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by

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Has the Euro changed the Business Cycle?*

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Abstract

In this paper we analyze European business cycles before and under EMU. Across the two periods we find 1) a significant decline in real exchange rate volatility, 2) significant changes in cross-country correlations, and 3) the volatility of macroeconomic fundamentals largely unchanged. We develop a two-country business cycle model and show that the calibrated model is able to replicate key features of the data prior to and under EMU. We find that the euro has a strong bearing on the transmission mechanism as cross-country spillovers increase substantially under EMU. As a result, foreign shocks become more and domestic shocks less important in accounting for the (unchanged) volatility of macroeconomic fundamentals.

Keywords: European business cycles, Euro, Optimum Currency Area, EMU, Monetary Policy, Exchange rate regime, Cross-country spillovers

JEL-Codes: F41, F42, E32

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1 Introduction

In January 1999 eleven European countries adopted the euro as a common currency and delegated monetary policy to the European Central Bank. Theory suggests that the creation of the European Monetary Union (EMU) alters European business cycles profoundly. Most importantly, the lack of exchange rate flexibility impairs macroeconomic adjustment in the face of asymmetric shocks if prices are sticky (Friedman 1953). This is the maintained hypothesis of the theory of optimum currency areas which balances foregone stabilization under a common currency with gains in transparency and lower transaction costs (Mundell 1961, McKinnon 1963, and Kenen 1969).

Against this background we analyze to what extent the euro has actually changed European business cycles. We proceed in two steps. First, taking a purely empirical perspective, we document significant changes in European business cycles. Second, we develop a general equilibrium model that allows us to decompose these changes into changes due to differences in policy, the exchange rate regime, and the exogenous shock structure. While empirical and theoretical studies of intra-European business cycles have flourished in recent years, our distinct contribution is to demonstrate the ability of a carefully calibrated model to account for the changes in European business cycles and to investigate the underlying causes through counterfactual experiments.[1]

Our empirical analysis focuses on a sample of nine European countries (Belgium, France, Finland, Germany, Netherlands, Ireland, Italy, Spain, and Portugal) and analyzes quarterly data for the periods 1985–1996 and 1999–2007, to which we refer as the 'PreEMU' and the 'EMU' sample, respectively. Given the limited number of observations, we focus on simple statistics to characterize business cycles: the volatility of macroeconomic fundamentals as well as their cross-country correlation. Comparing results for both samples, we find 1) a significant decline in real exchange rate volatility, 2) a significant increase (decrease) in the cross-country correlation of output (government spending), and 3) the volatility of macroeconomic fundamentals largely unchanged.

These findings are subject to the caveat that longer term developments triggered by the euro may not yet be manifest in the data.[2] It is reassuring, however, that our findings mirror those for the period when the Bretton-Woods-system had been abandoned in favor of a system of floating exchange rates. In an influential study, Mussa (1986) documented a dramatic rise in real exchange rate volatility in OECD countries in the period after 1973. Baxter and Stockman (1989) provide a more comprehen-

[1] Related empirical studies include Artis and Zhang (1997) who analyze the effect of the European exchange rate mechanism on business cycles correlations. More recent studies by Canova et al. (2007), Negro and Otrok (2008), Giannone et al. (2008), and Gerlach and Hoffmann (2008) study possible effects of the euro. The former studies fail to detect the emergence of a specific EMU cycle while focusing on either annual output data, or quarterly data up to 2005. The last study, in contrast, reports significant changes in various measures of business cycle comovement. Related theoretical studies include Collard and Dellas (2002), Kollmann (2004), and Faia (2007).

[2] For instance, the euro may, by stimulating trade integration at the inter- and intraindustry level, affect the extent of specialization across countries and hence business cycle synchronization in the long-run, see Krugman (1993).

sive analysis of the data and find, in addition, evidence suggesting a decline in the cross-country correlations of economic activity, but an increase in the correlation of government spending. Finally, they document that macroeconomic fundamentals display quite similar volatilities under and after the Bretton-Woods system of fixed exchange rates (see also Flood and Rose 1995).[3]

Focusing on the recent European experience, we attempt to identify the causes underlying the documented changes. In order to do so, we put forward a two-country general equilibrium model. As unemployment fluctuations are the major concern regarding business cycle fluctuations in Europe, our model features a non-Walrasian labor market along the lines of Mortensen and Pissarides (1994). The two-country structure draws on Chari et al. (2002), but also distinguishes between the production of traded and non-traded goods in order to better capture the comovement of macroeconomic aggregates across countries (Stockman and Tesar 1995). We assume that price setting is constraint by the Calvo mechanism and that prices are sticky in the buyer's currency. All model features are fairly standard. To our knowledge, however, no attempt has been made to calibrate such a model to specific characteristics of European economies before and after the introduction of the euro.

To calibrate the model we use data for Germany and an aggregate of the remaining European countries in our sample, except for Belgium and the Netherlands, which maintained a de-facto peg to the Deutsche Mark during PreEMU. We distinguish a PreEMU and an EMU scenario by allowing estimated shock processes as well as fiscal and monetary policies to differ. The latter are characterized through estimated feedback rules, whereas we consider exogenous processes for technology and, as a way to capture non-fundamental exchange rate volatility, shocks that drive a wedge in the uncovered interest rate parity condition (Kollmann 2002). While these shocks are assumed to occur only under the PreEMU scenario, the process governing technology shocks is invariant across policy regimes. We assess the performance of the model in replicating key features of the data under both scenarios and, importantly, the documented changes across periods. We find that the model performs well on both counts, which is noteworthy, as our estimation procedures are carried out independently and prior to the simulations of the model.

A number of interesting findings emerge from analyzing the international transmission mechanism implied by the calibrated model. First, the absence of non-fundamental exchange rate shocks under EMU allows to match quantitatively the decline in real exchange rate volatility. Second, changes in the conduct of fiscal policy have virtually no bearing on business cycles, except for the behavior of fiscal aggregates. Third, the exchange rate regime has a strong impact on the transmission of technology shocks across countries. Relative to PreEMU, cross-country spillovers of shocks increase substan-

[3] It thus appears that macroeconomic fundamentals are sheltered from exchange rates fluctuations and theoretical studies have, in fact, highlighted the importance of limited exchange rate pass-through to account for the observations by Mussa and Baxter-Stockman (Duarte 2003 and Monacelli 2004). Note that this explanations has potentially important policy implications: if pass-through is limited, exchange rates fail to operate as automatic stabilizers thereby undermining the case for flexible exchange rates (Devereux and Engel 2003 and Corsetti 2008).

tially under EMU, while the effect of domestic shocks on domestic variables declines—reflecting a common monetary stance (and a muted real exchange rate response). Importantly, this change in the transmission mechanism implies two off-setting effects on the volatility of macroeconomic fundamentals and can thus not be detected in reduced form evidence. It is, however, of potentially great interest for policy making.

The remainder of the paper is organized as follows. Section 2 analyzes properties of the data. Section 3 outlines the model structure. Section 4 discusses the calibration of the model and its performance in accounting for key features of the data. Section 5 per.forms counterfactual experiments to understand changes in European business cycles. Section 6 concludes.

2 Properties of the data

In this section we summarize properties of macroeconomic times series for output and its components as well as those of the unemployment rate, inflation, and the real exchange rate. Our sample includes nine European countries, all of which introduced the euro in January 1999: Belgium, France, Finland, Germany, Ireland, Italy, Netherlands, Spain, and Portugal (EA9).[4] As a control group we include seven countries which did not adopt the euro; four European countries: Norway, Sweden, Switzerland, and the UK, as well as three non-European countries: Canada, Japan, and the US.

We consider quarterly data for two periods. First, our PreEMU sample comprises data from 1985 until 1996. The starting point of sample is motivated by the observation that business cycle fluctuations became more moderate from the mid-eighties onwards, see Stock and Watson (2005) for evidence on the G7 countries. In order to take a possible anticipation of the introduction of the euro into account, we chose the end date two years before the actual creation of EMU.[5] Our EMU sample runs from 1999 to 2007. We apply the HP-filter with a smoothing parameter of 1600 to all series in order to isolate business cycle fluctuations.[6]

Identifying a 'euro-effect' on European business cycles across the two samples is complicated by the rich variety of exchange rate arrangements in the decades prior to the introduction of the euro. During our sample period 1985–1996, the European Monetary System was subjected to considerable turbulence and the width of the targeted bands was increased to $\pm 15\%$ after the 1992 crisis. In addition, capital controls had been in place up to 1990 or later for some countries. Hence, for a set of countries there was considerable exchange rate flexibility and therefore monetary control. To keep things manageable and yet to isolate the effect of fixing exchange rates, we distinguish among those countries which successfully limited exchange rate variability vis-à-vis Germany already in the

[4] We lack data for Austria and Luxembourg.

[5] Results are not sensitive to extending the PreEMU sample up to 1999.

[6] To filter the data, we use the longest time series available, i.e. 1970Q1–2007Q4. A detailed description of the data sources and the aggregation method is provided in the appendix.

PreEMU period (Belgium, Netherlands) and the remaining countries where exchange rate volatility relative to Deutsche Mark was higher. We refer to the latter group as EA6: Finland, France, Ireland, Italy, Portugal, and Spain.[7]

In figure 1 we display the standard deviations of the variables of interest before and under EMU for all nine EMU countries in our sample as well as for the seven non-EMU countries. Standard deviations are computed in percent per quarter and, except for those of output, are scaled by the standard deviation of output. In each panel, the standard deviation for the period prior to EMU is plotted against the horizontal axis; the standard deviation for the EMU period is plotted against the vertical axis. A point on the $45°$ line indicates that for a particular country no change in the standard deviation can be observed. Points above the $45°$ line indicate an increase in volatility, while points below the $45°$ line indicate a reduction in volatility. EMU countries are represented by solid points, while those of the control group are represented by circles.

The upper left panel displays the standard deviation of output. There is a tendency for a decline in volatility, but this seems to be the case for EMU as well as for non-EMU countries. Except for the real exchange rate (lower right panel), there is little evidence for systematic change across periods. It thus appears that the volatility of those variables changed in the same way as output. The reduction of the volatility of the real exchange rate (relative to that of output) is quite pronounced for the euro countries, while no systematic change can be observed for non-EMU countries.

Figure 2 displays the cross-country correlation for output and its components, the unemployment rate, and inflation in the PreEMU and the EMU sample for all countries in our sample.[8] Again, we use the horizontal (vertical) axis to measure the correlation before (under) EMU. According to this measure, it appears that the comovement of macroeconomic aggregates increased somewhat under EMU. A remarkable exception is government spending, where cross-country correlations declined markedly under EMU.

Table 1 summarizes the evidence for three groups of countries. We report standard deviations and correlations for Germany relative to EA6 (left panel). The values for standard deviations for EMU countries in the middle panel are averages over all EA9 countries, while the right panel displays the average of the non-EMU countries, using long-run PPP-adjusted GDP as weights.[9] We use a non-linear Wald test to evaluate whether changes are significant and use an asterisk to indicate significance

[7] In the appendix we plot monthly percentage change of the nominal exchange rate in these eight countries. Fluctuations in the exchange rates of Belgium and the Netherlands were much more limited than those of the EA6 group. We include France in the EA6 group, because exchange rate volatility was almost twice as large as for Belgium.

[8] For non-EMU countries we consider the aggregate of the remaining non-EMU countries as the corresponding counterpart. For each member of the EA6 group we use the aggregate of the remaining eight EMU-countries. For Belgium, Netherlands, and Germany, instead, we only consider EA6 as a counterpart, because it is only with respect to these countries that a significant change in the exchange rate regime occurred as a result of the introduction of the euro.

[9] We obtain similar values for the corresponding statistics for EA6, see table 4 below.

