchange rate movements will be able to restore the equilibrium in the trade balance. As the elasticity of substitution becomes smaller, it is clear that the required fluctuations in the exchange rate need to be higher. We know from the traditional and static Marshall-Lerner condition that the impact of the exchange rate on the current account will reverse for some critical value. A similar critical value exists in these dynamic and more complex open economy models, although it is difficult to understand the exact value of this critical point as it will also depend on the degree and the speed of the pass-through of the exchange rate on relative prices, the implied import shares of the final expenditures, and the domestic service component in the import distribution sector. For values of the substitution elasticity approaching the critical value, the fluctuations in the exchange rate are extremely high. At the critical value the sign of the exchange rate response to shocks in the supply of domestic and foreign shocks will reverse. For even smaller values, the expenditures switching effects of the exchange rate are minimal and income and wealth effects will be dominant in explaining the behaviour of the current account.

Graph 1 summarises the impact of the productivity shock in the model version with a low substitution elasticity. The exchange rate shows a gradual appreciation following the productivity shock. Because of the wealth effects that result from the terms-of-trade amelioration, domestic consumption and real wages react much stronger to the productivity shock. The spill-over effect on the US economy will also change completely: consumption will rather tend to decrease because of the terms-of-trade loss, but on the other hand, there will be a positive expenditure switching effect towards US goods.

4.1.2 Investment-specific technology shocks (see Graph 2)

The second type of productivity shock that is identified in the model is the investment-specific technology shock. This shock decreases the price of investment goods and makes it interesting for firms to invest and to increase the capital stock. In the short-run, this shock resembles much more a demand shock than a supply shock. Higher investment translates in higher imports and therefore in a deterioration in the trade balance. The strong deterioration of the trade balance contrasts with the TFP shock. With a high substitution elasticity the exchange rate has to depreciate over time in order to produce the expenditure switching effect in demand towards the domestic good and to stabilise again the long-run trade balance. With a lower substitution elasticity, it will again be the wealth effects of the terms-of-trade that are the dominant equilibrating mechanism: a sufficient strong appreciation support domestic demand and offsets the net trade deficit.

The exchange rate fluctuations remain however of a relatively small size. The spill-over effects on US output are positive mainly because of the increased import demand by the euro area. This direct effect dominate the wealth and substitution effects.

The results for the two types of productivity shocks point out that positive productivity shocks are only able to explain a strong appreciation of the exchange rate if the substitution elasticity is relatively small. All the productivity shocks lead to a deterioration in the current account. We will analyse below to what extent the strong productivity developments in the US during the last decade have contributed to the EUR-USD fluctuations and the destabilising developments in the current account over that period. Probably other models of technological progress, which take the form of product innovation rather than process innovation, will be able to generate a stronger real appreciation of the exchange rate. Intuitively this result is likely because the major impact of such shocks is to generate an additional demand for the innovative economy in contrast to the productivity shocks here which have their major impact via the expansion of supply.

4.1.3 Mark-up shocks (see Graph 3)

In the model we have both price and wage mark-up shocks that are modelled as ARMA(1,1) processes. These shocks lead to higher prices and persistently higher inflation and lower aggregate demand and supply. Higher domestic prices have a positive effect on the terms-of-trade. The lower income depresses imports. Together these effects lead to a positive current account. The exchange rate response will again depend on the elasticity of substitution: with a higher substitution, the real exchange rate appreciates so that the strong expenditure switching effect can stabilise the current account. With a lower substitution, the real exchange rate depreciates in order to offset the positive terms-of-trade effects. The impact of the mark-up shocks is very similar to a negative productivity shock: higher mark-ups restrain supply and this will require a real appreciation of the exchange rate if the degree of substitution is sufficiently high (this result corresponds also with Benigno and Thoenissen, 2002).

4.1.4 Domestic demand shocks (see Graph 4)

Domestic demand shocks lead to an important appreciation of the currency. The effect is very similar for shocks in consumption and investment caused by changes in the risk premium and for a public spending shocks. Higher demand implies that the relative price of the domestic goods relative to the foreign goods increases. The strong response of the interest rate to the surge in output and inflation also supports the temporal appreciation of the exchange rate. Again the spill-over effects on the US output are limited because the positive effects resulting from the net trade flows are offset by the negative terms-of-trade effect on domestic demand in the US economy.

4.1.5 Monetary policy shocks (see Graph 5)

The same mechanisms are at work for a monetary policy shock. Higher interest rates have a negative effect on domestic demand and as the UIRP holds, the exchange rate appreciates. The exchange rate reaction implies an additional transmission mechanism of a monetary policy shock. The appreciation generates a further negative contribution to GDP via net exports. However, compared to the closed economy model, the terms-of-trade effect tends to weaken the transmission channel of the interest rate shock on domestic consumption.

4.2 Open economy shocks

4.2.1 Oil shocks and import price shocks (see Graph 6)

The oil price shock is estimated to have a standard error of 8,5% with a high autocorrelation of 0.96 and corrected for the two period moving average that is used as observed data. The impact on GDP is around 0.1% in the first and second year. Both consumption and investment decline after the shock. Consumption declines because of the monetary policy response but also because of the negative wealth effect following the term of trade loss of the oil importing economies. As we assumed that a fraction of oil imports is used immediately in final consumption and the other fraction is used as a production factor in domestic production, the pass-through of the oil price is quite complex in the model. The share of oil imports used in final consumption is assumed to be characterized by flexible prices, so that the consumption price adjusts immediately. On the other hand, oil is part of the production cost of domestic firms and the oil price will work gradually through the final sales price of domestic goods in line with the estimated stickiness of the domestic price setting. The complex pass-through implies that consumption prices will first adjust immediately due to the oil component in final consumption and then there will be some additional inflationary pressure through the domestic price component. The pass-through in the domestic sales price will however be largely offset by the decline in other domestic costs and especially in real wages. The further pass-through of oil prices also depend on the exchange rate reaction to the shock. This response will again depend on the degree of substitution in the trade-flows. The impact effect on the current account is negative because of higher costs of oil imports. If the expenditure switching effect is strong enough, a depreciation will stabilise the long-run current account. This implies that domestic wealth and demand in the euro area are further eroded, but on the other hand the real trade balance reacts slightly positively (see Jimenez-Rodriguez and Sanchez, 2004 for empirical evidence on this). If on the other hand the substitution is low, an appreciation and the resulting term of trade gains will offset the oil price shock.

The impact of import price shocks is more complicated. The impact on inflation and negative terms-of-trade effect are very similar, but a higher import price also ameliorates the competitiveness of the economy. The result is an appreciation of the exchange rate independent of the assumption on the substitution elasticity.

4.2.2 Uncovered interest rate parity shocks (see Graph 7)

The UIRP shock has to take up the remaining unexplained fluctuations in the exchange rate. The standard error of this shock is very large (4.5%) and highly persistent. A large exchange rate appreciation leads to a strong decrease in import prices. Although the exchange rate shock is typically overshooting on impact, the maximum response on import prices is only attained after one year and after two years for the consumption price. The appreciation also causes an important shift in demand toward the foreign goods what results in a negative trade balance. At the same time there are important gains in the terms-of-trade which generate a large positive wealth effect that supports domestic demand. In the short-run this terms-of-trade effect dominates, but if the substitution elasticity is high enough, the relative size of the two effects will reverse once the expenditure switching effects are fully realised. In that case the current account follows the typical J-curve profile. If the substitution effect is weak, the current account will remain positive for a considerable time.

4.2.3 ROW demand shocks (see Graphs 8)

A positive ROW demand shock improves the net trade balance but crowds out domestic demand because of the persistent inflationary effects that calls for a strong monetary policy reaction. The implications for the exchange rate again differ according to the strength of the substitution effects. With a high substitution, the exchange rate appreciates and the net trade balance is reversed. A lower substitution implies a depreciation with further negative domestic demand effects as a result. The depreciation redistributes the demand shock over the two economies.

5 Further model validation tests through summary statistics for the open economy variables

In Table 4 we summarise a series of statistics that describe some important open economy characteristics observed in the data. The table is based on HP-filtered data and the real exchange rate is always expressed as the euro in terms of US dollar. We also report the same statistics calculated for the three estimated models. The list of variables is similar to the one reported in Chari, Kehoe and McGrattan (2002).

Table 4: Stylised facts

	DATA		HIGH SUBSTITUTION MODEL		LOW SUBSTITUTION MODEL		MODEL WITHOUT UIRP	
	US	Euro Area	US	Euro Area	US	Euro Area	US	Euro Area
st.dev.								
GDP	1,55	1,03	1,67	1,53	1,68	1,47	1,66	1,50
Consumption	1,19	0,92	1,74	1,69	1,70	1,75	1,69	1,78
Investment	5,20	2,54	6,00	4,14	6,10	3,89	5,91	3,94
Employment	1,32	0,72	1,19	0,55	1,21	0,51	1,19	0,52
Net Trade	0,40	0,48	0,46	0,64	0,42	0,52	0,43	0,56
Real Exchange Rate	7,84		7,36		7,25		7,50	
Relative Consumption Price	0,93		1,26		1,25		1,30	
autocorrelation								
GDP	0,87	0,87	0,87	0,89	0,87	0,88	0,87	0,88
Consumption	0,86	0,86	0,88	0,90	0,88	0,90	0,88	0,90
Investment	0,92	0,88	0,93	0,92	0,93	0,91	0,93	0,92
Employment	0,89	0,97	0,82	0,94	0,83	0,94	0,83	0,94
Net Trade	0,86	0,86	0,85	0,85	0,84	0,84	0,85	0,85
Real Exchange Rate	0,86		0,70		0,71		0,84	
Relative Consumption Price	0,93		0,94		0,94		0,94	
Cross Correlation over Countries								
GDP	0,42		0,05		0,00		0,05	
Consumption	0,33		-0,04		-0,08		-0,07	
Investment	0,34		-0,08		-0,12		0,01	
Employment	0,06		0,02		0,00		0,03	
Cross Correlation within Countries								
GDP-Net Trade	-0,47	-0,35	-0,42	0,01	-0,50	-0,30	-0,44	-0,28
Consumption - Net Trade	-0,61	-0,61	-0,52	-0,35	-0,59	-0,54	-0,58	-0,55
Investment - Net Trade	-0,48	-0,52	-0,51	-0,33	-0,54	-0,49	-0,48	-0,47
GDP - Real Exchange Rate	0,06	0,10	-0,10	-0,10	-0,22	0,10	0,02	0,00
Consumption - Real Exchange Rate	0,04	0,30	-0,16	0,00	-0,23	0,19	-0,11	0,13
Investment - Real Exchange Rate	0,08	0,21	-0,09	0,05	-0,20	0,18	0,04	0,00
Net Trade - Real Exchange Rate	0,24	-0,53	0,30	-0,29	0,29	-0,37	0,23	-0,30
Relative Consumption - Real Exchange Rate	0,18		0,11		0,29		0,16	
Relative GDP - Real Exchange Rate	0,01		0,01		0,23		-0,02	

The models generate a relatively high volatility in consumption and in net trade especially for the euro area. The standard error of consumption in the models is of the same size or slightly higher than the standard error of GDP, while the opposite holds in the data. The standard deviation of the net trade balance is also slightly higher than in the data especially for the model with a high substitution elasticity. The typical open economy shocks clearly increase the volatility of consumption but not of GDP because consumption and the trade balance tend to compensate each other. The stimuli of net trade are typically offset by adjustments in domestic demand. The volatility of investment is also increased by these shocks but not as strongly as the volatility of consumption because the latter is much more sensitive to the wealth effects generated by the open economy shocks.

In the data, the real exchange rate is found to be quite volatile and it behaves in a very persistent way. The models reproduce the standard deviation of the real exchange rate and the relative consumption price quite well. The nominal exchange rate fluctuations and the deviations from PPP are clearly the main cause of the real exchange rate movements. In terms of autocorrelations the models are able to match the data except for the real exchange rate which has a lower correlation in the data generated by the models that have UIRP imposed. The relatively low correlation of the real exchange rate in these models can be explained by the typical overshooting reaction of the exchange rate in response to various shocks. This short lived overshooting of the exchange rate implies sudden jumps and a stronger mean-revertion and more predictable behaviour in the theoretical exchange rate. This systematic strong reaction of the exchange rate to shocks is clearly not observed with the same strength in the data.