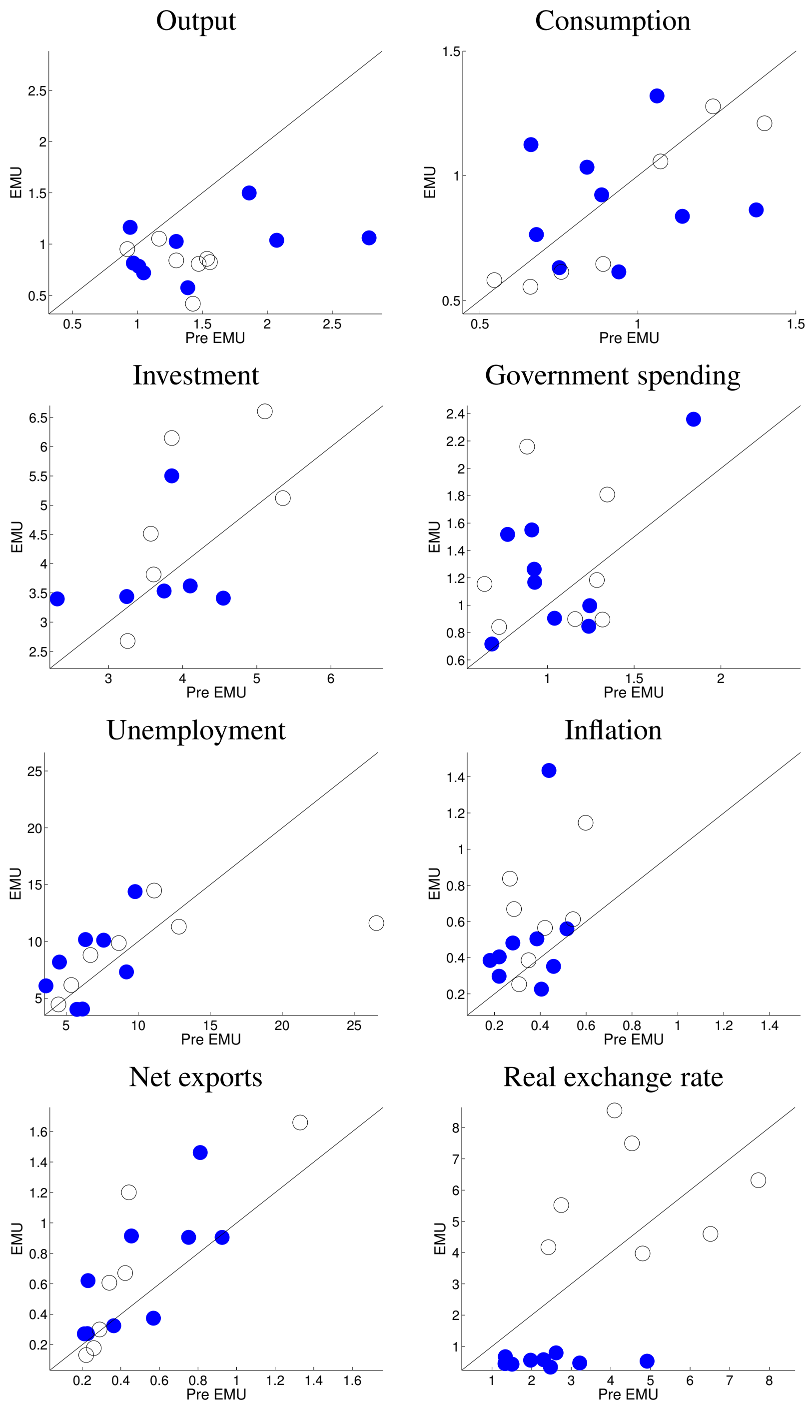

Figure 1: Standard deviations of macroeconomic time-series before and under EMU. Notes: solid points represent EMU countries, circles represent non-EMU countries; standard deviations are scaled by standard deviation of output; standard deviation of output is expressed in percent; statistics computed on quarterly HP-filtered data for period 1985–1996 and 1999–2007.

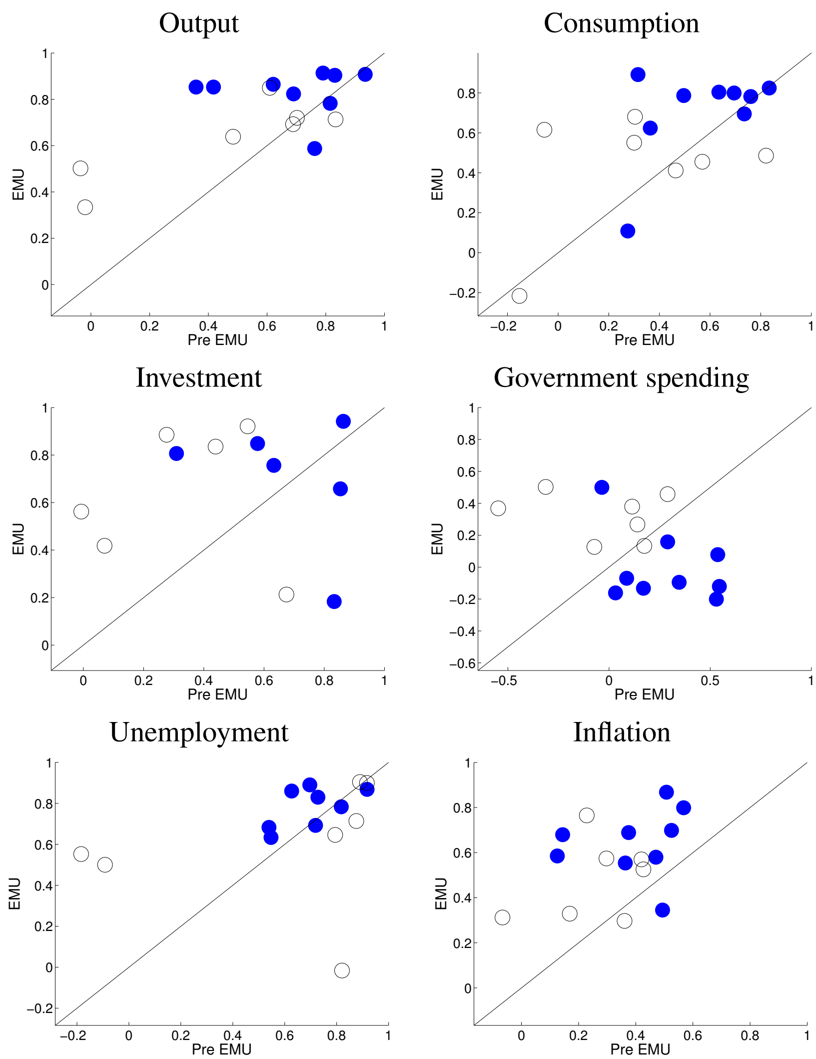

Figure 2: Cross-country correlations of macroeconomic time-series. Notes: see figure 1.

Table 1: Cyclical properties of time series before and under EMU

	Germany/EA6		EMU Avg		Non-EMU Avg	
	PreEMU	EMU	PreEMU	EMU	PreEMU	EMU
Volatility						
Std. Y *100	1.30	1.03	1.20	0.87**	1.10	0.87*
Std C/Std Y	0.68	0.76	0.93	0.84	0.87	0.70***
Std I/Std Y	2.31	3.40***	3.01	3.48**	3.63	4.45*
Std G/Std Y	1.04	0.90	1.02	0.95	1.14	1.03
Std U/Std Y	9.18	7.32	6.96	7.37	7.76	8.51
Std Infl/Std Y	0.22	0.30	0.33	0.48*	0.36	0.46
Trade						
Std RX/Std Y	2.48	0.34***	2.74	0.48***	5.23	5.00
Std NX/Std Y	0.23	0.27	0.38	0.45	0.27	0.27
Cross-Country						
Corr. Y Y^*	0.42	0.85**	0.66	0.86**	0.54	0.62
Corr. C C^*	0.36	0.62	0.60	0.72*	0.41	0.32
Corr. I^*	0.58	0.85***	0.67	0.85***	0.27	0.75***
Corr. G G^*	0.35	-0.10**	0.38	-0.07***	-0.28	0.42***
Corr. U U^*	0.73	0.83	0.71	0.77	0.66	0.72
Corr. Infl $Infl^*$	0.49	0.35	0.43	0.61***	0.37	0.49

Notes: statistics are computed for time series after applying HP-filter. PreEMU and EMU periods cover 1985–1996 and 1999–2007, respectively.

at the 10% level, two asterisks for the 5% level, and three for the 1% level.[10]

The most dramatic change across the two sample periods is the reduction in the volatility of real exchange rates. In fact, for our sample we find a decline by a factor of about 6-7. We thus confirm for EMU the well know finding that the exchange rate regime is a key determinant of real exchange rate volatility. In an influential study, Mussa (1986) documented that the variability of real exchange rates increased systematically in the period after 1973 relative to the Bretton-Woods period.[11] Regarding the cross-country correlations we find a significant increase in the correlation of output and investment among EMU countries. Note, however, that the correlation of investment increases between non-EMU countries as well. Interestingly, the cross-country correlation of government spending falls

[10] The test statistic of the Wald test is given by

$$W = [r(b) - q]'\{R(b)\hat{V}R'(b)\}^{-1}[r(b) - q] \sim \chi^2(1),$$

with b being a vector of variances of the original variables. The function $r(b)$ maps these variances into the statistic of interest, for example $Std(C_{PreEMU})/Std(Y_{PreEMU}) - Std(C_{EMU})/Std(Y_{EMU})$. The derivative $R(b)$ is defined as $\partial r(b)/\partial b'$. Finally, $\hat{V}$ is the estimated variance-covariance matrix of b, i.e. the variances and covariances of the included variances. We estimate $\hat{V}$ employing the Newey-West adjustment for autocorrelation and heteroscedasticity using a lag length of $T^{1/4}$, with T being the sample length.

[11] Mussa's study relies mostly on plots of the real exchange rate. He finds: "the size of the observed difference in the short-term variability of real exchange rates under floating rather than fixed exchange rates is generally so large that measures of statistical significance are irrelevant. The consistent observation of these large differences, without exception, across a broad array of cases is fatal to the hypothesis of nominal exchange rate neutrality." (p. 123).

across EMU countries but increases across non-EMU countries. Also the average change in the cross-country correlation of inflation is positive and significant. A third finding is that there seems to be no systematic change in overall volatility. While the standard deviation of output falls (significantly for the EMU average), we also observe a significant decline for our sample of non-EMU countries across the two sample periods.

Our findings thus mirror the observation reported by Baxter and Stockman (1989) as regards a possible change in business cycle statistics after the breakdown of the Bretton-Woods system of fixed exchange rates. They find little change in the volatility of macro aggregates—except for a strong increase in real exchange rate volatility, but document that the cross-country correlation of economic activity was higher under the Bretton-Woods system of fixed exchange rates. They also document a considerable increase in the correlation of government consumption in the post-Bretton-Woods period.[12]

Given that the change in real exchange rate volatility is certainly the most striking change which can be related to the introduction of the euro, we follow Mussa (1986) and decompose movements in the real exchange rate into movements of the nominal exchange rate and the ratio of price levels. Figure 3 plots the results for Germany, the EA6-countries, and the UK. As real exchange rates move quite closely with nominal rates, much of its volatility vanishes after 1999 in the EMU countries.

3 The model

In order to provide a structural account of the data before and under EMU, we now put forward our two-country business cycle model. The good market structure draws on earlier work by Chari et al. (2002), among others. Important differences concern price setting behavior where we rely on the Calvo scheme and the fact that we consider a non-traded goods sector as in Stockman and Tesar (1995) and labor market frictions along the lines of Mortensen and Pissarides (1994).

In the following we give a formal exposition of the model, discussing in turn the problems of the final goods firm, intermediate goods firms, labor market firms, and the representative household. We close the model with feedback rules characterizing monetary and fiscal policy. As both countries have isomorphic structures, we focus on the domestic economy, i.e. on the 'home' country. When necessary we refer to foreign variables by means of an asterisk. All variables are expressed in per-capita terms. The relative size of the home country, i.e. its population divided by the population of the foreign country, is denoted by n.

[12]Kollmann (2005), in contrast, focusing on an aggregate of Germany, France, and Italy on the one hand and the US on the other, finds that the cross-country correlations of real macro aggregates and the price level were markedly higher in the post-Bretton-Woods era relative to the Bretton-Woods period.

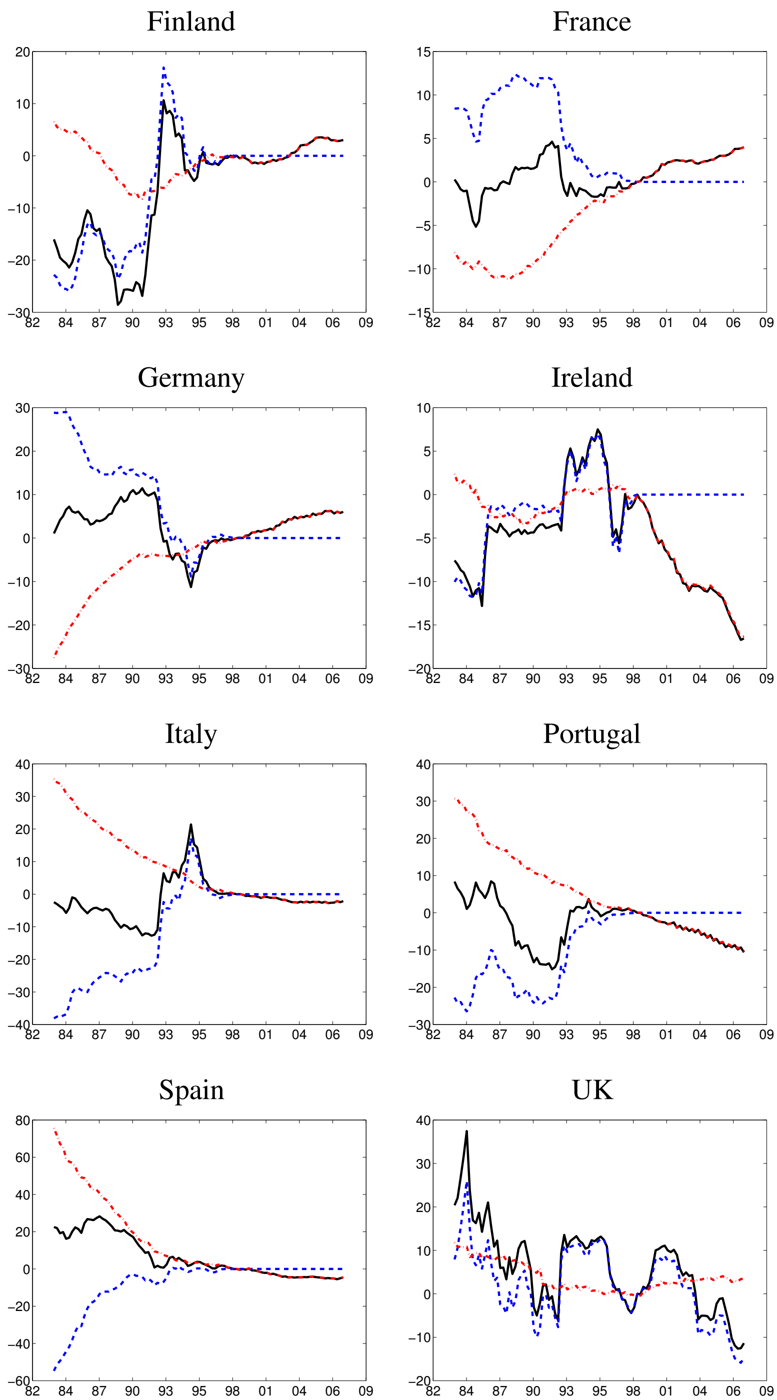

Figure 3: Real exchange rate (solid line), nominal exchange rate (dashed line), and price ratio (dashed-dotted line). Notes: real exchange rate is measured as the (log of) the price ratio times the nominal exchange rate, where the price ratio is given by CPI^{*}/CPI. Except for the UK, variables are defined relative to remaining European countries.

3.1 Final good firms

Final goods, F_t, which are not traded across countries, are composites of intermediate goods produced by a continuum of monopolistic competitive firms in both countries. We use $j \in [0,1]$ to index intermediate good firms as well as their products and prices. Final goods firms purchase domestically produced intermediate goods, $A_t(j)$, imported intermediate goods, $B_t(j)$, and domestically produced non-traded goods, $N_t(j)$. Taking their domestic currency prices $P_{A,t}(j)$, $P_{B,t}(j)$, and $P_{N,t}(j)$ as given, final good firms operate under perfect competition. A representative final good firm minimizes expenditures in order to meet the demand for final goods subject to an aggregation technology. Letting C_t, I_t, and G_t denote consumption, investment, and government spending, respectively, and χV_t a resource loss arising from labor market frictions discussed below, the constraint of the final good firms can be stated as follows

$$\begin{aligned} F_t &= C_t + I_t + G_t + \chi V_t \\ &= \left\{ \begin{array}{c} \upsilon^{\varrho+1}\left[\omega^{\varsigma+1}\left(\int_0^1 A_t(j)^{-\varepsilon}dj\right)^{\frac{\varsigma}{\varepsilon}} + (1-\omega)^{\varsigma+1}\left(\int_0^1 B_t(j)^{-\varepsilon}dj\right)^{\frac{\varsigma}{\varepsilon}}\right]^{\frac{\varrho}{\varsigma}} \\ +(1-\upsilon)^{\varrho+1}\left(\int_0^1 N_t(j)^{-\varepsilon}dj\right)^{\frac{\varrho}{\varepsilon}} \end{array} \right\}^{-\frac{1}{\varrho}}, \end{aligned} \tag{1}$$

where $\sigma \equiv (1+\varsigma)^{-1}$ measures the trade price elasticity of substitution, $\epsilon \equiv (1+\varepsilon)^{-1}$ denotes the elasticity of substitution between intermediate goods of the same type, and $\eta = (1+\varrho)^{-1}$ measures the elasticity of substitution between tradeable and non-tradeable goods. The parameters υ and ω are the weights of traded and imported goods in final and traded goods, respectively.
Expenditure minimization implies that the price of final goods is given by

$$P_{F,t} = \left[\upsilon {P_{T,t}}^{1-\eta} + (1-\upsilon)\, {P_{Nt}}^{1-\eta}\right]^{\frac{1}{1-\eta}}, \text{ with } P_{T,t} = \left[\omega {P_{A,t}}^{1-\sigma} + (1-\omega)\ {P_{B,t}}^{1-\sigma}\right]^{\frac{1}{1-\sigma}}, \tag{2}$$

where

$$P_{k,t} = \left(\int_0^1 P_{k,t}(j)^{1-\epsilon}dj\right)^{\frac{1}{1-\epsilon}} \text{ for } k \in A, B, N. \tag{3}$$

We discuss below how prices of varieties, $P_{k,t}(j)$, are determined. The index k is used to denote traded domestically produced, imported, or non-traded intermediate goods. Expenditures minimization by final good firms at home and abroad gives rise to demand for domestically produced intermediate goods of the tradeable type, $A_t(j)$ and $A_t^*(j)$, respectively

$$A_t(j) = \upsilon\left(\frac{P_{A,t}(j)}{P_{A,t}}\right)^{-\epsilon}\left(\frac{P_{A,t}}{P_{T,t}}\right)^{-\sigma}\left(\frac{P_{T,t}}{P_{F,t}}\right)^{-\eta}(1-\omega)F_t \tag{4}$$

$$A_t^*(j) = \upsilon\left(\frac{P_{A,t}^*(j)}{P_{A,t}^*}\right)^{-\epsilon}\left(\frac{P_{A,t}^*}{P_{T,t}^*}\right)^{-\sigma}\left(\frac{P_{T,t}^*}{P_{F,t}^*}\right)^{-\eta}\omega F_t^*. \tag{5}$$

For non-traded goods, $N_t(j)$, we have

$$N_t(j) \quad = \quad (1-\upsilon)\left(\frac{P_{N,t}(j)}{P_{N,t}}\right)^{-\epsilon}\left(\frac{P_{N,t}}{P_{F,t}}\right)^{-\eta} F_t. \tag{6}$$

3.2 Intermediate goods firms

The production of intermediate goods is governed by the following production function

$$Y_{k,t}(j) = Z_{k,t}K_{k,t}(j)^{\theta}L_{k,t}(j)^{1-\theta}, \tag{7}$$

where $Z_{k,t}$ denotes technology in sector $k \in \{A, N\}$. $K_{k,t}(j)$ and $L_{k,t}(j)$ measure the amount of capital and labor employed by firm j, respectively. Capital and labor inputs are not firm specific and can be adjusted freely in each period such that marginal costs for each firm within each sector are given by

$$MC_{k,t} = \frac{P_{L,t}L_{k,t}}{(1-\theta)Y_{k,t}} = \frac{R_{k,t}K_{k,t}}{\theta Y_{k,t}}, \tag{8}$$

where $P_{L,t}$ and $R_{k,t}$ denote the price of labor and capital, respectively—note that only the latter is sector specific.

We assume that price setting is constrained exogenously by a discrete time version of the mechanism suggested by Calvo (1983). Each firm has the opportunity to change its price with a given probability $1-\xi_k$. With respect to firms which produce traded intermediate goods, we assume that prices are set in buyer's currency. As a result, intermediate goods producers' problems differ depending on whether they produce traded or non-traded goods.

Consider first the problem of a generic firm in the non-traded goods sector. We assume that it sets its price $P_{N,t}(j)$, given the opportunity to readjust, in order to maximize the expected discounted value of net profits:

$$\max \sum_{l=0}^{\infty} (\xi_N)^l E_t \rho_{t,t+l} N_{t,t+l}(j) \left[P_{N,t}(j) - MC_{N,t+l}\right]/P_{F,t+l}. \tag{9}$$

subject to demand functions defined by (6) and the production function (7). $N_{t,t+l}(j)$ denotes demand in period $t+l$ given that prices have been last adjusted in period t. $\rho_{t,t+l}$ is the pricing kernel used to discount profits. As firms are owned by households, we assume that $\rho_{t,t+l} = \frac{\beta_{t+l}U_{C,t+l}}{\beta_t U_{C,t}}$, where β_t and $U_{C,t}$ denote discount factor and marginal utility of households, respectively. We discuss the household problem in detail below.

Traded good firms set possibly different prices for the domestic and foreign market. We assume that the frequency of price adjustment is determined by the destination market, not by the origin of the product. Domestic prices $P_{A,t}(j)$ are set in order to maximize the expected discounted value of net profits

$$\max \sum_{l=0}^{\infty} (\xi_A)^l E_t \rho_{t,t+l} A_{t,t+l}(j) \left[P_{A,t}(j) - MC_{A,t+l}\right]/P_{F,t+l}, \tag{10}$$

subject to demand functions defined by (4) and the production function (7). Foreign prices $P^*_{A,t}(j)$ are set to maximize the following expression

$$\max \sum_{l=0}^{\infty} (\xi^*_A)^l E_t \rho_{t,t+l} A^*_{t,t+l}(j) \left[S_{t+l} P^*_{A,t}(j) - MC_{A,t+l} \right] / P_{F,t+l}, \tag{11}$$

subject to demand functions defined by (5), and the production function (7). ξ^*_A measures the probability that a price remains in effect in the foreign market and S_t is the nominal exchange rate.

3.3 Households

A representative household allocates consumption expenditures on final goods, C_t, and supplies labor, H_t. Preferences are given by

$$E_0 \sum_{t=0}^{\infty} \beta_t \left(\frac{C_t^{1-\gamma} - 1}{1-\gamma} - \vartheta \frac{H_t^{1+\mu}(1-U_t)}{1+\mu} \right) \tag{12}$$
$$\beta_0 = 1, \;\; \beta_{t+1} = \beta(C_t)\beta_t, \;\; \beta(C_t) = (1 + \psi C_t)^{-1},$$

where the function $\beta(C_t)$ ensures that the discount factor β_t increases in response to a rise in average consumption. This effect is not internalized by the household.[13] The parameter $\psi > 0$ determines the value of the discount factor in steady state. U_t denotes the measure of workers that are unemployed. Labor and capital are internationally immobile; households in each country own the capital stock: $K_{A,t}$ and $K_{N,t}$ are employed in the production of intermediate traded goods and non-traded goods, respectively. As in Christiano et al. (2005), we assume that it is costly to adjust the rate of investment. Specifically, we assume for the law of motion for capital in each sector

$$K_{k,t+1} \;\; = \;\; (1-\delta)K_{k,t} + \digamma(I_{k,t}, I_{k,t-1}), \text{ with } \digamma = \left[1 - \frac{\kappa}{2} \left(\frac{I_{k,t}}{I_{k,t-1}} - 1 \right)^2 \right] I_{k,t}, \tag{13}$$

where $\kappa \geq 0$ measures the extent of adjustment costs. Total investment expenditures are given by $I_t = I_{A,t} + I_{N,t}$.

As regards international financial markets, we only allow for trade in riskless bonds, Θ_t and Θ^*_t denominated in domestic and foreign currency, respectively. The budget constraint of the domestic household is therefore given by

$$\begin{aligned} & (W_t H_t (1-U_t) + R_{A,t} K_{A,t} + R_{N,t} K_{N,t} + \Upsilon_t) - P_{F,t}(C_t + T_t + I_t) \\ = \;\; & R_t^{-1} \Theta_{t+1} + R_t^{*-1} S_t \Theta^*_{t+1}/n - \Theta_t - S_t \Theta^*_t / n \end{aligned} \tag{14}$$

where R_t and R^*_t denote domestic and foreign gross nominal interest rates and W_t is the wage rate. T_t measures lump-sum taxes and Υ_t denotes intermediate and labor market firms' profits discussed below. Households maximize (12) subject to (13) and (14).