The model also fails to generate a significant positive correlation between output or the main demand components of the two economies. In contradiction with the data, consumption and investment between the two countries are even negatively correlated in the models with UIRP. The spillover effects that are generated by the trade flows, capital flows, the terms-of-trade effects etc. are not strong enough to generate the observed synchronisation in the business cycle. The oil price is the only source of a common shock and is clearly not sufficiently important. The traditional solution for creating a positive correlation between the endogenous variables over the cycle is to allow for a correlation structure in the innovations. We have always postulated in the estimation that all shocks are orthogonal. To illustrate that this assumption is not contradicted by the estimation outcomes, Table 5 summarise the correlation (contemporaneously and with one lead and lag) for the smoothed estimated innovations for the shocks that are most suspect to have a positive correlation. The table shows only three significant correlations, namely between the contemporaneous innovations in monetary policy and the import price shocks in the two countries, and between the one period lagged US risk premium shock and the euro area risk premium shock. These three correlations are significant but relatively small, although the correlation between the risk premium shocks is especially powerful to generate a positive correlation over the cycle as measured by the hp-filtered series (a correlation of 0.2 generates a positive correlation between GDP of around 0.2). These results suggest that a more developed financial structure that allows for more risk sharing and that is affected by some common shock to the required returns might form an important ingredient to explain the observed synchronisation.

The direct trade flows are one element of the spillover effect. In the data, we observe a strong negative correlation between output (and demand) and the net trade balance. The high income elasticity of imports with respect to income is probably responsible for this observation. The model with a low substitution elasticity and the model without UIRP are able to replicate this negative correlation quite accurately. In the case of a higher substitution elasticity, consumption and especially output are much less negatively correlated with net trade at least for the euro area. This result is related to the absence of a positive correlation between output and consumption and the real exchange rate in the model with a high substitution elasticity. In this version of the model, positive demand shocks that tend to raise imports and result in a negative net trade balance, are immediately offset by an exchange rate depreciation to restore the external balance in the long-run. Hence, this strong equilibrating reaction of the exchange rate to the trade balance counterbalances the usual negative relation between the trade balance and consumption and the exchange rate. The problem applies stronger for the euro area than for the US economy, because we imposed the net foreign asset stability condition in terms of the euro area external assets (this choice is not neutral in our model because we allow for trade-flows with the rest of the world so

Table 5: Correlation between the innovations over the two economies

	US => EA	contemporaneous	EA => US
TFP shock	-0,06	0,07	-0,06
risk premium shock	**0,19**	0,10	0,03
gov. spend. shock	-0,01	0,04	-0,15
mon. pol. shock	0,10	**0,29**	0,01
price m-up shock	0,06	0,02	0,07
invest. shock	0,01	0,00	0,05
export demand	-0,03	-0,08	0,12
meas. er. in cons. pr.	0,14	0,05	-0,01
import price shock	0,04	**0,23**	0,13
wage m-up shock	-0,01	0,11	0,08

Critical value for 124 observations 0.176 (for i.i.d series)

that the bilateral trade is not necessary balanced). The low substitution economy does not have the same problem because the equilibrating adjustment of the exchange rate to the net trade balance has the opposite sign and is therefore enforcing the negative correlation.

The NOEM is often criticised for being unable to generate the observed correlation between the real exchange rate and the relative consumption between countries (e.g. Chari *et al.*, 2002). In the data, countries with high consumption (on the cyclical frequency) tend to appreciate. However in the NOEM with a standard calibration, a country specific expansionary monetary policy or productivity shock will raise consumption while the real exchange rate will depreciate. The exchange rate acts as a risk-sharing device by redistributing the wealth effect over the two countries through the terms-of-trade. As discussed already before, substitution elasticities below the critical value are able to reverse this correlation, resulting in a relatively stronger positive correlation between relative consumption and the real exchange rate. Also the risk premium shock driving consumption away from the standard equilibrium condition, is able to generate correlations between relative consumption and the real exchange rate that are consistent with the data. In the model without UIRP and an exogenous exchange rate, the explanation goes from the exchange rate appreciation to the high relative consumption via the terms-of-trade wealth effects. So in our case, neither of the models have a problem with the correlation between the exchange rate and the relative consumption levels. The typical issue that occurs in highly stylised models which are often concentrated on monetary shocks or productivity shocks, does not pose a problem in our more general model where various shocks, such as the uncovered interest rate shocks and the risk premium shocks, imply deviations from UIRP and therefore disconnect the strict linkage between relative consumption and the exchange rate.

6 The unconditional variance decomposition of the forecast errors

Table 6 in appendix summarizes the results for the unconditional variance decomposition of the forecast errors for output, inflation, the nominal exchange rate and the trade balance based on the model estimates.

The first observation that follows from the output variance decomposition is the predominant role of the domestic shocks for output (around 96% for the US and some 90% for the euro area over the short horizon increasing to 96% for the longer horizon). The unexpected short-run output fluctuations are mainly explained by domestic demand shocks, that is the risk premium shock and the government spending shock, while the variance over the business cycles, i.e. over a horizon from 10 to 40 quarters, is also heavily influenced by the supply shocks (productivity and labour supply). Spillover effects from shocks in the US economy towards the euro area or the other way around are too weak to explain a significant proportion of the output fluctuations. Trade shocks originating in the rest of the world do have a significant impact but this effect is short lived. The impact of these exogenous demand shocks is larger for the euro area than for the US economy. Oil price shocks and exchange rate shocks do have a very small contribution to the output variance (3%) at the business cycle frequency. The impact of monetary policy shocks is situated at the short and medium run. The contribution of monetary shocks is stronger for the euro area (with a peak contribution of 20% at the one year horizon) than for the US (14%) which is mainly explained by the higher estimated persistence of the monetary policy shock in the euro area that more than compensates for the lower variance of the shock. Finally the various mark-up shocks, with the wage mark-up shock as the main contributor, explain some 10% of the output variance in both economies at the long horizon.

Compared to the previous calculations for the closed economy models (Smets and Wouters, 2005), the contribution of exogenous foreign demand shocks goes at the cost of the domestic demand shocks and especially the public spending shocks. This is not surprising given that the public spending shock was defined as the residual term in the GDP identity.

The variance decomposition for the three models is very similar. The rest of the world shocks are most important in the model without UIRP: the endogenous exchange rate response in the models with UIRP has a stabilising role that offsets the impact of the foreign disturbances.

Domestic shocks are also the major source for the forecast error in inflation. Spill-over effect between US and the euro area are again negligible, but the foreign shocks make up between 25% of the variance in the short-run and some 10 to 15% in the long-run. Oil shocks account for 5 to 9%, other import price shocks for 5 to 15% and UIRP shocks for 1 to 3% of the inflation variance. Domestic mark-up shocks are indicated by far as the major source for the variance of the inflation process: price mark-up shocks are crucial in the short-run and wage mark-up shocks explain the long-run variance and take up most of the long-run trends in inflation that were explained by the inflation objective shock in our previous models. Other domestic shocks, mainly productivity and monetary policy shocks, do explain at maximum 10% of inflation.

The variance decomposition of the exchange rate is interesting for the models with an endogenous explanation of the exchange rate through the UIRP condition. The uncovered interest parity shock explains between 60 and 70% of the one period forecast error variance but although the shock is relatively persistent, the contribution decreases to 55% at a 10-quarter horizon and 25% at the 10-year horizon. Other shocks seem to explain a non-negligible share of the exchange rate variance especially at longer horizons. In the two economies, domestic shocks explain some 20% on impact and some 45 to 50% at the 10-year horizon. Productivity and wage mark-up shocks have the highest contribution which is mainly due to their persistent nominal effects. Monetary policy shocks contribute for less than 5% to the exchange rate variance. The other rest of the world shocks, import price, oil prices and export shocks explain the remaining part of the exchange rate volatility.

The decomposition of the trade balance also provides some useful insights. Most of the short-run variance (60 to 70%) in the trade balance is explained by the exogenous world demand shocks but their relative contribution decreases quickly over the longer horizon. Import price shocks and more important UIRP shocks explain also an important share of the net trade balance: this is especially the case in the model without UIRP imposed and a purely exogenous exchange rate. In the model with UIRP and a low substitution elasticity, the UIRP shocks deliver only a very small impact on the trade balance. In that model, the world demand shocks are more persistent but domestic shocks appear also as more important in that case. These results are in line with the findings in Bergin (2004), where the "financial" exchange rate shock also explains a major proportion of the trade balance. These effects are however largely offset as far as domestic demand is concerned by compensating wealth effects, and the impact of these shocks on final demand is therefore much smaller than on the trade flows.

Together these results for the exchange rate and the trade balance decomposition illustrate that the model is able to explain a significant proportion of the dynamics in these variables by structural shocks that have a clear economic interpretation. This is a promising result for further research. What is however less satisfactory is that spill-over effects of foreign shocks to the domestic variables remain very small. Bilateral trade flows are not sufficiently important to generate strong spill-over effects. These results are also influenced by the strong wealth effects from terms-of-trade changes that often compensate the substitution effects. The exact nature of these wealth effects depend on the assumptions about the capital market access for the households. Either one can go in the direction of more capital market access so that the households benefit from more complete risk sharing and all households are affected more symmetrically by the shocks. Or one can try to reduce the wealth effect by reducing the planning horizon of the households or by assuming liquidity constraints. The introduction of such financial constraints, as recently suggested by Gali *et* *al.* (2004) in the context of fiscal shocks, can increase the income multiplier and reduce to some extend the wealth effects.

A comparison of the exchange rate decomposition with previous studies is difficult because most of these papers are situated in the SVAR approach and therefore their analysis is limited to a small number of variables and shocks. Following Clarida and Gali (1995), the shocks are typically classified as nominal, demand and supply shocks and these shocks regroup our more detailed classification. Applications on the euro-dollar exchange rate are of course absent also in the older literature.

7 The historical decomposition

In discussing the historical decomposition, we concentrate on three variables: output, the nominal exchange rate and the net trade balance in the US. These results are summarized in Table 7 (in appendix) for the model with high and low substitution elasticity.

For output, it is interesting to look first at the main shocks behind the business cycle. The identified shocks and their contribution to output are very similar between the two models. Risk premium shocks, affecting consumption and investment, play a key role over the cycle especially in the US. These shocks have a negative contribution during all of the recessions in both the US and euro area. Monetary policy shocks also had a negative contribution in the beginning of the eighties in both the US and the euro are and the beginning of the nineties in the euro area. During the 1974 recession, monetary policy was clearly accommodating but surprisingly, monetary policy does not seem to deviate from its historical rule during the last recession in the US. Investment specific technology shocks were cyclical in the euro area and in the US for the more recent recessions. Public spending shocks were not contributing much to the cyclical fluctuations. The recession of 1974 was further characterised by a series of adverse price shocks: oil price, import price and domestic price shocks all contributed negatively in the two economies. The recent oil price shock started only in the second half of 2004, and its impact on average growth (2003-2004) is of course still weak but clearly present (0.25% of the output decline over 2004). A comparison with the oil price fluctuations in 1998 (50% decline) and 1999 (50% increase) shows that the contribution of these developments on output is of the order of 0.5%.

From a longer-term growth perspective, productivity developments and wage mark-up shocks are the dominant movers. For the euro area, TFP developments were favourable up to 1982 and turned negative since 1993. The opposite picture occurs for the US TFP shocks. Wage mark-up shocks had a compensating effect in the euro area both for the first and the last decade, while in the US they contributed to the slow growth performance over the seventies. Overall this analysis looks very similar to our earlier results based on the closed economy models. This could be expected given the minor role for spill-over effects and foreign shocks. The analysis of these specific recession periods confirms the results from the unconditional variance decomposition and points also to the important role of risk premium shocks in driving the business cycle. The correlation between the euro area and the US risk premium shocks is largely responsible for the synchronisation of the cycle, together with the monetary policy shocks during the Volcker period.

Table 7 also explains the contribution of the shocks to the major exchange rate movements over the period 1974-2004. The first conclusion is rather disappointing because most of the fluctuations are explained by the UIRP shocks. It is interesting to observe that the model with a high substitution is somewhat more successful during periods of larger external imbalances. Wage mark-up shocks had an important impact on the nominal exchange rate up to 1985: this effect reflects the long-run inflationary effects of these shocks that result in nominal depreciations. But because similar shocks occurred in the two economies, the combined impact on the exchange rate was relatively minor. This mechanism explains to a certain extent the success of the model to explain the long-run developments in nominal exchange rates as it appeared from the unconditional variance decomposition. Another striking result is the contribution of the negative productivity developments in the euro area: according to the model with high substitution, these developments supported the euro exchange rate while they had the opposite effect in the model with a low substitution.