[13] The assumption of an endogenous discount factor induces stationarity of the model around a deterministic steady state, see Schmitt-Grohé and Uribe (2003) for details.

Combining the first order conditions for domestic and foreign bond holdings gives rise to the uncovered interest rate parity condition: $R_t = R_t^* E_t \Delta S_{t+1}$. We assume, following Kollmann (2005), that there are disturbances to this condition:

$$R_t = R_t^* E_t \Delta S_{t+1} \varepsilon_t^{UIP}, \tag{15}$$

where ε_t^{UIP} follows an exogenous process specified below. Assuming that such shocks originate in the foreign exchange market provides a convenient way to account for non-fundamental exchange rate volatility as documented, for instance, in Flood and Rose (1995).[14]

3.4 Labor market firms

We assume that intermediate good firms purchase labor services from labor market firms, where total demand for the labor good is given by $L_t = L_{A,t} + L_{N,t}$. We consider a non-Walrasian labor market assuming that a labor market firm is a match between a single worker and a single firm, which produces the labor good according to a homogeneous production function:[15]

$$l_t(i) = H_t(i). \tag{16}$$

The perfectly competitive labor good sector aggregates the production of the continuum of matches of individual workers to the final labor market good: $L_t = \int_0^{1-U_t} l_t(i) di = (1 - U_t) H_t$. We consider a symmetric equilibrium where all matches provide the same amount of labor and therefore drop the index i from now on. We assume a standard homogenous matching function that relates the number of matches M_t to the number of vacancies V_t and unemployed U_t:

$$M_t = s V_t^{\Psi} U_t^{1-\Psi}, \tag{17}$$

$$\frac{M_t}{V_t} \equiv \pi_{f,t} = s \left(\frac{V_t}{U_t} \right)^{\Psi - 1}, \tag{18}$$

$$\frac{M_t}{U_t} \equiv \pi_{ue,t} = s \left(\frac{V_t}{U_t} \right)^{\Psi}, \tag{19}$$

where Ψ measures the matching elasticity, and s is a scaling constant. $\pi_{f,t}$ denotes the probability of finding a worker from the firms' perspective, $\pi_{ue,t}$ is the probability of finding a job from the workers' perspective. Real profits of a single firm J_t and the surplus of the match from the workers' perspective V_t are given by

$$J_t = \frac{P_{L,t} H_t - W_t H_t}{P_{F,t}} + E_t (1 - f) \rho_{t,t+1} J_{t+1}, \tag{20}$$

$$V_t = \frac{W_t H_t - b_t}{P_{F,t}} - \frac{\vartheta}{U_{C_t}} \frac{H_t^{1+\mu}}{1 + \mu} + E_t \rho_{t,t+1} (1 - f - \pi_{ue,t}) V_{t+1}, \tag{21}$$

[14] Bacchetta and van Wincoop (2008) for example attribute deviations from UIP to infrequent foreign currency portfolio decisions, which can arise due to relatively small fees for managing foreign exchange positions.

[15] This setup ensures that, if we fix the unemployment rate at a constant level and shut down the labor market friction, our model delivers the standard neoclassical outcome.

where f is the exogenous destruction rate of the match and U_{C_t} denotes the marginal utility of consumption. Note that in a bargaining model productivity and wages do not equalize. The wedge, i.e. profits of the firm, determines the amount of vacancies posted, and is described below. We draw on Hall and Milgrom (2008) and Jung and Kuester (2008) by assuming that the threat point of the worker in the bargaining process is not given by the value of being unemployed (standard Nash-bargaining), but by the cost of delaying bargaining for one period. This allows us to use the static bargaining solution given by

$$\frac{\vartheta H_t^{\mu}}{U_{C_t}} = \frac{P_{L,t}}{P_{F,t}} \tag{22}$$

for hours worked, delivering an efficient choice of hours worked identical to the one obtained in the neoclassical limiting case. Our labor market friction manifests itself in the following wage setting equation

$$W_t = \Omega P_{L,t} + (1-\Omega)\left[\frac{P_{L,t}}{1+\mu} + \widetilde{b}\overline{W}\right]. \tag{23}$$

Here Ω denotes the bargaining power of the worker. Our setup implies that wages are a convex combination of productivity and the outside option. The latter is given by the saved amount of leisure and an abstract strike value $b_t = \widetilde{b}\overline{W}H_t$, where $\widetilde{b} \in [0,1]$ expresses the outside option in percentage terms of average (steady state) wage per hour $\overline{W}$, see Jung and Kuester (2008).[16] Note that, by setting $\widetilde{b} = 0$, we can reproduce cyclical properties of a Walrasian labor market where wages (almost) perfectly comove with productivity and movements in the unemployment rate are essentially shut down.

The free entry condition ensures that on average firms make no profits when posting a new vacancy:

$$\chi = \pi_{f,t} E_t \rho_{t,t+1} J_{t+1}, \tag{24}$$

where χ are real vacancy posting costs expressed in terms of the consumption good and accounted for in the total resource constraint of the economy. Finally, the implied law of motion for the unemployment rate U_t is given by:

$$U_{t+1} = U_t(1 - f - \pi_{ue,t}) + f. \tag{25}$$

[16] Note that we fix $\overline{W}$ to the steady state value, but allow the outside option to comove positively with hours worked. This allows us to reproduce a version of the static Nash-bargaining equation with hours worked. The main difference to the standard Nash-solution is the absence of a term $\chi\frac{V}{U}$, which turns out to be small and negligible given our calibration strategy but complicates the derivation. For our purpose it is enough to assume this mild form of wage rigidity supposing that the outside option does not move one to one with the business cycle. In the present context, we interpret $\widetilde{b}$ as an abstract outside option that will be *set* to match the amount of unemployment volatility observed in the data; it may either be interpreted as unemployment benefits or as the cost of delying/striking for one period. This allows us to sidestep on the debate between Hagedorn and Manovskii (2008) and Shimer (2005) and use this parameter to align the model and the data with respect to matching observed unemployment volatilities.

3.5 Market clearing, aggregation, and definitions

In equilibrium, firms and households maximize profits or utility for given initial conditions and government policies (specified below). In each sector, markets clear at the level of intermediate goods. As in Galí and Monacelli (2005), we define an index for aggregate output in each sector $Y_{A,t} \equiv \left(\int_0^1 Y_{A,t}(j)^{-\varepsilon}dj\right)^{\frac{1}{\varepsilon}}$ and $Y_{N,t} \equiv \left(\int_0^1 Y_{N,t}(j)^{-\varepsilon}dj\right)^{\frac{1}{\varepsilon}}$. Substituting for $Y_{A,t}(j) = A_t(j) + A_t^*(j)/n$ and $Y_{N,t}(j) = N_t(j)$ in both expressions using the demand functions given by (4)-(6) gives the aggregate relationships

$$\begin{aligned} Y_{A,t} &= \upsilon\left[\left(\frac{P_{A,t}}{P_{T,t}}\right)^{-\sigma}\left(\frac{P_{T,t}}{P_{F,t}}\right)^{-\eta}(1-\omega)F_t + \left(\frac{P^*_{A,t}}{P^*_{T,t}}\right)^{-\sigma}\left(\frac{P^*_{T,t}}{P^*_{F,t}}\right)^{-\eta}\omega F_t^*/n\right], \\ Y_{N,t} &= (1-\upsilon)\left(\frac{P_{N,t}}{P_{F,t}}\right)^{-\eta}F_t. \end{aligned} \tag{26}$$

From the definition of marginal costs (8), we can write an intermediate good firms' production function as $Y_{k,t}(j) = K_{k,t}(j)R_{k,t}(\theta MC_{k,t})^{-1}$. Aggregation over firms gives $\int_0^1 Y_{k,t}(j)dj = K_tR_{k,t}(\theta MC_{k,t})^{-1}$ or, using again (8), we have for each sector

$$\zeta_{k,t}Y_{k,t} = Z_{k,t}K_{k,t}^{\theta}H_{k,t}^{1-\theta}, \tag{27}$$

where $\zeta_{k,t} \equiv \int_0^1 \frac{Y_{k,t}(j)}{Y_{k,t}}dj = \int_0^1 \left(\frac{P_{k,t}(j)}{P_{k,t}}\right)^{-\epsilon} dj$ provides a measure for output and price dispersion at the level of intermediate goods in each sector.

Market clearing on factor markets requires

$$L_{k,t} = \int_0^1 L_{k,t}(j)dj, \qquad K_{k,t} = \int_0^1 K_{k,t}(j)dj \tag{28}$$

for all k, and the asset market clears by Walras' law.

As a measure for real GDP we define

$$Y_t \equiv C_t + I_t + G_t + \chi V_t + \frac{S_tP^*_{A,t}}{P_{F,t}}A_t^*/n - \frac{P_{B,t}}{P_{F,t}}B_t, \tag{29}$$

where exports and imports are defined as $A_t^* \equiv \left(\int_0^1 A_t^*(j)^{-\varepsilon}dj\right)^{\frac{1}{\varepsilon}}$ and $B_t \equiv \left(\int_0^1 B_t(j)^{-\varepsilon}dj\right)^{\frac{1}{\varepsilon}}$, respectively.

Using (5) and the corresponding domestic counterpart to substitute for $A_t^*(j)$ and $B_t(j)$ gives in aggregate terms

$$A_t^* = \upsilon\left(\frac{P^*_{A,t}}{P^*_{T,t}}\right)^{-\sigma}\left(\frac{P^*_{T,t}}{P^*_{F,t}}\right)^{-\eta}\omega F_t^*, \quad B_t = \upsilon\left(\frac{P_{B,t}}{P^*_{T,t}}\right)^{-\sigma}\left(\frac{P_{T,t}}{P_{F,t}}\right)^{-\eta}(1-\omega)F_t. \tag{30}$$

Finally, we define the real exchange rate and the trade balance as follows

$$RX_t \equiv \frac{S_tP^*_{F,t}}{P_{F,t}}, \qquad NX_t \equiv \frac{S_tP^*_{A,t}A_t^*/n - P_{B,t}B_t}{P_{F,t}Y_t}. \tag{31}$$

3.6 Government policies

We close the model by specifying feedback rules characterizing monetary and fiscal policies. Regarding the latter, we assume that government spending reacts to lagged output growth and its own past value:

$$\log G_t = (1-\rho_g)\log G + \rho_g \log G_{t-1} + \phi \log\left(Y_{t-1}/Y_{t-2}\right) + \varepsilon_{g,t}, \tag{32}$$

where variables without time-subscript refer to steady state values and $\varepsilon_{g,t}$ denotes i.i.d. government spending shocks. We assume that lump-sum taxes adjust to balance the government budget in each period: $G_t = T_t$. Note that while this rule is fairly simple, it strikes us as a convenient way to capture a possible change in the endogenous conduct of fiscal policy. We consider a response to lagged rather than current output growth because of decision and implementation lags, see Blanchard and Perotti (2002).[17]

Monetary policy is characterized by an interest rate feedback rule of the following type

$$\log R_t = \rho \log R_{t-1} + (1-\rho)E_t\left[\varpi + \varphi_\pi \log \Pi_{t-1,4} + \varphi_y \log\left(Y_t/Y_{t-1}\right) + \varphi_r \log R_t^*\right] + \varepsilon_{r,t} \tag{33}$$

where $\Pi_{t,i} \equiv P_{F,t+i}/P_{F,t} = \prod_{j=t}^{i} \Pi_{t,j}$ such that $\Pi_{t-1,4}$ denotes four quarter cumulated future inflation (of final goods). $\varepsilon_{R,t}$ is an i.i.d. shock to monetary policy. The coefficients φ_π, φ_y and φ_r determine how interest rates are adjusted in response to expected inflation, output growth, and foreign interest rates. They may take different values in home and abroad. Furthermore, we allow innovations to government spending and to the interest rate to be correlated across countries as we discuss below. Monetary policy rules of this type have been shown to provide a good description of monetary policy in Europe, see, for instance, Clarida et al. (1998).

4 Model simulation

We use a first-order approximation to the equilibrium conditions around a deterministic steady state to study the properties of the model numerically. Before discussing the results, the following subsection provides the rationale for the parameter values used in the simulation of the model.

4.1 Calibration

We calibrate our two-country model to capture key features of the German economy relative to EA6. Importantly, we consider both a 'PreEMU' and a 'EMU' scenario. To pin down parameter values, we rely on new estimates, which we report below, as well as on estimates of earlier studies. Details on data and data sources are provided in the appendix. We distinguish three sets of parameters:

[17] We leave more sophisticated specifications—notably by considering debt—for future research (recall that in the present version of the model Ricardian equivalence holds and the time path of taxes/government debt is irrelevant for the allocation for any given stream of government spending).

1) parameters characterizing preferences and technologies; 2) parameters capturing the behavior of monetary and fiscal policy, and 3) parameters governing the exogenous shock processes.

Preferences and Technologies The first set of parameters are displayed in table 2; we assume identical values under PreEMU and EMU because these parameters are arguably 'deep' enough to be invariant with respect to changes in the policy regime. In the upper (lower) panel, we report the values of those parameters which are identical (different) across countries. In the right column of the table, we display target values or sources which serve to pin down the parameter values shown in the left column.[18]

Table 2: Parameter values of theoretical economy: structural parameters

Symmetric parameters		**Value**		**Calibration target / source**	**Value**	
Inverse Frisch	μ	2.00		Domeij and Flodén (2006)		
Utility weight of work	ϑ	37.6		Hours worked steady state	0.30	
Risk aversion	γ	1.00		Balanced growth		
Trade price elasticity	σ	0.90		Heathcote and Perri (2002)		
Non-traded price elast.	η	0.44		Stockman and Tesar (1995)		
Elast. of discount factor	ψ	.014		K/Y	12.00	
Depreciation rate	δ	.015		I/Y	0.186	
Adjustment costs	κ	1.50		Std(I)/Std(Y)	Table 4	
Price elasticity	ϵ	6.0		Markup	0.200	
Capital share	θ	0.34		Labor share	0.66	
Government share	$\overline{G}/\overline{Y}$	0.21		Government spending share	0.21	
Country size home	n	0.49		GDP Germany vs. EA6		
Separation rate	f	.045		Bachmann (2005)		
Bargain parameter	Ω	0.50		Shimer (2005)		
Matching elasticity	Ψ	0.50		Petrongolo and Pissarides (2001)		
Asymmetric parameters		**Germany**	**EA6**	**Calibration target / source**	**Germany**	**EA6**
Outside option	$\tilde{b}$	0.64	0.62	Std(U)/Std(Y)	Table 4	
Vacancy posting	χ	0.12	0.16	Unemployment steady state	0.075	0.096
Matching constant	s	0.55	0.42	Normalization V/U	1.000	1.000
Weight traded goods	υ	0.38	0.35	Production manuf./services	0.621	0.537
Weight domestic goods	ω	0.85	0.90	Import & exp. share Germany	0.053	0.067
Price rigidities tradables	ξ_T	0.84	0.72	Price duration indust. goods	6.173	3.569
Price rigidities non-tradables	ξ_N	0.87	0.82	Price duration services	7.752	5.595

Notes: Parameters remain unchanged across simulations, see main text for discussion of target values. Price durations are measured in quarters. Variables without time subscript refer to steady state values.

One period in the model corresponds to one quarter. We set $\mu = 2$, implying a Frisch wage elasticity of labor supply of 0.5, see Domeij and Flodén (2006). We set ϑ such that hours worked in steady state are 0.3. Furthermore, we assume that $\gamma = 1$, consistent with balanced growth. Regarding trade price elasticities, we set $\sigma = 0.9$, which corresponds to the estimate reported in Heathcote

[18] In general equilibrium, calibration targets typically depend on values of several parameters; nevertheless it is possible to pin down specific parameter values by focusing on one particular target value. Unless stated otherwise, we draw on the Economic Outlook database to compute target statistics, see OECD (2008a).

and Perri (2002). Following Stockman and Tesar (1995) we assume $\eta = 0.44$. We target a steady-state quarterly capital-to-output share of 12 and an average investment-to-output ratio of 0.186 to pin down the elasticity of the discount factor ψ and the depreciation rate δ, respectively. Capital adjustment costs, i.e. κ is set to match the volatility of investment, reported in table 4 below (average value across countries and scenarios). We determine ϵ such that the average markup is 20 percent, see Rotemberg and Woodford (1991). We set θ to match average wage shares of two thirds for Germany and EA6.[19] The observation that government spending accounts for 21 percent of GDP on average allows us to pin down the steady-state share of government spending accordingly. The relative size of the domestic economy n is set to reflect the ratio of German output relative to EA6. Regarding labor markets, we assume $\lambda = 0.045$ in line with estimates for firing/separation rates for Germany at quarterly frequency, see Bachmann (2005). Following Shimer (2005) and Petrongolo and Pissarides (2001), respectively, we set the bargaining parameter Ω and the matching elasticity Ψ to one half.

Next, we turn to parameters which are allowed to take different values in Germany and EA6 in order to capture important heterogeneities in the labor market. First, we determine the outside option by targeting the unemployment volatility reported in table 4 below (average value across countries and scenarios).[20] To pin down vacancy posting costs, we target the average unemployment rate, which is 7.5% for Germany and 9.6% for EA6. Finally, we normalize the number of vacancies posted to pin down values for s.

A last set of parameters is set to determine the weight of traded and non-traded goods and the extent of price rigidities. In both respects, we allow for asymmetries as they are likely to impact fundamentally on intra-European business cycles. The weight of traded goods in total output υ is determined by the average ratio of output in the manufacturing sector relative to services. This ratio is 0.62 for Germany and 0.54 for the EA6 aggregate.[21] Given the parameter υ, the shares of imports and exports in steady state are governed by ω. For the period 1985–2007, we find that German imports from EA6 average at 5.32 percent of GDP, while exports to EA6 average at 6.67 percent, respectively.[22] We pin down price rigidities on the basis of the frequency of price changes reported in Dhyne et al. (2006). For the traded and non-traded goods sector, we consider data for non-energy industrial goods and services, respectively. Price durations are highest within the non-traded goods sector in Germany and lowest

[19] Data for the capital-to-output ratio and the wage share are obtained from the AMECO database, see European Commission DG ECFIN (2008).

[20] Our model does not suffer from a lack of volatility of unemployment, stressed by Shimer (2005), because of sluggish real wage adjustment which in turn induces profits to fluctuate strongly over the cycle. For details see, among others, Hagedorn and Manovskii (2008) and Hall and Milgrom (2008).

[21] Source: STAN database, see OECD (2008b).

[22] In the medium to long term the import-to-GDP ratio is likely to depend on the nominal exchange rate regime. In fact, following Rose (2000) the importance of the exchange rate regime for trade has been discussed by a number of authors. During our sample period, a considerable increase in openness can be observed. We therefore considered the possibility of different degrees of openness, but found the quantitative implications for business cycle dynamics negligible. In what follows we therefore assume constant values for υ and ω.

in the traded goods sector in EA6. The Calvo parameters ξ_T and ξ_N are set to match average price durations.[23]

Policy rules The behavior of fiscal and monetary policy is characterized by feedback rules (32) and (33), which are allowed to differ under the PreEMU and EMU scenario according to our estimates for the PreEMU sample (1985–1996) and the EMU sample (1999–2007). First, regarding the monetary policy rule, drawing on Clarida et al. (1998), we employ a three-stage least squares approach, using four lags of CPI-inflation, the short-term interest rate, the oil price, and output growth as instruments in the first step of the procedure. We estimate two different rules for Germany and EA6 for PreEMU and a common monetary policy rule for EMU. In the former case, we estimate both rules simultaneously, allowing for possible correlation of monetary policy shocks. While we restrict the parameter φ_r to be zero for Germany, we estimate it for EA6. Results are reported in the second panel of table 3. For Germany we find considerable interest rate smoothing and a fairly strong response of interest rates to inflation and economic activity, measured by output growth. For EA6, we find less strong responses to both variables, but a considerable response to German interest rates.[24] For EMU, our estimates for the interest rate feedback rule are within the range of values documented by earlier studies.

Second, regarding fiscal policy, we allow for a change in the parameters governing the rules (32) under EMU relative to PreEMU and estimate them for both sample periods by OLS.[25] Results are reported in the first panel of table 3 for both sample periods. We find quite persistent processes for government spending for both sample periods, notably for EA6. According to our estimates, fiscal policy has been conducted more countercyclically under PreEMU.[26]

Forcing processes In estimating the UIP shocks we follow Kollmann (2005). Rewriting (15) in logs without expectations provides a measure for the realized deviations from UIP:

$$\ln(\hat{\varepsilon}_t^{UIP}) \equiv \ln(R_t) - \ln(R_t^*) - \ln(\Delta S_{t+1}).$$

In order to extract the expected ex-ante component, ε_t^{UIP}, we regress $\ln(\hat{\varepsilon}_t^{UIP})$ on its own four lags and other variables known at time t: contemporaneous values and four lags of output, inflation, and the interest rate—each for Germany and EA6. Next, we estimate an AR(1) process on the fitted

[23] Aggregation follows Baharad and Eden (2004). We assume that price durations for domestically produced traded intermediate goods and for imports are the same within each country (i.e. $\xi_A^* = \xi_B$ and $\xi_A = \xi_B^*$); hence there is one value for price stickiness for each sector (ξ_T and ξ_N) in each country.

[24] Note that the equilibrium is uniquely determined for these parameter values.

[25] A linear trend is included in the estimation. Note that our specification excludes a contemporaneous response of government spending to output a priori. We thus employ an identification assumption which is frequently made in the VAR literature on fiscal policy transmission, see Blanchard and Perotti (2002).

[26] Galí and Perotti (2003) fail to detect such an effect when comparing a pre-Maastricht period (1980–91) to a post-Maastricht period which ends, however, in 2002.

Table 3: Parameter values of theoretical economy: policy rules & shock processes

		PreEMU		**EMU**	
		Germany	**EA6**	**Germany**	**EA6**
Government spending					
Smoothing	ρ_g	0.60	0.99	0.58	0.87
Output growth	ϕ	-0.30	-0.07	$-.003$	-0.02
Var.-cov. matrix of government innov.		$\begin{bmatrix} 1.50 & 0.07 \\ 0.07 & 0.13 \end{bmatrix} * 10^{-4}$		$\begin{bmatrix} 0.71 & 0.07 \\ 0.07 & 0.43 \end{bmatrix} * 10^{-4}$	
Monetary policy					
Smoothing	ρ	0.88	0.67	0.62	
Inflation	φ_π	2.28	0.99	1.68	
Output growth	φ_y	0.37	0.01	0.78	
Germ. int. rate	φ_r	$--$	0.69	$--$	
Var.-cov. matrix of monetary innov.		$\begin{bmatrix} 0.88 & 0.20 \\ 0.20 & 1.80 \end{bmatrix} * 10^{-6}$		$3.77 * 10^{-6}$	
UIP process					
AR(1)-coeff UIP shock	ρ^{UIP}	0.35		-	
UIP shock variance	$\sigma^2_{\nu UIP}$	$1.90{*}10^{-4}$		-	
Technology process		**Germany**		**EA6**	
AR(1)-coeff. techn. traded		0.97		0.93	
AR(1)-coeff. techn. non-traded		0.99		0.95	
Var.-covar. matrix of technology innovations		$\begin{bmatrix} 1.47 & 0.18 & 0.57 & 0.08 \\ 0.18 & 0.31 & 0.04 & 0.01 \\ 0.57 & 0.04 & 0.83 & 0.06 \\ 0.08 & 0.01 & 0.06 & 0.11 \end{bmatrix} * 10^{-4}$			

Notes: parameter values for monetary and fiscal policy for PreEMU and EMU scenario, see main text for discussion.

values. Results are reported in the third panel of table 3. We find that predictable deviations from the uncovered interest rate parity are fairly short-lived, compared with Kollmann's estimate of $\rho^{UIP} = 0.5$ for the US. Note that we assume UIP shocks to occur only under PreEMU.

Regarding the technology process governing intermediate goods production, we assume that deviations from steady state follow an AR(1) process. To pin down parameter values, we rely on standard procedures based on Solow residuals. Specifically, we use data for the industrial sector where available (otherwise we employ data for the manufacturing sector) as a proxy for the traded goods sector, and the service sector for the non-traded goods sector. Estimating a SUR regression allows us to take the contemporaneous correlation of the innovations into account, both across sectors and countries. We estimate the shock process for the full sample period assuming that it is stable across exchange rate regimes.[27] Results are reported in the last panel of table 3, suggesting considerable autocorrelation as well as some correlation of innovations across sectors and countries.