As far as the US net-trade developments is concerned, the foreign net-trade shocks explain most of the recent action. The UIRP shocks have an important impact on the trade balance, and of course more so in the model with a high substitution elasticity, but the absence of a clear trend in this shock over the longer period implies that the exchange rate shocks are not driving the recent imbalances. This was different for the period 80-85 where exchange rate misalignment played a crucial role. Surprisingly, domestic demand in the US, at least as far as it is originating in the risk premium shock, is contributing positively to the net-trade developments over the most recent period. It is also interesting to note that the euro area productivity and mark-up shocks have opposite effects on the trade balance according to the two models.

References

[1] Adolfson, M., S. Laséen, J. Lindé and M. Villani (2004), "Bayesian Estimation of an Open Economy DSGE Model with Incomplete Pass-Through", mimeo, Riksbank.

[2] Anderton, R., di Mauro, F. and F. Moneta (2004), "Understanding the Impact of the External Dimension on the Euro Area: Trade, Capital Flows and Other International Macroeconomic Linkages", ECB Occasional Paper Series, No. 12.

[3] Benigno, P. (2001), "Price Stability with Imperfect Financial Integration", mimeo, New York University.

[4] Benigno, G. and C. Thoenissen (2002), "Equilibrium Exchange Rates and Supply Side Performance", Bank of England Working Papers No. 156

[5] Bergin, P. (2004), "How Well Can the New Open Macroeconomics Explain the Exchange Rate and Current Account?", NBER 10356.

[6] Campa, J. and L. Goldberg (2001), "Exchange Rate Pass-Through into Import Prices: a Macro and Micro Phenomenon. NBER Working Paper 8934.

[7] Chari, V.V., Kehoe, P.J. and E.R. McGrattan (2002), "Can Sticky Price Models Generate Volatile and Persistent Real Exchange Rates?", *Review of Economic Studies*, Vol. 69(3), pp. 533-563.

[8] Chinn, M. (2003), "Doomed to Deficits? Aggregate U.S. Trade Flows Re-examined", NBER Working Paper No. 9521.

[9] Clarida, R. and J. Gali (1994),"Sources of Real Exchange Rate Fluctuations: How Important are Nominal Shocks?", Carnegie Rochester Conference Series on Public Policy, vol. 41, pp. 1-56.

[10] Corsetti, G., Debola, L. and S. Leduc (2003), "International Risk-Sharing and the Transmission of Productivity Shocks", EUI Working Paper ECO No. 2003/22.

[11] Eichenbaum M. and J. Fisher (2004), "Evaluating the Calvo Model of Sticky Prices," NBER Working Papers 10617.

[12] Erceg, J., L. Guerrieri and Christopher Gust (2003), "SIGMA: A new Open Economy Model for Policy Analysis", mimeo.

[13] Fagan, G., J. Henry and R. Mestre (2001), "An Area-Wide Model (AWM) for the Euro Area", ECB Working Paper n°42.

[14] Gali, J., Lopez-Salido J.D. and J. Valles (2004), "Rule-of-Thumb Consumers and the Design of Interest Rate Rules", NBER no. 10392.

[15] Ghironi F. (1999), "Towards New Open Economy Macroeconometrics", Mimeo Boston College.

[16] Jimenez-Rodriguez, R. and M. Sanchez (2004), "Oil Price Shocks and Real GDP Growth: Empirical Evidence for Some OECD Countries", ECB Working Paper n°362.

[17] Justiniano A. and B. Preston (2004), "Small open economy DSGE models specification, estimation and model fit", manuscript IMF.

[18] Kimball, M. (1995), "The quantitative analytics of the basic neomonetarist model", *Journal of Money, Credit and Banking*, 27(4), pp. 1241-1277.

[19] Laxton, D. and P. Pesenti (2003), "Monetary Rules for Small, Open, Emerging Economies", *Journal of Monetary Policy*, Vol. 50 (5), pp. 1109-1146.

[20] Lubik, T.A. and F. Schorfheide (2003), "Do Central Banks Respond to Exchange Rate Movements? A Structural Investigation", Mimeo Johns Hopkins University, University of Pennsylvania.

[21] Lubik, T.A. and F. Schorfheide (2005), "A Baysian look at New Open Economy Macroeconomics", mimeo University of Pennsylvania.

[22] Murchison, S., Rennison, A. and Z. Zhu (2004), "A Structural Small Open-Economy Model for Canada", Bank of Canada, Working Paper 2004-4.

[23] Rabana, P. and Tuesta, V. (2005), "Euro-dollars exchange rate dynamics in an estimated two-country model: what is important and what is not", manuscript IMF.

[24] Schnatz, B., F. Vijselaar and C. Osbat (2003), "Productivity and the ("Synthetic") Euro-Dollar Exchange Rate", ECB Working Paper n°225.

[25] Smets, F. and R. Wouters (2002), "Openness, Imperfect Exchange Rate Pass-Through and Monetary Policy", *Journal of Monetary Economics*, 49(5), 947-981.

[26] Smets, F. and R. Wouters (2003a), "An estimated Dynamic Stochastic General Equilibrium Model of the Euro Area", *Journal of the European Economic Association* 1(5), 1123-1175.

[27] Smets, F. and R. Wouters (2003b), "Shocks and Frictions in US business cycles: a Bayesian DSGE Approach", mimeo, European Central Bank.

[28] Smets, F. and R. Wouters (2005), "Comparing Shocks and Frictions in US and Euro Business Cycles: a Bayesian DSGE Approach", *Journal of Applied Econometrics* 20(2), 161-183.

8 Appendix

8.1 Data description

For the US, consumption, investment and GDP are taken from the US Department of Commerce - Bureau of Economic Analysis databank. Real GDP is expressed in Billions of chained 1996 Dollars. Nominal Personal Consumption Expenditures and Fixed Private Domestic Investment are deflated with the GDP deflator. There are three inflation series which are the first difference of the log CPI, the log GDP deflator and the log import deflator respectively. Hours and wages are taken from the Bureau of Labour Statistics (hours and hourly compensation for the NFB sector for all persons). Hourly compensation is divided by the CPI price deflator to get the real wage variable. Hours are adjusted to take into account the limited coverage of the NFB sector compared to GDP. The index of average hours for the NFB sector is multiplied with civilian employment (16 years and over). The aggregate real variables are expressed per capita by dividing with the population over 16. All series are seasonally adjusted. The interest rate is the Federal Funds Rate. The net trade variable is simply the difference between exportation and importation.

For the euro area, all data are from the AWM database of the ECB (see Fagan *et al.*, 2001). Investment includes both private and public investment expenditures. Real variables are deflated with their own deflator. Inflation variables are the first difference of the log CPI, the log GDP deflator and the log import deflator. Real wages are obtained from the wage rate series divided by the CPI price deflator.

Consumption, investment, GDP, wages, hours/employment, and net trade are expressed in $100 \times \log$. Interest rate and inflation rates are expressed on a quarterly basis, as they appear in the model.

Table 6A: Variance Decomposition for the model with UIRP and HIGH elasticity of substitution

	output euro area				output US			
Horizon	1 q.	4 q.	10 q.	10 y.	1 q.	4 q.	10 q.	10 y.
euro area shocks	0.907	0.955	0.971	0.982	0.000	0.000	0.001	0.001
productivity	0.230	0.352	0.474	0.529	0.000	0.000	0.001	0.001
investment	0.041	0.028	0.026	0.020	0.000	0.000	0.000	0.000
risk premium	0.329	0.303	0.211	0.092	0.000	0.000	0.000	0.000
gov. expend	0.122	0.043	0.018	0.007	0.000	0.000	0.000	0.000
dom. p. markup	0.005	0.015	0.032	0.041	0.000	0.000	0.000	0.000
cons. p. markup	0.000	0.000	0.001	0.004	0.000	0.000	0.000	0.000
wage. p. markup	0.000	0.002	0.023	0.193	0.000	0.000	0.000	0.000
monetary policy	0.180	0.211	0.186	0.097	0.000	0.000	0.000	0.000
US shocks	0.002	0.001	0.001	0.000	0.967	0.976	0.972	0.959
productivity	0.000	0.000	0.000	0.000	0.060	0.104	0.167	0.225
investment	0.000	0.000	0.000	0.000	0.039	0.043	0.074	0.173
risk premium	0.002	0.001	0.001	0.000	0.564	0.586	0.500	0.321
gov. expend	0.000	0.000	0.000	0.000	0.180	0.086	0.054	0.034
dom. p. markup	0.000	0.000	0.000	0.000	0.004	0.012	0.021	0.020
cons. p. markup	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003
wage. p. markup	0.000	0.000	0.000	0.000	0.001	0.001	0.009	0.079
monetary policy	0.000	0.000	0.000	0.000	0.118	0.143	0.146	0.106
open economy shocks	0.092	0.044	0.029	0.017	0.033	0.024	0.028	0.039
UIRP	0.001	0.001	0.000	0.001	0.000	0.001	0.002	0.003
oil price	0.005	0.008	0.010	0.007	0.004	0.008	0.011	0.012
net trade ea	0.084	0.033	0.015	0.006	0.000	0.000	0.000	0.000
net trade US	0.000	0.000	0.000	0.000	0.028	0.015	0.011	0.014
imp. price ea	0.000	0.000	0.000	0.002	0.000	0.000	0.001	0.002
imp. price US	0.001	0.002	0.002	0.001	0.000	0.000	0.002	0.007

	Consumer Price Inflation euro area				Consumer Price Inflation US			
Horizon	1 q.	4 q.	10 q.	10 y.	1 q.	4 q.	10 q.	10 y.
euro area shocks	0.748	0.817	0.870	0.902	0.006	0.006	0.005	0.004
productivity	0.010	0.027	0.033	0.028	0.003	0.003	0.002	0.002
investment	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
risk premium	0.005	0.015	0.021	0.018	0.000	0.000	0.000	0.000
gov. expend	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
dom. p. markup	0.469	0.369	0.277	0.197	0.000	0.000	0.000	0.000
cons. p. markup	0.057	0.039	0.031	0.028	0.000	0.000	0.000	0.000
wage. p. markup	0.167	0.319	0.457	0.587	0.001	0.001	0.002	0.002
monetary policy	0.040	0.048	0.051	0.044	0.001	0.001	0.001	0.001
US shocks	0.012	0.008	0.006	0.004	0.794	0.812	0.842	0.859
productivity	0.001	0.001	0.001	0.001	0.011	0.019	0.021	0.019
investment	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003
risk premium	0.007	0.005	0.003	0.002	0.005	0.015	0.026	0.027
gov. expend	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
dom. p. markup	0.000	0.000	0.000	0.000	0.566	0.429	0.323	0.264
cons. p. markup	0.000	0.000	0.000	0.000	0.054	0.041	0.036	0.042
wage. p. markup	0.000	0.000	0.000	0.000	0.149	0.293	0.416	0.484
monetary policy	0.003	0.002	0.001	0.001	0.009	0.015	0.018	0.019
open economy shocks	0.240	0.175	0.125	0.093	0.200	0.182	0.153	0.137
UIRP	0.096	0.068	0.047	0.033	0.025	0.022	0.016	0.013
oil price	0.094	0.062	0.043	0.031	0.071	0.049	0.037	0.030
net trade ea	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000
net trade US	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
imp. price ea	0.041	0.038	0.030	0.026	0.007	0.008	0.008	0.009
imp. price US	0.008	0.005	0.004	0.004	0.096	0.102	0.091	0.084

Table 6A continued: Variance Decomposition for the model with UIRP and HIGH elasticity of substitution

	Trade Balance euro area				Trade Balance US			
Horizon	1 q.	4 q.	10 q.	10 y.	1 q.	4 q.	10 q.	10 y.
euro area shocks	0.078	0.089	0.075	0.078	0.022	0.039	0.054	0.087
productivity	0.001	0.002	0.005	0.018	0.008	0.017	0.027	0.043
investment	0.004	0.003	0.002	0.002	0.000	0.000	0.000	0.001
risk premium	0.060	0.066	0.045	0.026	0.008	0.009	0.006	0.005
gov. expend	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000
dom. p. markup	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002
cons. p. markup	0.000	0.000	0.001	0.002	0.000	0.000	0.001	0.002
wage. p. markup	0.008	0.015	0.021	0.026	0.004	0.008	0.016	0.030
monetary policy	0.001	0.001	0.000	0.003	0.001	0.003	0.004	0.004
US shocks	0.052	0.067	0.054	0.035	0.201	0.220	0.174	0.094
productivity	0.001	0.002	0.002	0.003	0.004	0.006	0.009	0.008
investment	0.002	0.003	0.004	0.004	0.009	0.011	0.016	0.018
risk premium	0.048	0.061	0.046	0.025	0.167	0.186	0.136	0.059
gov. expend	0.000	0.000	0.000	0.001	0.009	0.004	0.002	0.001
dom. p. markup	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
cons. p. markup	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
wage. p. markup	0.000	0.001	0.001	0.002	0.001	0.000	0.000	0.003
monetary policy	0.000	0.001	0.001	0.001	0.011	0.012	0.010	0.005
open economy shocks	0.870	0.844	0.871	0.888	0.777	0.741	0.772	0.819
UIRP	0.210	0.376	0.429	0.272	0.107	0.195	0.224	0.123
oil price	0.017	0.035	0.058	0.135	0.004	0.008	0.015	0.042
net trade ea	0.558	0.261	0.125	0.081	0.008	0.012	0.017	0.030
net trade US	0.000	0.000	0.000	0.000	0.621	0.453	0.410	0.534
imp. price ea	0.083	0.168	0.255	0.376	0.016	0.031	0.044	0.047
imp. price US	0.002	0.004	0.004	0.024	0.020	0.043	0.062	0.042