[27]We include a linear trend in the regression, as well as a dummy for the German reunification in the German series. The labor share is set to 0.66.

4.2 Model performance

We assess the ability of the model to account for European business cycles by confronting model predictions for the PreEMU and the EMU scenario with key features of the data for the corresponding sample period.[28] In each case we draw from the assumed distribution of shocks and generate time series of 52 observations (and an additional 60 observations to initialize the model), corresponding to the length of our PreEMU sample. After applying the HP-filter with a smoothing parameter of 1600, we compute the moments of interest and report averages over 100 simulations. The predictions for the home and foreign country are measured up against German and EA6 data, respectively.

Results are reported in table 4. In the left panel we list the empirical moments for Germany and EA6. The first and the second column replicate the values for the PreEMU and EMU period shown in table 1 as well as the corresponding moments for EA6. In a third column we report the difference between both periods, i.e. we subtract the value for the PreEMU period from the value of the EMU period. In the right panel we report the corresponding statistics for the model.

In the upper two panels we focus on the volatility of macroeconomic fundamentals. In terms of absolute volatility, measured by the standard deviation of output, the model predicts about 90 percent of the actual output volatility. In accordance with the data, the model predicts a decline in output volatility, but less so for EA6.[29] In terms of relative volatilities the model performs quite well, with volatilities of consumption and government spending mildly overpredicted for Germany and underpredicted for EA6. Note that the volatilities of investment and unemployment have served as a calibration target and can not be used to evaluate the model.[30]

In the third panel we focus on the volatility of the real exchange rate and the trade balance for Germany relative to its trading partners comprised in the EA6 aggregate. We find that the model's predictions not only match the volatility of the real exchange rate fairly well, but also its substantial decline under EMU. It is important to stress that while the model features non-fundamental exchange rate volatility (UIP shocks) only under PreEMU, real exchange rate volatility did not serve as a calibration target. Put differently, while the general direction of the change in real exchange rate volatility is not surprising, the quantitative accuracy of the model's predictions is remarkable. Below, we give a more detailed account of the exact contribution of UIP shocks to the volatility of real exchange rates. We also note that the model is less successful in predicting the (change in the) volatility of the trade

[28]As discussed above, under PreEMU both countries are characterized by distinct money policy rules and UIP shocks are assumed to occur, while under EMU we assume a common monetary policy and UIP shocks are absent. Tables 2 and 3 summarize that parameter values used in the simulations.

[29]Recall that we document a decline in volatility for non-EMU countries as well, suggesting that the actual decline may be unrelated to EMU.

[30]The extent of labor market frictions is crucial for the model to match actual unemployment fluctuations, but also affects the propagation of shocks more generally. Considering a version of the model which approximates a Walrasian labor market, we found that output volatility declines by about 20 percent.

Table 4: Model performance

	Data			Model		
	PreEMU	**EMU**	**Δ**	**PreEMU**	**EMU**	**Δ**
Germany/Home						
Std Y * 100	1.30	1.03	-0.27	1.17	0.89	-0.29
Std C/Std Y	0.68	0.76	0.08	0.85	0.89	0.05
Std I/Std Y	2.31	3.40	1.09	2.84	2.94	0.10
Std G/Std Y	1.04	0.90	-0.14	1.08	0.99	-0.09
Std U/Std Y	9.18	7.32	-1.68	9.10	9.48	0.38
Std π/ Std Y	0.22	0.30	0.08	0.04	0.10	0.05
EA6/Foreign						
Std Y * 100	1.07	0.70	-0.37	0.77	0.70	-0.07
Std C/Std Y	0.92	0.81	-0.11	0.74	0.64	-0.10
Std I/Std Y	3.72	3.58	-0.14	2.96	3.19	0.23
Std G/Std Y	0.72	0.59	-0.13	0.57	0.37	-0.21
Std U/Std Y	4.87	6.07	1.20	4.11	4.71	0.60
Std π/ Std Y	0.25	0.49	0.24	0.11	0.14	0.03
Trade						
Std RX/Std Y	2.48	0.34	-2.14	1.79	0.31	-1.47
Std NX/Std Y	0.34	0.36	0.02	0.12	0.04	-0.08
Cross-country						
Corr Y Y^*	0.42	0.85	0.43	0.52	0.70	0.17
Corr C C^*	0.36	0.62	0.26	0.41	0.72	0.31
Corr I I^*	0.58	0.85	0.27	0.51	0.46	-0.05
Corr G G^*	0.35	-0.10	-0.45	0.16	0.04	-0.12
Corr U U^*	0.73	0.83	0.10	0.59	0.68	0.08
Corr $\pi\pi^*$	0.49	0.35	-0.14	0.49	0.21	-0.27

Notes: statistics are computed on actual (simulated) time series for Germany (home country) and EA6 (foreign country) after applying the HP-filter to the log deviation of the original value from its trend (steady-state) value. First panel: standard deviations for Germany/home country; second panel: EA6/foreign country; third panel: standard deviation of real exchange rate and trade balance of Germany (home country) relative to EA6 (foreign country); lower panel cross-country correlation for variables in Germany (home country) and EA6 (foreign country). PreEMU and EMU periods cover 1985–1996 and 1999–2007, respectively. Δ-column measures difference between PreEMU and EMU period.

balance.

The performance of the model in predicting the cross-country correlation, shown in the lowest panel, is also quite strong. Not only does the model accurately predict the size of the correlation of almost all variables for the PreEMU sample. It also predicts the direction of change correctly for five out of six variables, i.e. an increase in the correlation of all variables except for government spending and inflation. International comovement has long puzzled the international business cycle literature. Backus et al. (1994, 1995), for instance, have stressed the consumption-output anomaly, i.e. the observation that cross-country correlations of output are typically much larger than those of consumption, while standard models predict otherwise. In this regard our assumption of a large non-traded goods sector plays an important role in aligning theory and evidence, see also Stockman and Tesar (1995). Additional factors driving the good performance of our model in terms of international comovement is the cross-correlation of innovations to the technology process as well as the presence of non-technology shocks.[31]

Overall, we find that the model performs well in predicting key features of the data. Despite some shortcomings in specific dimensions, the model is able to account for three key observations regarding European business cycles before and under EMU: 1) the volatility of the real exchange rate is substantially reduced under EMU; 2) there is some increase in cross-country business cycle correlation measured by output, but less correlation of government spending; 3) the volatility of macroeconomic fundamentals other than the real exchange rate is largely unchanged across the two sample periods.

5 Understanding (changes in) European business cycles

Given that the model is able to replicate key features of the data—both for the PreEMU and the EMU period—we now turn to the causes underlying the observed changes in European business cycles. We distinguish between changes due to differences in shock processes and changes in propagation following from either relinquishing monetary policy independence under EMU or from other alterations in the policy framework.

5.1 Shock processes

To isolate the effects of specific shocks we compute the predictions of the model while allowing for only one source of shocks at a time. In the two panels of table 5, we present results for the PreEMU and EMU scenario, respectively. Column 'ALL' replicates results from table 4, i.e. the case when all shocks occur, while columns 'TEC', 'MON', 'GOV', and 'UIP' display results obtained if either only technology shocks, monetary policy shocks, government spending shocks, or UIP shocks occur.

We find that technology shocks are by far the most important source of business cycle fluctuations, in both scenarios. With only technology shocks, output volatility is about 95 percent of what is observed if all shocks occur. Also relative volatilities and correlations are close to the all-shocks scenario, except for the real exchange rate volatility, which is considerably lower (a well known finding from standard open economy RBC models, see, for instance, Backus et al. 1995), as well as government spending and the trade balance.

Monetary policy shocks, in turn, account for some volatility of output, but more so for inflation. In the PreEMU period they are also a non-negligible source of real exchange rate volatility. This is different under EMU, where monetary policy shocks are symmetric by construction and therefore

[31]Results from simulations of the model aimed at isolating the distinct contribution of different model features to the overall model performance are available on request.

Table 5: Theoretical moments: sources of fluctuations

	PreEMU					EMU			
	ALL	**TEC**	**MON**	**GOV**	**UIP**	**ALL**	**TEC**	**MON**	**GOV**
Domestic									
Std Y * 100	1.17	1.13	0.35	0.22	0.13	0.89	0.82	0.34	0.14
Std C/Std Y	0.85	0.86	0.88	0.22	0.11	0.89	0.89	0.89	0.41
Std I/Std Y	2.84	2.90	2.86	0.48	0.36	2.94	2.95	2.74	0.87
Std G/Std Y	1.08	0.22	0.27	5.84	0.34	0.99	0.00	0.00	6.47
Std U/Std Y	9.10	9.54	6.20	0.96	0.43	9.48	9.95	6.15	1.04
Std π/ Std Y	0.04	0.03	0.12	0.06	0.04	0.10	0.09	0.12	0.05
Foreign									
Std Y * 100	0.77	0.75	0.26	0.03	0.05	0.70	0.71	0.15	0.04
Std C/Std Y	0.74	0.69	1.04	4.34	0.14	0.64	0.60	1.17	1.05
Std I/Std Y	2.96	3.05	2.20	2.38	0.29	3.19	3.22	1.59	1.99
Std G/Std Y	0.57	0.07	0.07	16.17	0.07	0.37	0.02	0.03	6.97
Std U/Std Y	4.11	4.26	2.43	2.74	0.80	4.71	4.74	1.45	2.08
Std π/ Std Y	0.11	0.05	0.30	0.09	0.22	0.14	0.12	0.31	0.17
Trade									
Std RX/Std Y	1.79	0.38	0.80	0.11	16.40	0.31	0.34	0.14	0.13
Std NX/Std Y	0.12	0.04	0.05	0.08	1.07	0.04	0.03	0.04	0.09
Cross-country									
Corr Y Y^*	0.52	0.58	0.32	-0.30	-1.00	0.70	0.73	0.82	-0.45
Corr C C^*	0.41	0.47	0.29	0.23	-0.94	0.72	0.67	0.92	0.80
Corr I I^*	0.51	0.52	0.30	0.74	-0.65	0.46	0.51	0.70	-0.12
Corr G G^*	0.16	0.42	0.33	0.08	-0.88	0.04	0.68	0.99	0.02
Corr U U^*	0.59	0.58	0.34	-0.42	-0.95	0.68	0.69	0.81	-0.64
Corr $\pi\pi^*$	0.49	0.47	0.55	0.07	-1.00	0.21	0.06	0.92	0.14

Notes: for computation of statistics see table 4. Column 'ALL' shows results under the assumption that all shocks occur. 'TEC': only technology shocks; 'MON': only monetary policy shocks; 'GOV': only government spending shocks; 'UIP': only UIP shocks. UIP shocks are absent under EMU.

induce very little real exchange rate movements and high comovement of macroeconomic aggregates across countries. Government spending shocks are of limited importance for output fluctuations, but increase the volatility of government spending while lowering its cross-country correlation relative to what is observed if only technology or monetary policy shocks occur. Regarding UIP shocks, we note that while their importance for output volatility is quite contained, they induce considerable volatility of the real exchange rate: if UIP shocks were the only source of fluctuations, the volatility of the real exchange rate would be about 16 times the volatility of output. A second noteworthy observation is that UIP shocks induce strongly negative comovements across countries.

These results shed some light on the changes in European business cycles brought about by EMU. First, a common monetary policy and the absence of idiosyncratic monetary policy shocks lower real exchange rate volatility and increase the cross-country correlation of business cycles. Second, the absence of UIP shocks works in the same direction. Third, the decline in the cross-country correlation of government spending appears to be driven by the change in the shock process determining the exogenous innovations to government spending itself.

5.2 Transmission

The calibrated model predicts only a mild decline of the volatility of macroeconomic fundamentals, but a strong decline of real exchange rate volatility—in line with the evidence. Mussa (1986), Baxter and Stockman (1989), and Flood and Rose (1995) provide similar evidence for earlier episodes suggesting that the volatility of macroeconomic fundamentals does not vary substantially across exchange rate regimes while exchange rate volatility does. This evidence apparently conflicts with the notion that—if prices are sticky—the exchange rate regime fundamentally alters the transmission mechanism, a notion stressed by Friedman (1953) and maintained by OCA theory.[32]

Against this background we assess the role of the exchange rate regime in the international transmission of shocks within our calibrated model.[33] In figures 4a and 4b we display the impulse responses under the PreEMU (dashed lines) and EMU (solid lines) calibration. We display the responses of domestic and foreign output and its components (figure 4a) as well as those of unemployment, inflation, the real exchange rate, and the trade balance (figure 4b), expressed in percentage deviations from steady state. In addition, we display in the lower panels of figure 4b the responses of a measure for the real long-term interest rate (λ). It allows us to assess the monetary policy stance and hence to account for the effect of the exchange rate regime on the transmission mechanism.[34]

The responses to technology shocks are displayed in the first (traded goods sector) and second (non-traded goods sector) column. Both shocks are expansionary: output, consumption, and investment increase both at home and abroad. The pattern of adjustment of unemployment mirrors those of output. Spillovers are typically positive: technology shocks in the traded goods sector induces a positive comovement across countries in all variables except for inflation, while technology shocks in the non-traded goods sector induce positive comovement except for unemployment, investment and inflation. Yet responses in the foreign economy are contained relative to the adjustment observed in the domestic economy.