	Exchange Rate			
Horizon	1 q.	4 q.	10 q.	10 y.
euro area shocks	0.123	0.124	0.131	0.254
productivity	0.062	0.066	0.070	0.049
investment	0.000	0.000	0.000	0.002
risk premium	0.008	0.005	0.004	0.022
gov. expend	0.000	0.000	0.000	0.000
dom. p. markup	0.000	0.000	0.003	0.014
cons. p. markup	0.003	0.004	0.004	0.003
wage. p. markup	0.003	0.002	0.002	0.104
monetary policy	0.047	0.046	0.048	0.061
US shocks	0.082	0.071	0.066	0.184
productivity	0.009	0.008	0.006	0.003
investment	0.000	0.000	0.000	0.004
risk premium	0.044	0.036	0.024	0.024
gov. expend	0.002	0.002	0.002	0.001
dom. p. markup	0.001	0.002	0.006	0.011
cons. p. markup	0.001	0.001	0.001	0.002
wage. p. markup	0.001	0.002	0.011	0.124
monetary policy	0.024	0.019	0.017	0.017
open economy shocks	0.794	0.805	0.803	0.562
UIRP	0.625	0.606	0.556	0.266
oil price	0.024	0.029	0.039	0.062
net trade ea	0.015	0.018	0.023	0.032
net trade US	0.000	0.000	0.000	0.000
imp. price ea	0.074	0.088	0.111	0.138
imp. price US	0.056	0.064	0.074	0.064

Table 6B: Variance Decomposition for the model with UIRP and LOW elasticity of substitution

	output euro area				output US			
Horizon	1 q.	4 q.	10 q.	10 y.	1 q.	4 q.	10 q.	10 y.
euro area shocks	0.903	0.948	0.962	0.982	0.000	0.000	0.000	0.000
productivity	0.230	0.388	0.563	0.726	0.000	0.000	0.000	0.000
investment	0.049	0.032	0.024	0.011	0.000	0.000	0.000	0.000
risk premium	0.335	0.287	0.166	0.052	0.000	0.000	0.000	0.000
gov. expend	0.140	0.052	0.020	0.006	0.000	0.000	0.000	0.000
dom. p. markup	0.004	0.010	0.021	0.020	0.000	0.000	0.000	0.000
cons. p. markup	0.000	0.000	0.001	0.003	0.000	0.000	0.000	0.000
wage. p. markup	0.000	0.001	0.017	0.103	0.000	0.000	0.000	0.000
monetary policy	0.145	0.177	0.151	0.060	0.000	0.000	0.000	0.000
US shocks	0.001	0.001	0.001	0.000	0.965	0.972	0.965	0.946
productivity	0.000	0.000	0.000	0.000	0.068	0.115	0.180	0.248
investment	0.000	0.000	0.000	0.000	0.037	0.041	0.070	0.158
risk premium	0.000	0.000	0.000	0.000	0.570	0.596	0.513	0.333
gov. expend	0.000	0.000	0.000	0.000	0.172	0.080	0.048	0.029
dom. p. markup	0.000	0.000	0.000	0.000	0.005	0.012	0.020	0.017
cons. p. markup	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003
wage. p. markup	0.000	0.000	0.000	0.000	0.001	0.001	0.010	0.072
monetary policy	0.000	0.000	0.000	0.000	0.112	0.128	0.123	0.086
open economy shocks	0.096	0.052	0.037	0.018	0.034	0.028	0.035	0.053
UIRP	0.006	0.012	0.015	0.008	0.000	0.001	0.002	0.002
oil price	0.003	0.006	0.006	0.003	0.006	0.011	0.015	0.017
net trade ea	0.087	0.034	0.014	0.004	0.000	0.000	0.000	0.000
net trade US	0.000	0.000	0.000	0.000	0.028	0.015	0.012	0.017
imp. price ea	0.000	0.000	0.001	0.002	0.000	0.000	0.000	0.001
imp. price US	0.000	0.000	0.000	0.000	0.000	0.001	0.006	0.016

	Consumer Price Inflation euro area				Consumer Price Inflation US			
Horizon	1 q.	4 q.	10 q.	10 y.	1 q.	4 q.	10 q.	10 y.
euro area shocks	0.809	0.852	0.889	0.916	0.000	0.000	0.000	0.000
productivity	0.050	0.064	0.061	0.052	0.000	0.000	0.000	0.000
investment	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
risk premium	0.002	0.008	0.013	0.011	0.000	0.000	0.000	0.000
gov. expend	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
dom. p. markup	0.456	0.349	0.266	0.198	0.000	0.000	0.000	0.000
cons. p. markup	0.064	0.046	0.038	0.039	0.000	0.000	0.000	0.000
wage. p. markup	0.209	0.345	0.464	0.573	0.000	0.000	0.000	0.000
monetary policy	0.029	0.040	0.047	0.043	0.000	0.000	0.000	0.000
US shocks	0.013	0.009	0.007	0.005	0.756	0.767	0.796	0.813
productivity	0.000	0.000	0.000	0.000	0.012	0.019	0.020	0.018
investment	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.001
risk premium	0.010	0.007	0.005	0.004	0.005	0.014	0.022	0.023
gov. expend	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
dom. p. markup	0.000	0.000	0.000	0.000	0.543	0.414	0.316	0.257
cons. p. markup	0.000	0.000	0.000	0.000	0.054	0.041	0.037	0.043
wage. p. markup	0.000	0.000	0.000	0.000	0.138	0.271	0.390	0.461
monetary policy	0.001	0.001	0.001	0.001	0.004	0.008	0.010	0.010
open economy shocks	0.178	0.139	0.105	0.079	0.243	0.233	0.203	0.186
UIRP	0.086	0.062	0.045	0.033	0.008	0.007	0.005	0.004
oil price	0.046	0.030	0.022	0.016	0.092	0.064	0.049	0.040
net trade ea	0.006	0.005	0.004	0.003	0.000	0.000	0.000	0.000
net trade US	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
imp. price ea	0.040	0.041	0.033	0.026	0.001	0.002	0.002	0.002
imp. price US	0.001	0.001	0.001	0.001	0.141	0.159	0.147	0.140

Table 6B continued: Variance Decomposition for the model with UIRP and LOW elasticity of substitution

	Trade Balance euro area				Trade Balance US			
Horizon	1 q.	4 q.	10 q.	10 y.	1 q.	4 q.	10 q.	10 y.
euro area shocks	0.113	0.185	0.246	0.390	0.029	0.046	0.062	0.096
productivity	0.035	0.084	0.152	0.298	0.010	0.022	0.039	0.075
investment	0.007	0.007	0.007	0.004	0.002	0.002	0.002	0.001
risk premium	0.050	0.062	0.046	0.020	0.014	0.017	0.012	0.005
gov. expend	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000
dom. p. markup	0.000	0.002	0.004	0.007	0.000	0.000	0.001	0.001
cons. p. markup	0.000	0.000	0.001	0.002	0.000	0.000	0.000	0.001
wage. p. markup	0.000	0.001	0.006	0.039	0.000	0.001	0.002	0.009
monetary policy	0.016	0.027	0.030	0.019	0.002	0.004	0.005	0.004
US shocks	0.013	0.020	0.019	0.011	0.219	0.264	0.227	0.129
productivity	0.000	0.000	0.000	0.001	0.012	0.022	0.030	0.027
investment	0.001	0.002	0.003	0.003	0.011	0.014	0.021	0.026
risk premium	0.012	0.018	0.016	0.007	0.167	0.198	0.150	0.058
gov. expend	0.000	0.000	0.000	0.000	0.007	0.003	0.001	0.001
dom. p. markup	0.000	0.000	0.000	0.000	0.000	0.002	0.003	0.002
cons. p. markup	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
wage. p. markup	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.007
monetary policy	0.000	0.000	0.000	0.000	0.021	0.025	0.021	0.009
open economy shocks	0.874	0.795	0.735	0.599	0.752	0.690	0.712	0.775
UIRP	0.020	0.047	0.063	0.039	0.029	0.059	0.073	0.038
oil price	0.000	0.000	0.001	0.003	0.003	0.007	0.010	0.013
net trade ea	0.840	0.712	0.613	0.488	0.000	0.002	0.006	0.016
net trade US	0.000	0.000	0.000	0.000	0.678	0.524	0.465	0.540
imp. price ea	0.006	0.015	0.024	0.022	0.005	0.010	0.014	0.009
imp. price US	0.008	0.020	0.034	0.046	0.037	0.088	0.144	0.159

	Exchange Rate			
Horizon	1 q.	4 q.	10 q.	10 y.
euro area shocks	0.076	0.087	0.130	0.386
productivity	0.013	0.020	0.040	0.102
investment	0.001	0.001	0.001	0.000
risk premium	0.021	0.017	0.011	0.004
gov. expend	0.000	0.000	0.000	0.000
dom. p. markup	0.004	0.007	0.014	0.028
cons. p. markup	0.000	0.000	0.000	0.005
wage. p. markup	0.020	0.028	0.054	0.239
monetary policy	0.016	0.013	0.010	0.007
US shocks	0.108	0.095	0.081	0.137
productivity	0.003	0.002	0.001	0.003
investment	0.004	0.004	0.005	0.002
risk premium	0.081	0.070	0.047	0.019
gov. expend	0.001	0.001	0.000	0.000
dom. p. markup	0.001	0.003	0.006	0.010
cons. p. markup	0.000	0.000	0.000	0.002
wage. p. markup	0.002	0.004	0.014	0.098
monetary policy	0.016	0.011	0.008	0.004
open economy shocks	0.816	0.818	0.789	0.477
UIRP	0.690	0.670	0.600	0.230
oil price	0.020	0.023	0.030	0.035
net trade ea	0.037	0.044	0.060	0.080
net trade US	0.000	0.000	0.000	0.000
imp. price ea	0.064	0.072	0.082	0.078
imp. price US	0.006	0.008	0.017	0.054

Table 6C: Variance Decomposition for the model without UIRP

	output euro area				output US			
Horizon	1 q.	4 q.	10 q.	10 y.	1 q.	4 q.	10 q.	10 y.
euro area shocks	0.896	0.942	0.954	0.962	0.000	0.000	0.000	0.001
productivity	0.214	0.361	0.531	0.706	0.000	0.000	0.000	0.000
investment	0.044	0.030	0.023	0.011	0.000	0.000	0.000	0.000
risk premium	0.336	0.293	0.173	0.052	0.000	0.000	0.000	0.000
gov. expend	0.138	0.050	0.020	0.005	0.000	0.000	0.000	0.000
dom. p. markup	0.002	0.008	0.018	0.017	0.000	0.000	0.000	0.000
cons. p. markup	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000
wage. p. markup	0.003	0.001	0.009	0.094	0.000	0.000	0.000	0.000
monetary policy	0.158	0.199	0.180	0.073	0.000	0.000	0.000	0.000
US shocks	0.001	0.001	0.000	0.001	0.963	0.969	0.958	0.938
productivity	0.000	0.000	0.000	0.000	0.081	0.140	0.222	0.306
investment	0.000	0.000	0.000	0.000	0.035	0.039	0.066	0.152
risk premium	0.000	0.000	0.000	0.000	0.536	0.548	0.443	0.253
gov. expend	0.000	0.000	0.000	0.000	0.181	0.083	0.047	0.025
dom. p. markup	0.000	0.000	0.000	0.000	0.007	0.016	0.025	0.018
cons. p. markup	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.004
wage. p. markup	0.000	0.000	0.000	0.000	0.001	0.001	0.019	0.096
monetary policy	0.000	0.000	0.000	0.000	0.121	0.142	0.135	0.086
open economy shocks	0.104	0.057	0.046	0.038	0.037	0.031	0.042	0.061
UIRP	0.006	0.009	0.014	0.013	0.002	0.003	0.005	0.008
oil price	0.006	0.010	0.014	0.012	0.006	0.011	0.017	0.024
net trade ea	0.092	0.037	0.016	0.004	0.000	0.000	0.000	0.000
net trade US	0.000	0.000	0.000	0.000	0.029	0.015	0.010	0.011
imp. price ea	0.000	0.000	0.002	0.007	0.000	0.000	0.000	0.001
imp. price US	0.000	0.000	0.000	0.000	0.000	0.002	0.009	0.017