Comparing the adjustment under PreEMU and EMU provides important insights into the role of the

[32]Duarte (2003) and Monacelli (2004) attempt to account for the empirical observations of Mussa and Baxter-Stockman within sticky price models. Duarte assumes that prices are predetermined in the buyer's currency for one period such that demand is completely isolated from exchange rate changes. As a result, she finds that exchange rate volatility changes substantially across exchange rate regimes, leaving the volatility of macroeconomic fundamentals largely unaffected. Monacelli also highlights the role of limited exchange rate pass-through, but considers a Calvo pricing scheme. Under his baseline calibration the exchange rate regime matters for the volatility of the real exchange rate, but also for the volatility of fundamentals. Output volatility, however, is shown to remain unchanged across exchange rates regimes for a high degree of openness and/or trade price elasticity.

[33]To simplify the exposition we focus on domestic shocks. The effects of shocks originating in the foreign economy are not fully symmetric due to the asymmetries of the model, but fairly similar to the effects of domestic shocks on the foreign economy.

[34]Specifically, we use the Lagrange multiplier on the household budget constraint as a measure for expected long-term real interest rates. Abstracting from endogenous changes in the discount factor, it corresponds, in terms of deviations from steady state, to the sum of future real short-term rates up to a first-order approximation of the model, see the discussion in Woodford (2003).

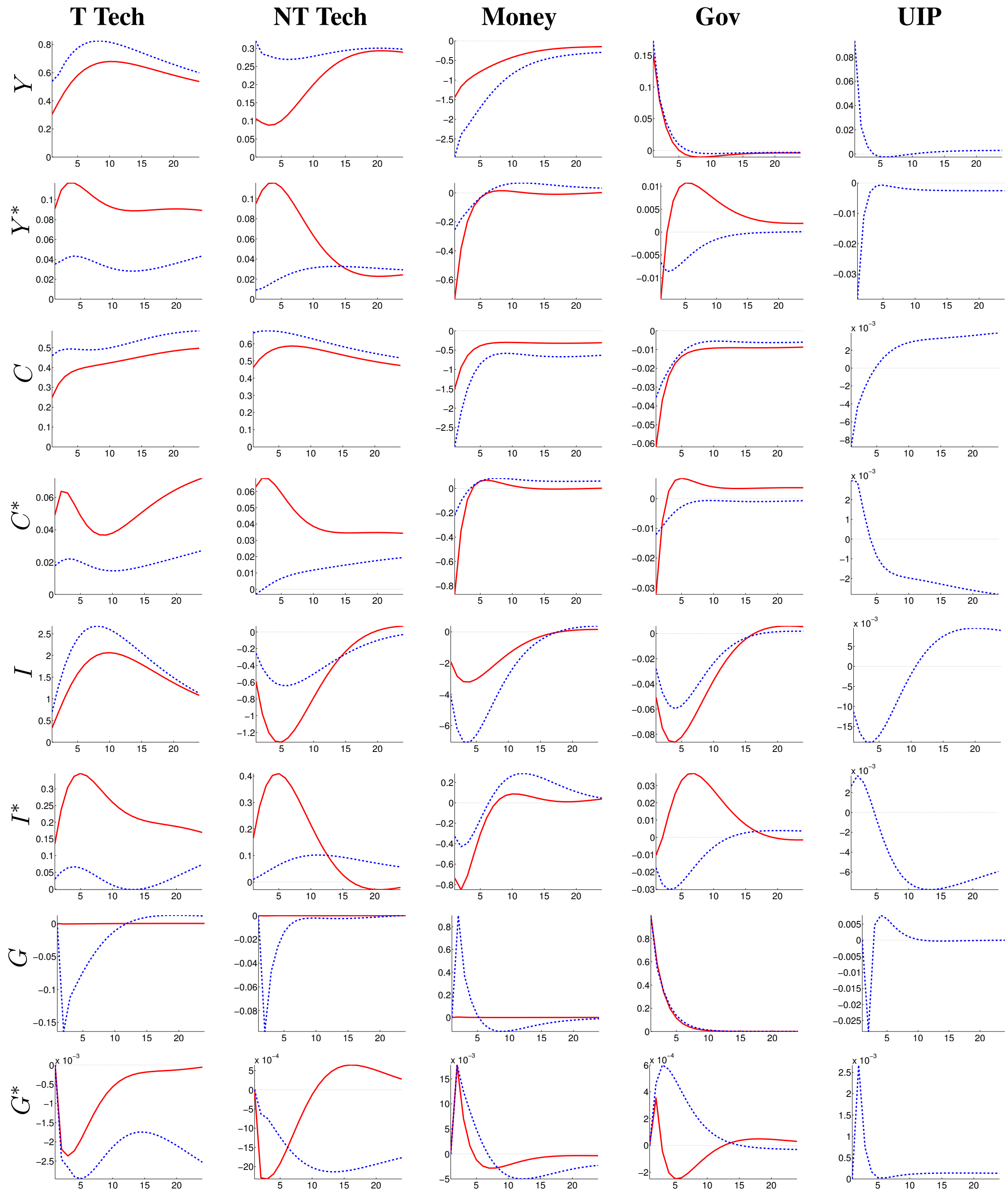

Figure 4a: Shock transmission under PreEMU (dashed) and EMU (solid) scenario.

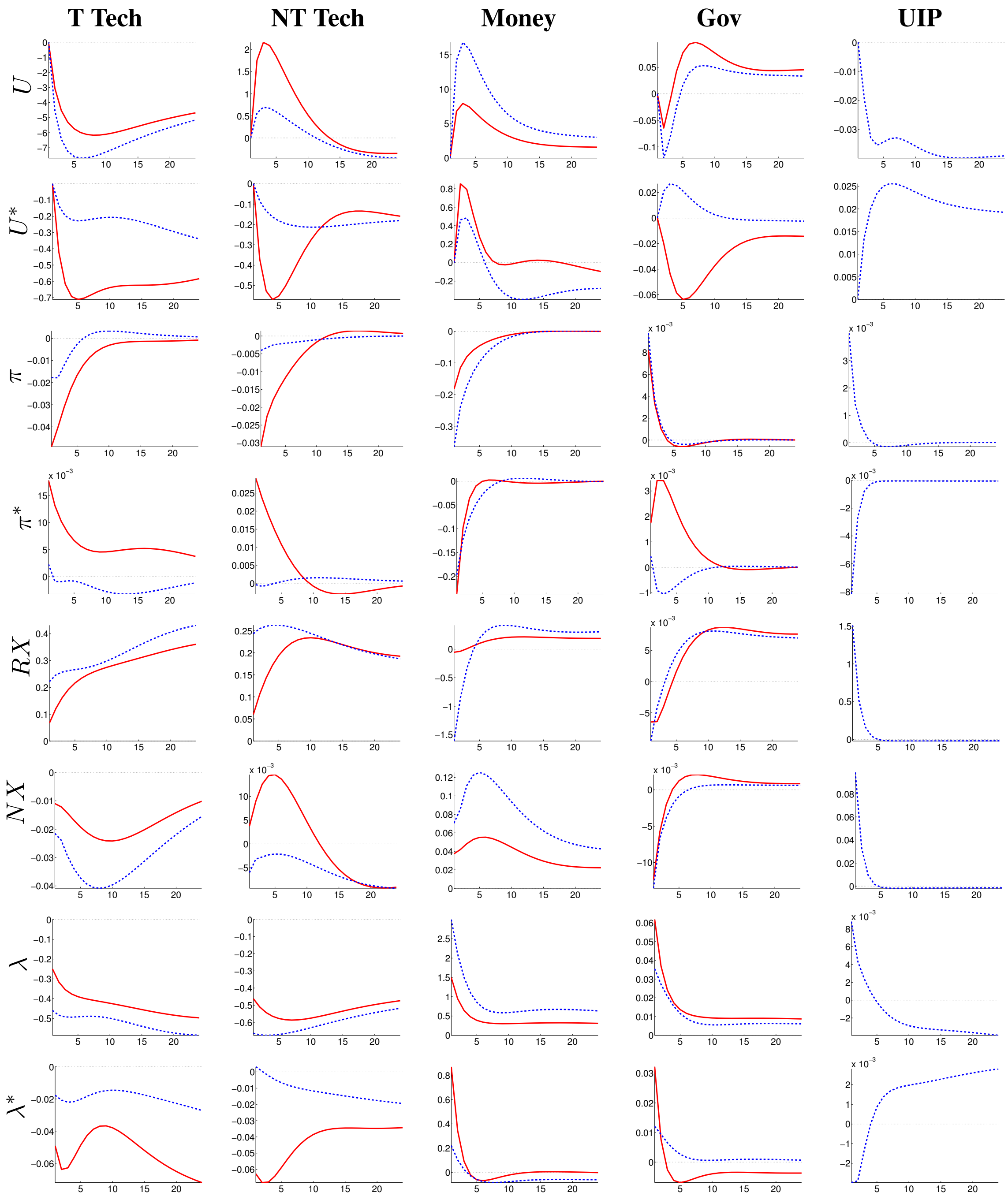

Figure 4b: Shock transmission under PreEMU (dashed) and EMU (solid) scenario.

Table 6: Cross-country spillovers of technology shocks

	PreEMU			EMU		
	ALL	**TEC**	**TEC***	**ALL**	**TEC**	**TEC***
Domestic						
Std Y	1.17	1.15	0.05	0.89	0.79	0.17
Std C	0.99	0.98	0.02	0.79	0.71	0.13
Std I	3.33	3.41	0.06	2.61	2.45	0.43
Std G	1.27	0.25	0.01	0.88	0.00	0.00
Std U	10.68	10.85	0.56	8.41	7.95	1.15
Std π	0.05	0.03	0.00	0.09	0.08	0.01
Foreign						
Std Y	0.77	0.07	0.72	0.70	0.22	0.60
Std C	0.57	0.03	0.50	0.45	0.11	0.37
Std I	2.28	0.16	2.29	2.25	0.67	1.98
Std G	0.44	0.00	0.05	0.26	0.01	0.01
Std U	3.17	0.35	3.08	3.31	1.18	2.73
Std π	0.09	0.01	0.04	0.10	0.03	0.09

Notes: Standard deviation in percent. Column 'ALL' shows results under the assumption that all shocks occur. 'TEC': only domestic technology shocks; 'TEC*': only foreign technology shocks.

exchange rate in the international transmission mechanism. Relative to PreEMU, domestic technology shocks generate larger cross-country spillovers under EMU, while their impact on domestic variables is reduced. To rationalize this observation, note that domestic technology shocks depreciate the real exchange rate (RX increases), but less so under EMU because the nominal exchange rate channel is absent and prices are sticky. As a result, demand for domestic goods increases relatively less, while demand for foreign goods increases relatively more—compared to PreEMU. Hence, macroeconomic fundamentals (except for inflation) respond less to domestic technology shocks and more to foreign technology shocks. The difference in the real exchange rate response under both exchange rate regimes is consistent with our measure for long-term real interest rates. While technology shocks lower long-term real interest rates (lower panels of figure 4b), they do less so under EMU in the domestic economy, and more so abroad. This reflects a common monetary stance (and a muted exchange rate response) under EMU which aligns the adjustment process in both countries.

Table 6 quantifies how EMU changes cross-country spillovers of technology shocks. It reports the standard deviations of macroeconomic fundamentals under PreEMU (left panel) and under EMU (right panel). In both cases we report the standard deviation if either all shocks ('ALL'), only domestic technology shocks ('TEC'), or only foreign technology shocks ('TEC*') occur. Under PreEMU domestic fundamentals are to a large extent driven by domestic technology shocks. Reflecting increased spillovers, the importance of domestic shocks decreases under EMU, while those of foreign shocks increases considerably. Put differently, the change in the transmission mechanism generates two off-setting effects as regards the volatility of macroeconomic fundamentals. It thus appears that the unchanged volatility of macroeconomic fundamentals masks important changes in the underlying transmission mechanism: a substantial increase in the cross-country spillovers under EMU.