	Consumer Price Inflation euro area				Consumer Price Inflation US			
Horizon	1 q.	4 q.	10 q.	10 y.	1 q.	4 q.	10 q.	10 y.
euro area shocks	0.759	0.797	0.843	0.871	0.001	0.001	0.002	0.004
productivity	0.032	0.045	0.045	0.037	0.000	0.000	0.000	0.000
investment	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002
risk premium	0.006	0.010	0.012	0.010	0.000	0.000	0.000	0.000
gov. expend	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
dom. p. markup	0.447	0.332	0.245	0.177	0.000	0.000	0.000	0.000
cons. p. markup	0.070	0.048	0.039	0.038	0.000	0.000	0.000	0.000
wage. p. markup	0.186	0.329	0.458	0.567	0.000	0.000	0.000	0.001
monetary policy	0.018	0.032	0.043	0.041	0.000	0.000	0.000	0.000
US shocks	0.001	0.001	0.002	0.003	0.760	0.771	0.803	0.818
productivity	0.000	0.000	0.000	0.000	0.018	0.028	0.030	0.027
investment	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002
risk premium	0.000	0.000	0.000	0.000	0.007	0.015	0.020	0.021
gov. expend	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
dom. p. markup	0.000	0.000	0.000	0.000	0.527	0.387	0.295	0.258
cons. p. markup	0.000	0.000	0.000	0.000	0.052	0.038	0.034	0.039
wage. p. markup	0.000	0.001	0.001	0.002	0.151	0.295	0.411	0.458
monetary policy	0.000	0.000	0.000	0.000	0.004	0.007	0.011	0.012
open economy shocks	0.240	0.201	0.155	0.126	0.240	0.228	0.196	0.180
UIRP	0.059	0.045	0.032	0.024	0.013	0.013	0.011	0.010
oil price	0.069	0.044	0.031	0.022	0.088	0.060	0.046	0.040
net trade ea	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
net trade US	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
imp. price ea	0.112	0.112	0.093	0.080	0.000	0.000	0.001	0.002
imp. price US	0.000	0.000	0.000	0.000	0.139	0.154	0.139	0.128

Table 6C continued: Variance Decomposition for the model without UIRP

	Trade Balance euro area				Trade Balance US			
Horizon	1 q.	4 q.	10 q.	10 y.	1 q.	4 q.	10 q.	10 y.
euro area shocks	0.122	0.170	0.169	0.143	0.014	0.019	0.021	0.033
productivity	0.029	0.059	0.083	0.101	0.002	0.004	0.006	0.006
investment	0.007	0.006	0.005	0.002	0.001	0.001	0.001	0.000
risk premium	0.053	0.058	0.036	0.012	0.006	0.006	0.004	0.002
gov. expend	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000
dom. p. markup	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
cons. p. markup	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
wage. p. markup	0.002	0.003	0.002	0.004	0.001	0.002	0.003	0.018
monetary policy	0.026	0.042	0.042	0.023	0.003	0.005	0.006	0.006
US shocks	0.010	0.013	0.013	0.020	0.169	0.183	0.140	0.073
productivity	0.001	0.001	0.001	0.000	0.015	0.025	0.029	0.020
investment	0.000	0.001	0.001	0.001	0.007	0.008	0.011	0.015
risk premium	0.007	0.008	0.006	0.003	0.114	0.116	0.074	0.026
gov. expend	0.000	0.000	0.000	0.000	0.006	0.002	0.001	0.000
dom. p. markup	0.000	0.000	0.000	0.001	0.000	0.001	0.001	0.001
cons. p. markup	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
wage. p. markup	0.001	0.001	0.003	0.013	0.001	0.001	0.000	0.002
monetary policy	0.002	0.002	0.002	0.001	0.026	0.031	0.023	0.009
open economy shocks	0.868	0.817	0.818	0.836	0.817	0.798	0.839	0.894
UIRP	0.081	0.196	0.307	0.462	0.067	0.149	0.235	0.365
oil price	0.000	0.001	0.002	0.002	0.001	0.001	0.001	0.001
net trade ea	0.693	0.402	0.197	0.059	0.001	0.001	0.000	0.000
net trade US	0.000	0.000	0.000	0.000	0.669	0.477	0.367	0.325
imp. price ea	0.083	0.195	0.283	0.297	0.044	0.093	0.129	0.131
imp. price US	0.010	0.023	0.030	0.016	0.035	0.077	0.106	0.072

	Exchange Rate			
Horizon	1 q.	4 q.	10 q.	10 y.
euro area shocks	0.000	0.000	0.000	0.000
productivity	0.000	0.000	0.000	0.000
investment	0.000	0.000	0.000	0.000
risk premium	0.000	0.000	0.000	0.000
gov. expend	0.000	0.000	0.000	0.000
dom. p. markup	0.000	0.000	0.000	0.000
cons. p. markup	0.000	0.000	0.000	0.000
wage. p. markup	0.000	0.000	0.000	0.000
monetary policy	0.000	0.000	0.000	0.000
US shocks	0.000	0.000	0.000	0.000
productivity	0.000	0.000	0.000	0.000
investment	0.000	0.000	0.000	0.000
risk premium	0.000	0.000	0.000	0.000
gov. expend	0.000	0.000	0.000	0.000
dom. p. markup	0.000	0.000	0.000	0.000
cons. p. markup	0.000	0.000	0.000	0.000
wage. p. markup	0.000	0.000	0.000	0.000
monetary policy	0.000	0.000	0.000	0.000
open economy shocks	1.000	1.000	1.000	1.000
UIRP	1.000	1.000	1.000	1.000
oil price	0.000	0.000	0.000	0.000
net trade ea	0.000	0.000	0.000	0.000
net trade US	0.000	0.000	0.000	0.000
imp. price ea	0.000	0.000	0.000	0.000
imp. price US	0.000	0.000	0.000	0.000

Table 7 A: Historical decomposition of output

Historical Decomposition of output in the model with a high substution elasticity: average growth rate and relative contribution of the shocks for the EURO AREA

Subperiod (recessions in bold)	Observed growth	Contribution of Euro area shocks								Contribution of US Shocks								Contribution of foreign shocks					
		prodty	riskp	gov	monpol	p	inv	pc	w	prodty	riskp	gov	monpol	p	inv	pc	w	nt_ea	nt_us	pm_ea	pm_us	oil	uirp
74:1-75:1	**-1,04**	**0,13**	**-0,33**	**-0,57**	**0,53**	**-0,16**	**-0,17**	**0,02**	**-0,25**	**0,00**	**-0,04**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,07**	**0,00**	**-0,06**	**-0,05**	**-0,10**	**0,00**
75:1-79:4	0,21	0,15	0,16	0,06	0,01	0,11	-0,03	0,02	-0,25	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	-0,01	0,00	-0,01	0,01	-0,02	0,00
79:4-82:4	**-0,71**	**0,16**	**0,01**	**-0,12**	**-0,50**	**-0,07**	**0,02**	**0,00**	**-0,17**	**0,00**	**-0,01**	**0,00**	**-0,01**	**0,00**	**0,00**	**0,00**	**0,00**	**-0,06**	**0,00**	**-0,02**	**-0,02**	**0,02**	**0,03**
82:4-90:1	0,13	-0,04	0,04	0,06	-0,11	0,06	0,04	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,01	0,00	0,01	0,01	0,04	-0,01
90:1-93:2	**-0,33**	**0,12**	**-0,17**	**-0,06**	**-0,28**	**-0,04**	**-0,14**	**0,00**	**0,06**	**0,00**	**-0,01**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,08**	**0,00**	**0,01**	**0,01**	**0,01**	**0,01**
93:2-00:1	0,11	-0,20	-0,10	0,00	0,26	-0,07	0,04	-0,02	0,17	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,02	0,00	0,01	0,00	0,01	0,00
00:1-03:1	**-0,33**	**-0,38**	**-0,09**	**0,00**	**0,15**	**-0,06**	**-0,09**	**0,00**	**0,25**	**0,01**	**-0,02**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**-0,01**	**0,00**	**0,02**	**0,00**	**-0,02**	**-0,03**
03:1-04:4	-0,09	-0,49	-0,08	0,06	0,18	-0,07	0,06	0,00	0,22	0,01	0,01	0,00	0,00	0,00	0,00	0,00	0,00	-0,08	0,00	0,00	0,03	-0,03	-0,01

Historical Decomposition of output in the model with a high substution elasticity: average growth rate and relative contribution of the shocks for the US

Subperiod (recessions in bold)	Observed growth	Contribution of Euro area shocks								Contribution of US Shocks								Contribution of foreign shocks					
		prodty	riskp	gov	monpol	p	inv	pc	w	prodty	riskp	gov	monpol	p	inv	pc	w	nt_ea	nt_us	pm_ea	pm_us	oil	uirp
74:1-75:1	**-1,51**	**0,00**	**-0,01**	**0,00**	**0,01**	**0,00**	**0,00**	**0,00**	**-0,01**	**-0,05**	**-0,66**	**-0,13**	**0,01**	**-0,20**	**0,04**	**0,05**	**-0,11**	**0,00**	**-0,05**	**-0,05**	**-0,09**	**-0,11**	**-0,01**
75:1-79:4	0,14	0,01	0,00	0,00	0,00	0,00	0,00	0,00	-0,01	-0,07	0,22	-0,03	0,05	0,00	0,15	0,02	-0,14	0,00	0,00	0,00	-0,01	-0,02	-0,01
79:4-82:4	**-0,84**	**0,00**	**0,00**	**0,00**	**-0,01**	**0,00**	**0,00**	**0,00**	**0,00**	**-0,10**	**-0,14**	**-0,04**	**-0,57**	**-0,03**	**0,06**	**-0,01**	**-0,08**	**0,00**	**-0,02**	**0,00**	**-0,04**	**0,01**	**0,01**
82:4-90:1	0,32	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,06	0,10	0,04	0,17	0,02	-0,10	-0,03	0,11	0,00	0,01	0,01	0,01	0,03	0,00
90:1-93:2	**-0,27**	**0,01**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,13**	**-0,41**	**-0,04**	**0,06**	**-0,01**	**-0,09**	**-0,04**	**0,08**	**0,00**	**-0,03**	**0,01**	**0,02**	**0,01**	**-0,01**
93:2-00:1	0,22	-0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,02	0,16	-0,01	0,02	0,00	-0,04	-0,01	0,09	0,00	-0,02	0,01	0,00	0,01	0,01
00:1-03:1	**-0,41**	**-0,01**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,01**	**0,23**	**-0,43**	**0,06**	**-0,08**	**0,04**	**-0,10**	**0,00**	**-0,07**	**0,00**	**-0,05**	**0,02**	**-0,01**	**-0,01**	**0,04**
03:1-04:4	0,39	-0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,44	0,06	-0,04	-0,01	-0,05	0,14	0,00	-0,04	0,00	0,00	-0,02	0,02	-0,04	-0,02

Table 7 B: Historical decomposition of the exchange rate and the US nettrade balance

Historical Decomposition of exchange rate fluctuations in the model with a HIGH substution elasticity

Subperiod	Observed change	Contribution of Euro area shocks								Contribution of US Shocks								Contribution of foreign shocks					
		prodty	riskp	gov	monpol	p	inv	pc	w	prodty	riskp	gov	monpol	p	inv	pc	w	nt_ea	nt_us	pm_ea	pm_us	oil	uirp
74:1 - 80:1	20,19	-5,07	0,84	-0,33	-14,21	0,62	0,85	-0,14	-16,30	-0,59	-1,06	0,96	-1,53	1,40	1,53	-4,71	18,06	4,66	-0,24	5,01	-3,80	-8,30	27,70
80:1-85:1	-75,06	-3,82	-7,43	-0,01	6,83	-0,29	0,36	3,36	-20,11	0,63	5,96	-0,77	-4,55	0,00	3,37	-4,18	14,63	-3,99	-0,08	-12,29	0,82	-2,86	-58,52
85:1-88:1	58,99	4,47	-0,23	0,29	2,53	1,81	-0,59	-1,30	-11,54	-0,22	2,93	0,07	0,27	-2,17	1,85	-1,84	2,85	-1,53	-0,26	4,38	1,07	1,83	49,32
01:2-98:4	-29,87	4,61	1,82	-0,04	-3,73	-0,38	0,09	0,32	-0,18	1,78	5,92	0,14	-0,14	-1,46	-0,19	1,86	-2,67	0,02	-0,35	-10,50	-1,44	-4,07	-26,32
04:4--01:2	39,68	5,30	1,07	0,19	-5,55	-2,08	0,51	0,35	3,15	2,28	1,78	-0,34	-0,43	-0,07	-1,76	3,24	-2,61	-1,23	-0,59	5,53	4,34	-2,50	21,89

Historical Decomposition of exchange rate fluctuations in the model with a LOW substution elasticity

Subperiod	Observed change	**Contribution of Euro area shocks**								**Contribution of US Shocks**								**Contribution of foreign shocks**					
		prodty	riskp	gov	monpol	p	inv	pc	w	prodty	riskp	gov	monpol	p	inv	pc	w	nt_ea	nt_us	pm_ea	pm_us	oil	uirp
74:1 - 80:1	20,19	5,46	2,75	-0,59	-4,43	0,51	-1,19	2,36	-32,22	-0,28	-3,59	0,74	-1,57	1,62	-0,78	-5,23	19,76	-9,11	0,12	6,18	7,82	7,44	17,34
80:1-85:1	-75,06	5,15	-5,28	-0,21	1,84	-0,64	1,34	0,82	-27,91	1,22	5,03	-0,63	-1,37	0,12	1,70	-3,85	15,84	-7,86	0,10	-10,41	4,68	2,08	-63,85
85:1-88:1	58,99	-0,16	-0,41	0,43	1,78	3,80	-0,15	0,93	-12,33	0,35	1,72	0,15	0,49	-2,49	2,50	-1,28	3,74	3,93	0,01	5,77	3,70	-2,01	43,69
01:2-98:4	-29,88	-5,45	2,39	-0,08	-1,62	-0,25	-0,77	-0,19	3,76	1,43	5,72	0,00	0,04	-1,37	0,68	2,09	-2,09	-4,52	0,40	-10,11	0,83	3,66	-29,28
04:4--01:2	39,68	-7,77	-1,01	0,30	-2,66	-2,75	-0,12	-0,24	8,09	0,45	1,84	-0,30	-0,32	0,07	-2,49	3,21	-2,12	-0,98	0,35	3,77	0,59	2,12	32,79

Historical Decomposition of the nettrade balance in the model with a HIGH substution elasticity for the US (nettrade balance expressed as a % of GDP)

Subperiod	Observed change	Contribution of Euro area shocks								Contribution of US Shocks								Contribution of foreign shocks					
		prodty	riskp	gov	monpol	p	inv	pc	w	prodty	riskp	gov	monpol	p	inv	pc	w	nt_ea	nt_us	pm_ea	pm_us	oil	uirp
74:1 - 80:1	0,27	-0,34	0,13	0,00	-0,30	-0,08	-0,01	-0,09	0,59	0,13	-0,32	0,07	-0,03	0,08	-0,36	-0,03	0,23	0,36	-0,57	-0,28	0,22	-0,74	1,08
80:1-85:1	-1,72	-0,44	-0,34	0,01	0,15	0,01	0,07	0,07	0,23	0,08	0,14	-0,07	0,36	-0,03	0,05	0,01	0,07	-0,20	0,27	0,69	-0,04	-0,38	-2,41
85:1-88:1	0,27	0,00	0,00	0,00	0,05	-0,09	-0,02	-0,04	-0,02	0,04	0,21	0,02	-0,33	-0,07	0,40	0,02	-0,14	-0,14	-0,96	0,00	-0,53	0,02	1,85
01:2-98:4	-1,48	0,30	0,16	0,00	-0,10	-0,01	-0,02	0,00	-0,16	-0,04	0,25	0,02	-0,06	-0,11	0,17	0,00	0,02	-0,08	-1,20	0,44	0,07	-0,13	-1,01
04:4--01:2	-1,76	0,31	-0,12	0,00	-0,08	0,08	0,02	0,00	-0,22	-0,37	0,63	-0,01	0,05	0,01	-0,12	0,00	0,07	-0,02	-1,70	-0,25	-0,48	-0,10	0,49

Historical Decomposition of the nettrade balance in the model with a LOW substution elasticity for the US (nettrade balance expressed as a % of GDP)

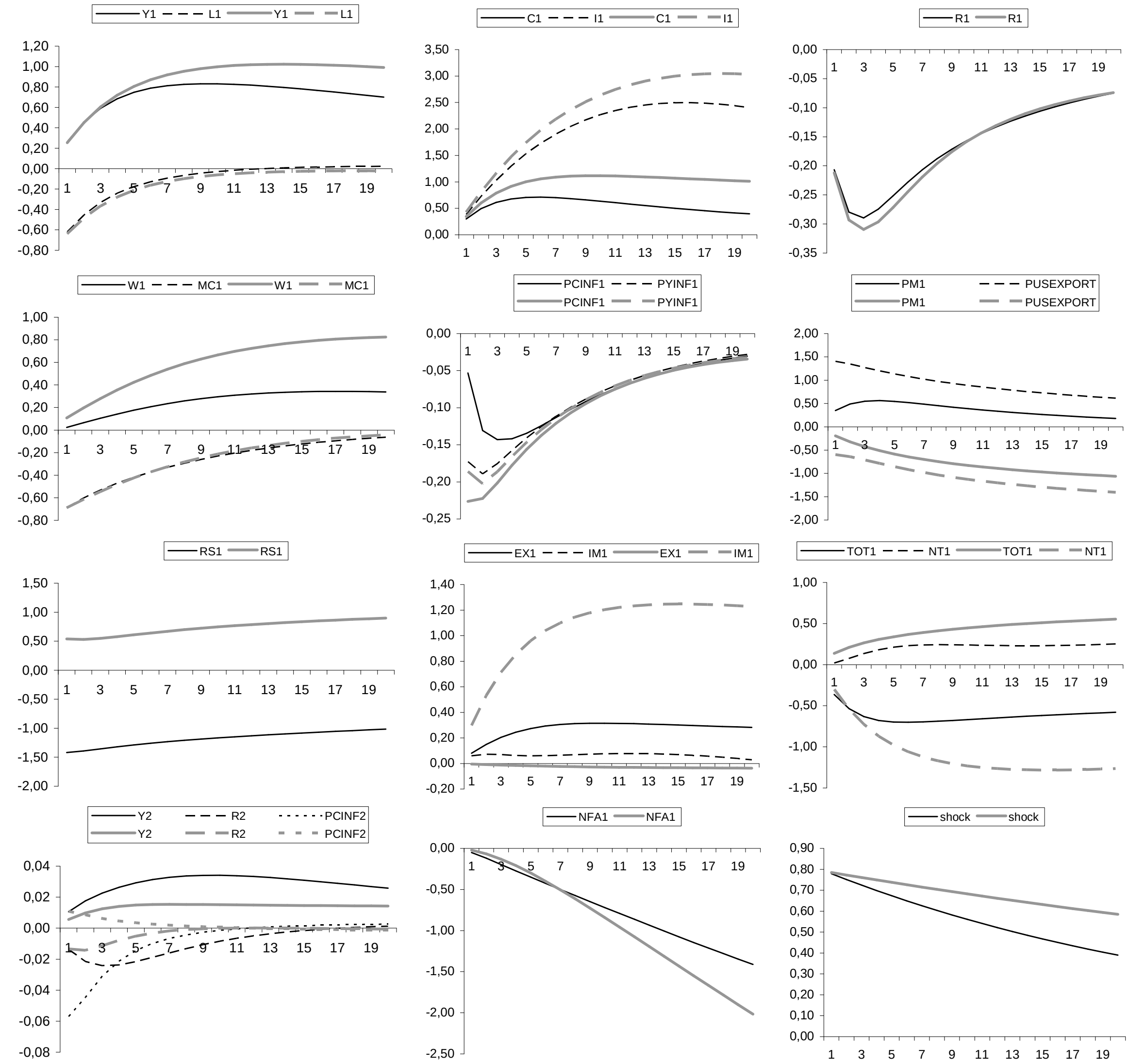
Subperiod	Observed change	Contribution of Euro area shocks								Contribution of US Shocks								Contribution of foreign shocks					
		prodty	riskp	gov	monpol	p	inv	pc	w	prodty	riskp	gov	monpol	p	inv	pc	w	nt_ea	nt_us	pm_ea	pm_us	oil	uirp
74:1 - 80:1	0,27	0,27	0,19	0,00	0,25	0,04	-0,14	0,06	-0,42	0,20	-0,41	0,05	-0,05	0,12	-0,42	-0,07	0,39	-0,34	-0,60	-0,09	0,73	0,40	0,20
80:1-85:1	-1,72	0,26	-0,20	0,00	-0,30	-0,02	0,12	-0,06	-0,20	0,13	0,07	-0,06	0,52	-0,05	-0,04	0,05	0,06	-0,23	-0,54	0,47	-0,06	0,06	-1,63
85:1-88:1	0,27	-0,10	-0,01	0,00	-0,08	0,07	0,03	0,04	-0,01	0,10	0,09	0,03	-0,38	-0,09	0,39	0,06	-0,18	0,01	-0,29	-0,01	-0,07	-0,10	0,76
01:2-98:4	-1,48	-0,41	0,15	0,00	0,21	0,01	-0,05	-0,01	0,12	-0,04	0,20	0,01	-0,11	-0,13	0,17	0,01	0,06	-0,03	-1,43	0,24	-0,03	0,12	-0,55
04:4--01:2	-1,76	-0,43	-0,16	0,00	0,10	-0,04	-0,06	0,00	0,15	-0,61	0,61	0,01	0,10	0,03	-0,16	-0,01	0,07	-0,13	-1,52	-0,17	-0,25	0,06	0,64

In the following graphs, the number 1 in variables name indicates that the variable relates to the euro area while number 2 indicates that it relates to the US economy.

Variable list

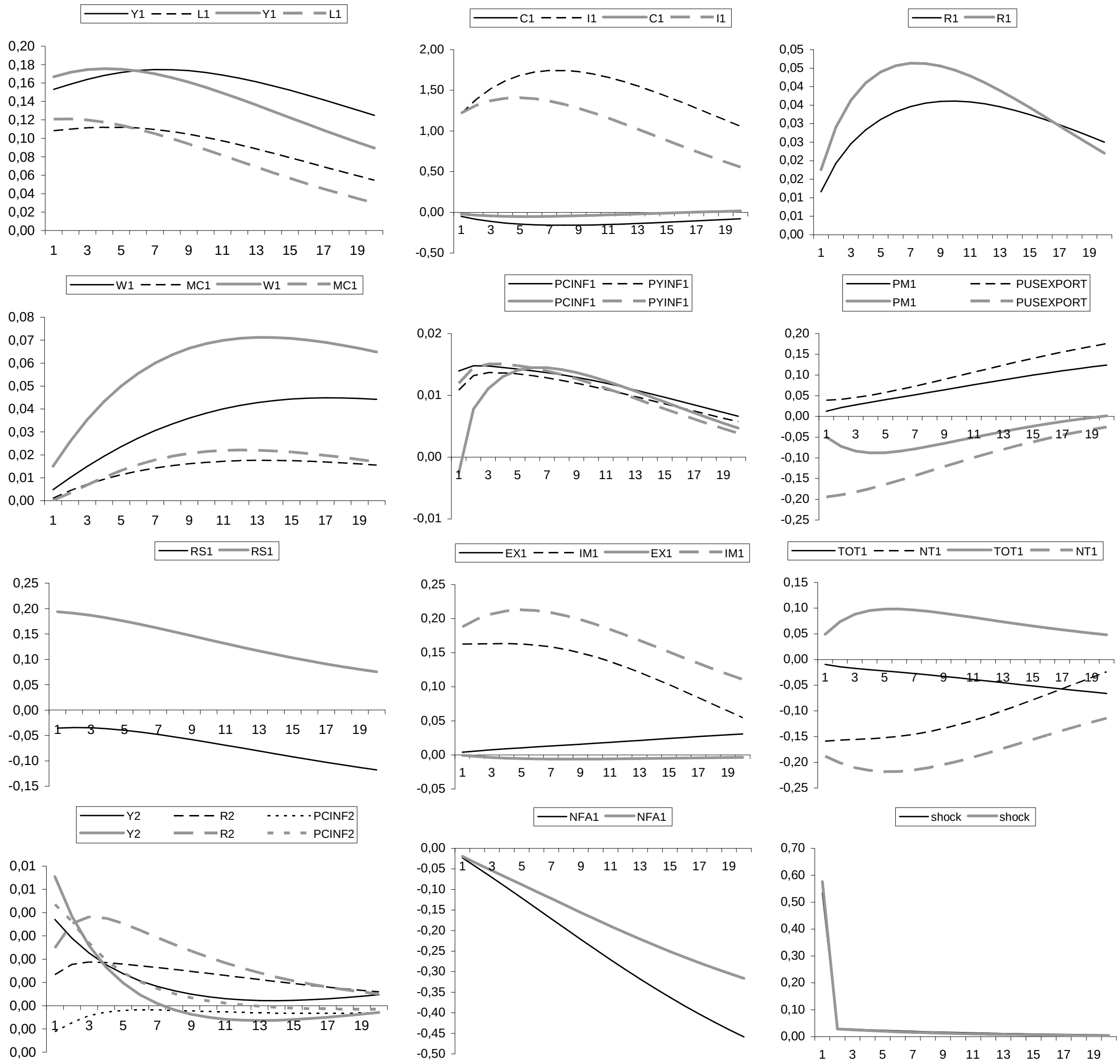
C	: real consumption	PCINF	: consummer price inflation (annualised)
EX	: real export	PYINF	: domestic price inflation (annualised)
I	: investment	PM	: import price index
IM	: real import	PUSEXPORT	: US export prices expressed in euro
L	: labour supply	R	: nom. short term interest rate (annualised)
MC	: marginal cost	RS	: real exchange rate
NFA	: current account	TOT	: terms of trade
NT	: trade balance	W	: real wage
		Y	: real output

Graph 1: productivity shock



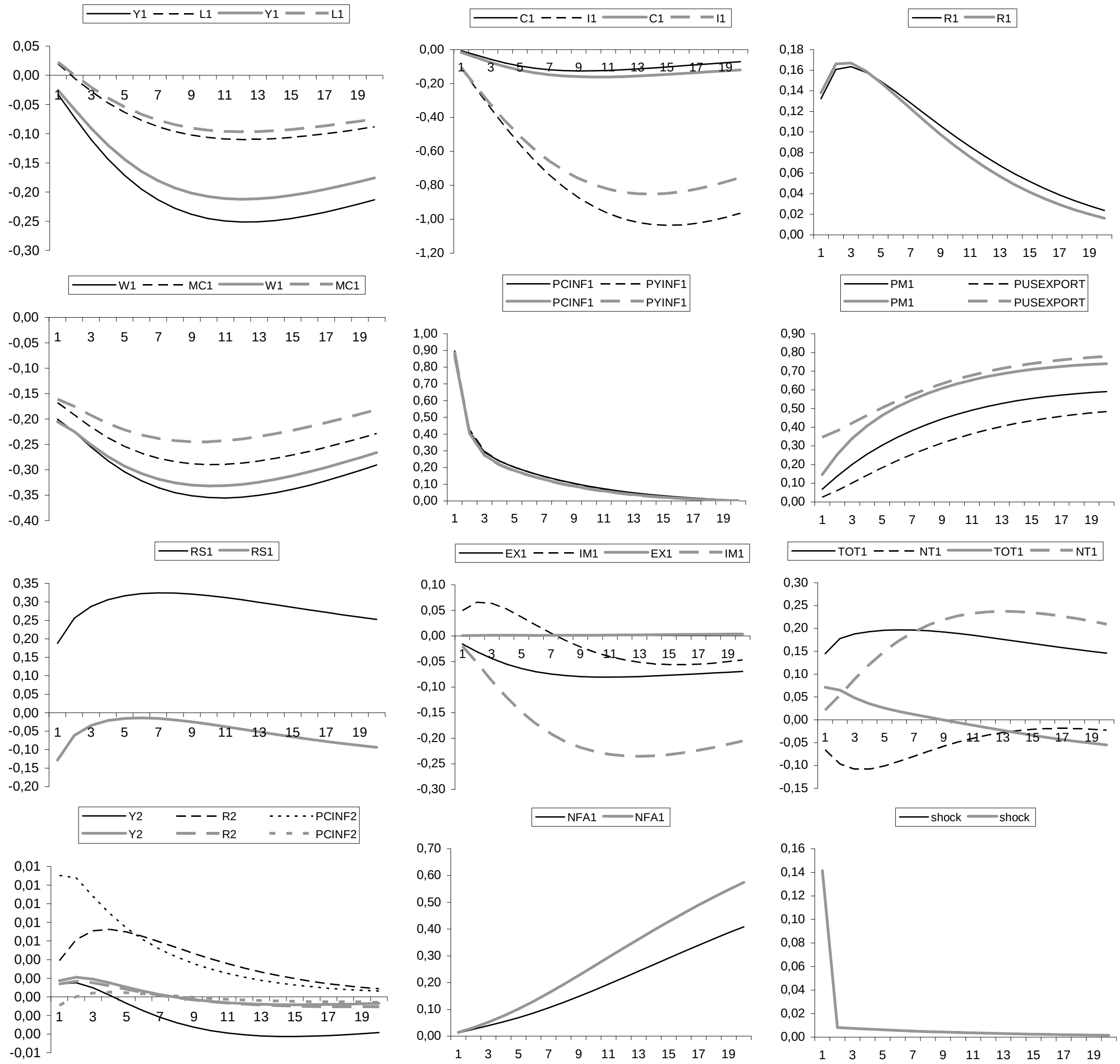
Black lines: high elast. of subst.
Gray lines: low elast. of subst.

Graph 2: investment shock



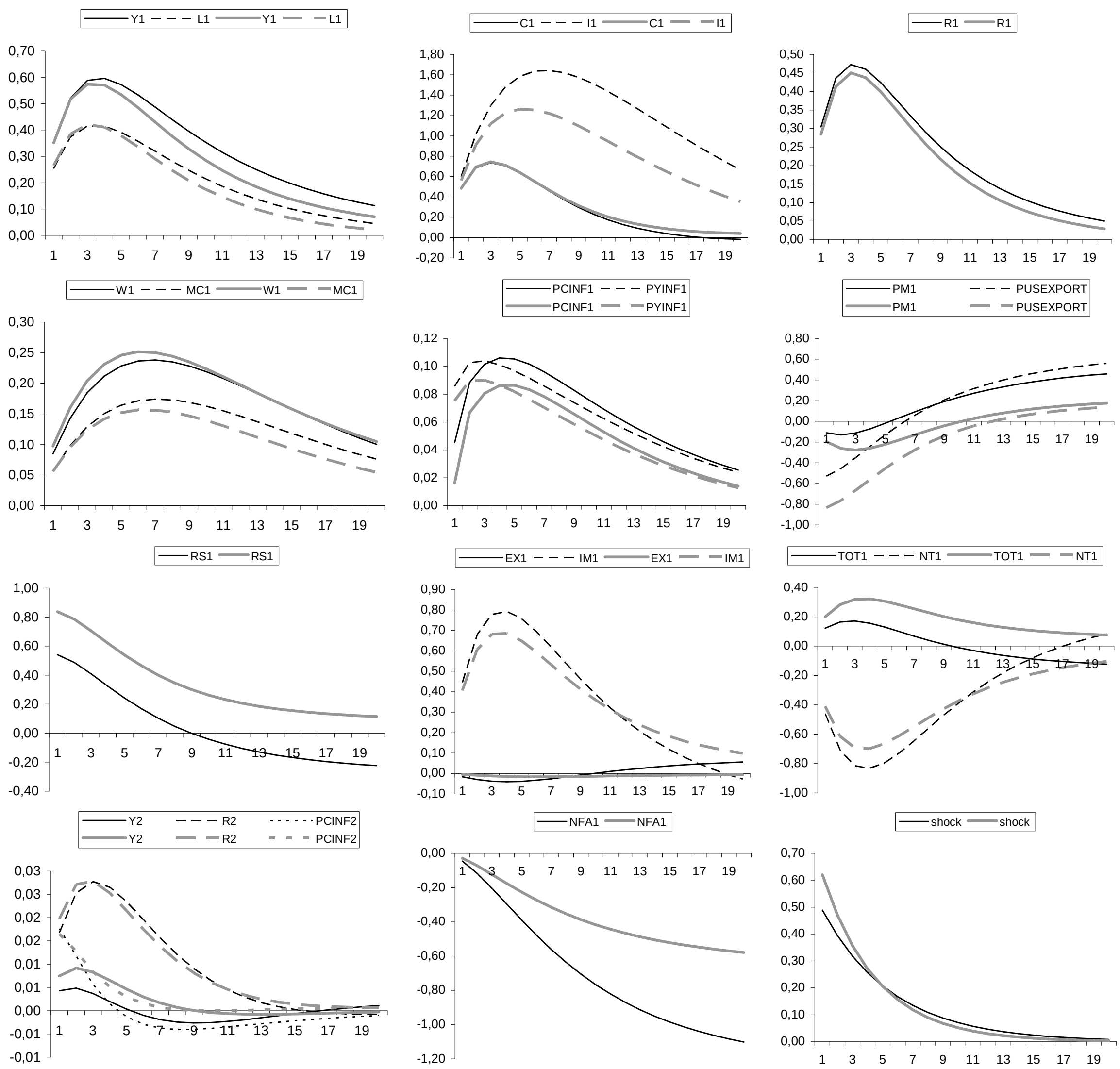
Black lines: high elast. of subst.
Gray lines: low elast. of subst.

Graph 3: price mark-up shock



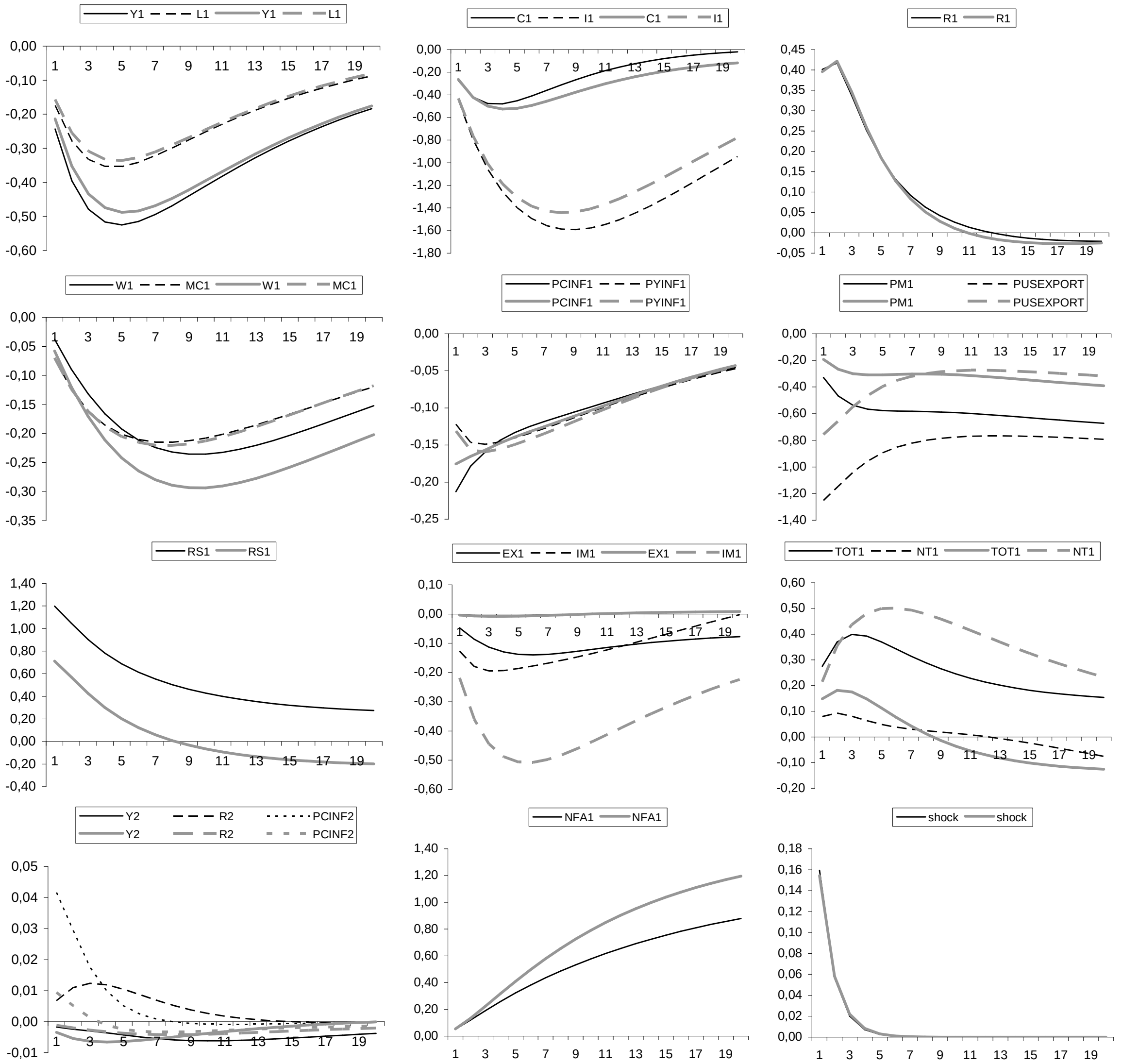
Black lines: high elast. of subst.
Gray lines: low elast. of subst.

Graph 4: risk premium shock



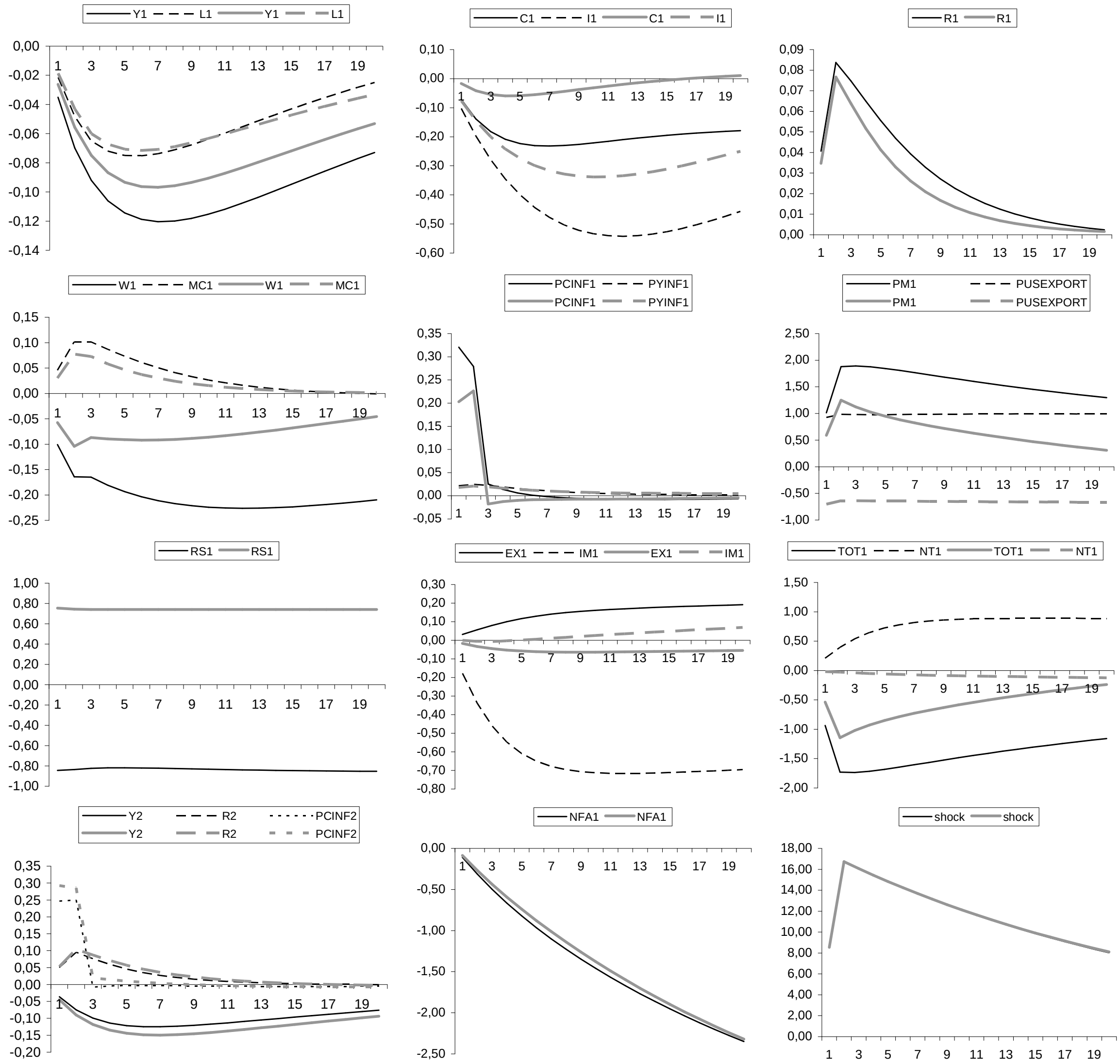
Black lines: high elast. of subst.
Gray lines: low elast. of subst.

Graph 5: monetary policy shock



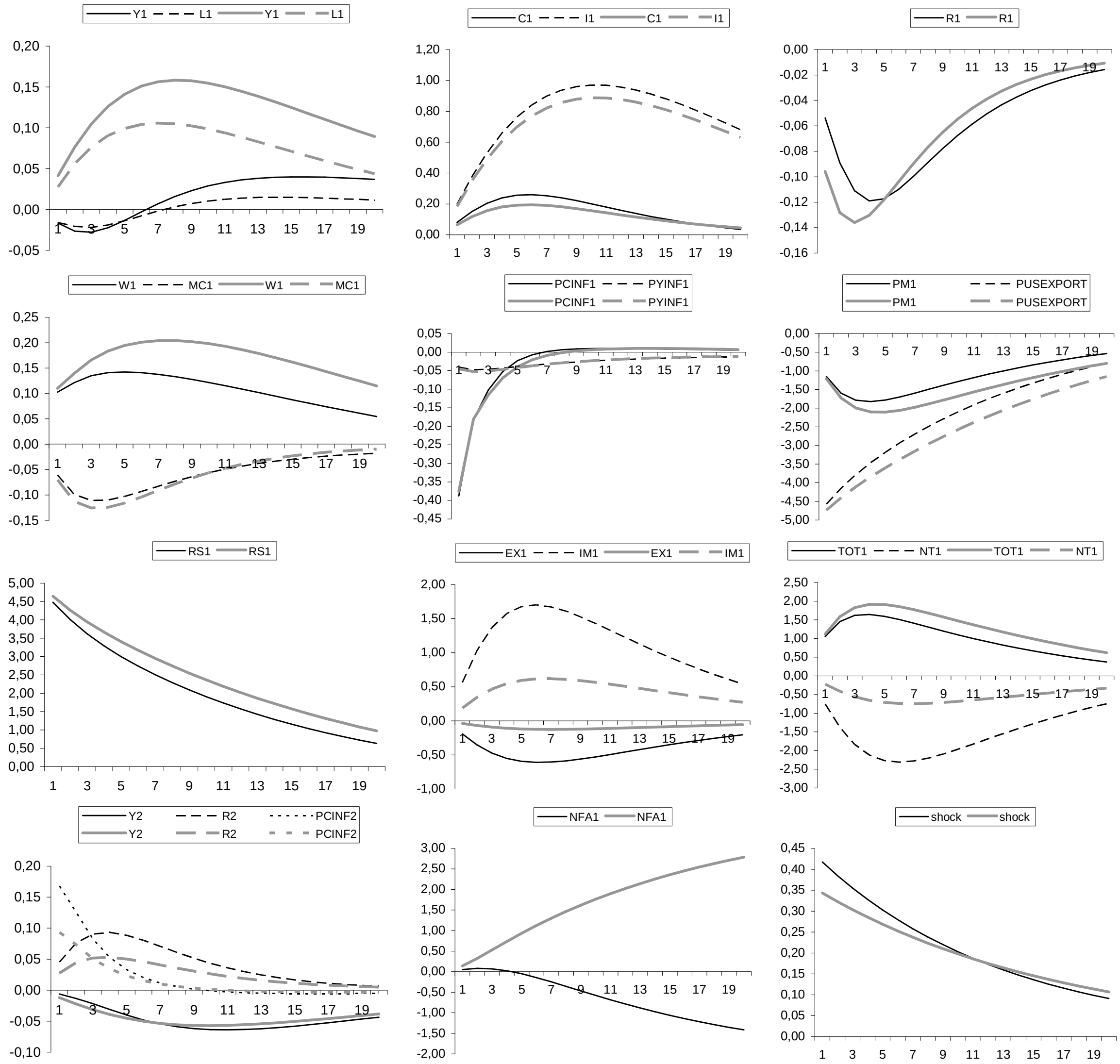
Black lines: high elast. of subst.
Gray lines: low elast. of subst.

Graph 6: oil price shock



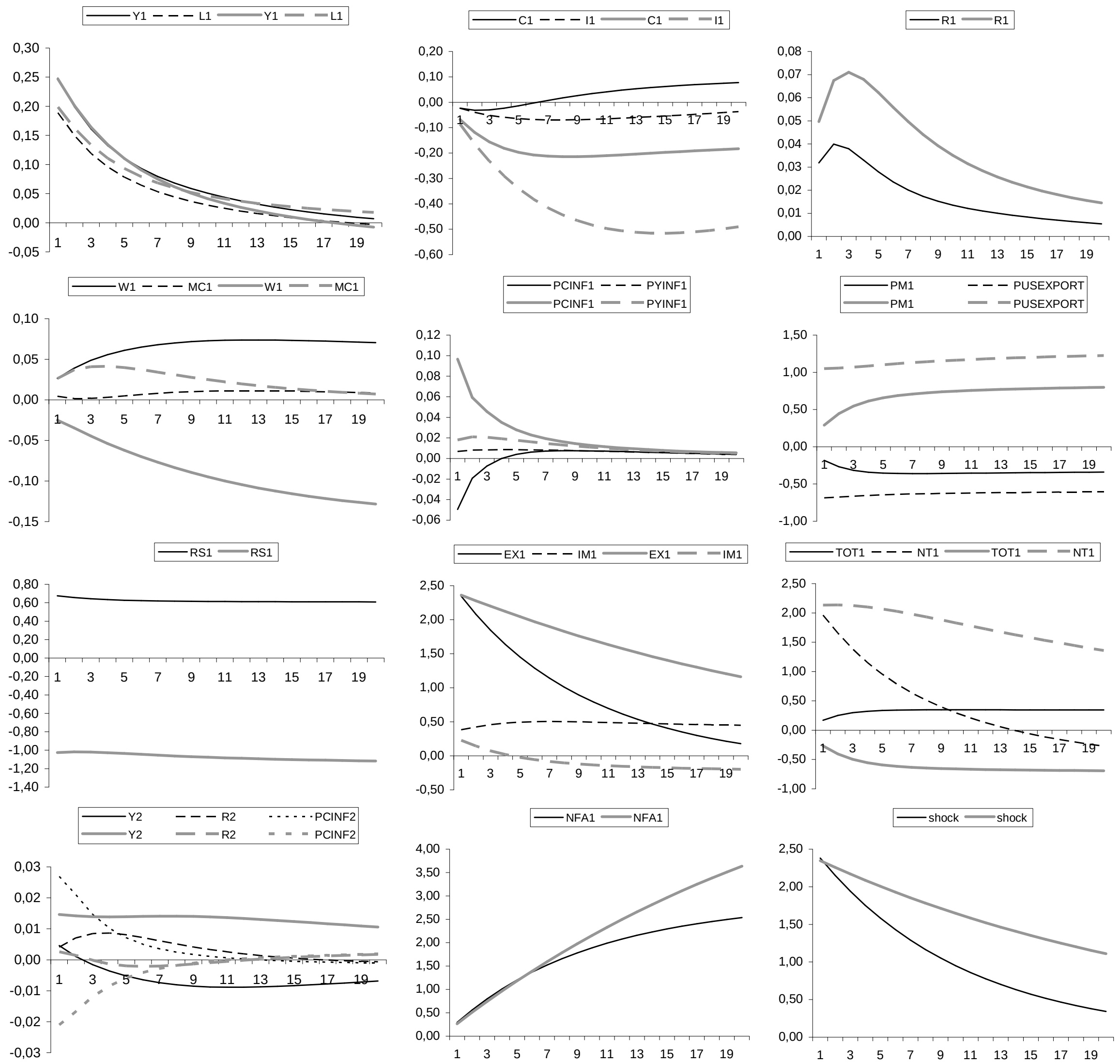
Black lines: high elast. of subst.
Gray lines: low elast. of subst.

Graph 7: UIRP shock



Black lines: high elast. of subst.
Gray lines: low elast. of subst.

Graph 8: ROW demand shock



Black lines: high elast. of subst.
Gray lines: low elast. of subst.