The effect of EMU on the transmission of non-technology shocks is also non-negligible, although less consequential for business cycle statistics. The effects of a contractionary monetary policy shock are displayed in the third column of figure 4. An immediate effect of the shock is the increase in the domestic real long-term rate, because of nominal rigidities. Output and its components contract, inflation falls. In the PreEMU scenario this results in a strong appreciation of the real exchange rate. Under EMU the adjustment process is more symmetric, because in this case a domestic monetary policy shock corresponds to a union-wide shock.

The responses to domestic government spending shocks and UIP shocks are displayed in the fourth and fifth column of figure 4, respectively. An increase in government spending tends to increase domestic output and to lower domestic consumption and investment. The effect on foreign output is quite contained, but changes sign under EMU. UIP shocks occur only under PreEMU. They depreciate the real exchange rate and induce a strong negative comovement of macroeconomic fundamentals across countries.

5.3 Decomposition of change

We now turn to a systematic decomposition of the differences predicted by the model for PreEMU and EMU—isolating the quantitative contributions of the features that are different in both scenarios. Results are reported in figure 5 for four statistics of interest: the standard deviation of output, the standard deviation of the real exchange rate, the cross-country correlation of output, and the cross-country correlation of government spending.[35] The left and the right charts of each plot represent the statistic for the PreEMU and EMU calibration, respectively. The bars in between represent values from counterfactual simulations which are meant to simulate a gradual transition from PreEMU to EMU by altering one feature at a time (from left to right).

First, we simulate the model under PreEMU except that we assume that UIP shocks are absent (second bar): real exchange rate volatility falls strongly, almost to the EMU level. Second, we assume in addition to abstracting from UIP shocks that fiscal policy is conducted as suggested by our estimates for the EMU sample. This modification has little effect on all variables, except on government spending itself: the cross-country correlation falls (third bar: EMUgov). Third, we assume that monetary policy is conducted independently across countries with the rule coefficients taking values estimated for the common EMU rule. In this case we find the volatility of output reduced, because of the higher output coefficient in the ECB interest rate rule (fourth bar: EMUrules). Fourth, we additionally impose that monetary policy shocks occur simultaneously in both countries, while drawing from the distribution

[35]The corresponding statistics for other moments are reported in table A-2 in the appendix.

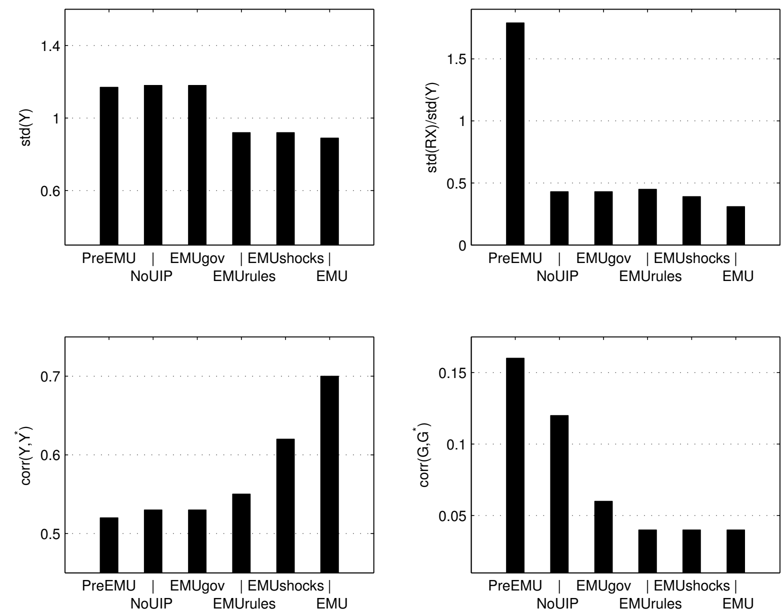

Figure 5: Decomposition of change. Notes: for computation of statistics see table 4; left and right bars replicate results for PreEMU and EMU calibration, respectively. Middle bars from left to right simulate gradual transition from PreEMU to EMU: no UIP shocks, fiscal rules/shocks as under EMU, independent monetary policy rules but with EMU coefficients, monetary policy shocks occur symmetrically (volatility as under EMU).

of monetary policy shocks estimated for the EMU sample. As a result, we observe an increase in the cross-country correlation of output (fifth bar: EMUshocks). Finally, the sixth bar plots results for the EMU scenario, such that differences relative to the fifth bar isolate the effect of the exchange rate regime change *per se* on business cycles: the most dramatic effect is a further increase in the cross-country correlation of output, while the volatility of output hardly changes. This is consistent with our previous observations that EMU induces profound changes on the transmission mechanism of technology shocks: cross-country spillovers increase strongly, resulting in higher comovement of macroeconomic fundamentals but leaving volatilities largely unchanged, as the domestic effects of shocks are muted.

6 Conclusion

Has the euro changed the European business cycle? On the one hand, changes are likely if price rigidities are non-negligible and, hence, the nominal exchange rate regime is non-neutral in the short run—the maintained hypothesis of OCA theory. On the other hand, earlier research suggests that the volatility of macroeconomic fundamentals does not differ systematically across exchange rate regimes (Baxter and Stockman 1989, Flood and Rose 1995). Against this background, we address the question empirically and within a structural business cycle model.

In a first step, we document that there are (apparently limited) changes in European business cycles which can be related to the euro. Specifically, three findings emerge from analyzing European time series data relative to a sample of non-EMU countries and comparing the periods 1985–1996 and 1999–2007. First, the volatility of real exchange rates falls substantially under EMU. Second, the cross-country correlations of output and its components tend to increase, except for government spending for which we document a decline. Third, the volatility of macroeconomic aggregates is largely unchanged.

In a second step, we develop and calibrate a general equilibrium model taking an intra-European perspective: abstracting from the rest of the world, we focus on Germany vis-à-vis EA6 (an aggregate comprising Finland, France, Ireland, Italy, Portugal, and Spain). We calibrate the model for both sample periods, allowing estimated policies and shock processes to differ across PreEMU and EMU scenarios. Importantly, under EMU there is a common monetary policy for both countries and the exchange rate regime is fixed. As a result of the latter, there are no shocks originating in the foreign exchange market (UIP shocks).

We find that the model performs quite well in predicting key features of the data, both for the Pre-EMU sample and for EMU. Consequently, it also correctly predicts the changes documented for the data. Given the empirical success, we use the model to identify the causes of the change in business cycles. Three findings are particularly noteworthy. First, changes in the conduct of fiscal policy are of little consequence, except for the behavior of fiscal aggregates. Second, the disappearance of UIP shocks induces a fall in real exchange rate volatility within the model, which is quantitatively in line with the empirical observations. Third, and most importantly, our structural analysis shows that the euro has induced profound changes on European business cycles: cross-country spillovers increase substantially, while the effects of domestic shocks on the domestic economy are muted. As these changes have off-setting effects on the volatility of macroeconomic fundamentals, they cannot be detected in unconditional time series data. Nevertheless, the changes in the propagation of shocks raise important questions for welfare and policy making. We intent to pursue them in future research.

Appendix

A Further tables and figures

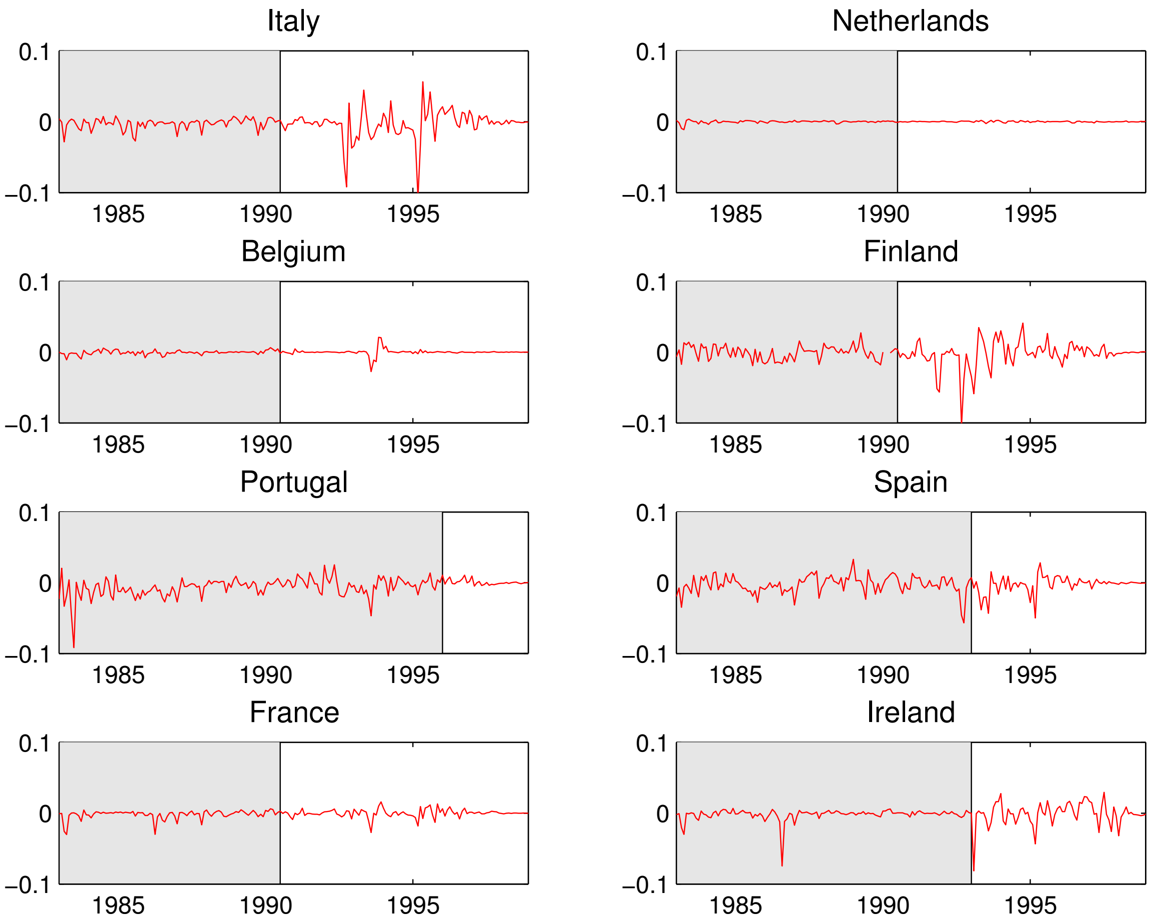

Figure A-1: Nominal exchange rate vis-à-vis Germany 1980-1998: monthly percentage change. Source: Bundesbank; gray area indicates periods with (partial) capital controls in place, see Eichengreen (1997), p. 158.

	GE Pre	GE EMU	IT Pre	IT EMU	SP Pre	SP EMU	IR Pre	IR EMU	BE Pre	BE EMU	FI Pre	FI EMU	POR Pre	POR EMU	FR Pre	FR EMU	NE Pre	NE EMU
Std. Y * 100	1.30 (0.20)	1.03 (0.09)	0.97 (0.13)	0.81 (0.14)	1.39 (0.14)	*** 0.57 (0.08)	1.86 (0.33)	1.50 (0.16)	1.01 (0.10)	0.78 (0.13)	2.78 (0.49)	*** 1.06 (0.13)	2.07 (0.19)	*** 1.04 (0.10)	1.05 (0.13)	* 0.72 (0.12)	0.94 (0.09)	1.16 (0.12)
Std C/Std Y	0.68 (0.08)	0.76 (0.10)	1.37 (0.23)	** 0.86 (0.10)	1.06 (0.12)	1.32 (0.17)	0.66 (0.19)	* 1.12 (0.15)	0.89 (0.15)	0.92 (0.11)	0.94 (0.07)	** 0.61 (0.14)	0.84 (0.14)	1.03 (0.12)	0.75 (0.09)	0.63 (0.09)	1.14 (0.11)	** 0.84 (0.08)
Std I/Std Y	2.31 (0.14)	*** 3.40 (0.27)	NaN (NaN)	NaN (NaN)	NaN (NaN)	NaN (NaN)	3.85 (0.27)	* 5.50 (0.89)	4.55 (0.79)	3.41 (0.59)	3.75 (0.28)	3.53 (0.39)	NaN (NaN)	NaN (NaN)	3.25 (0.24)	3.44 (0.26)	4.10 (0.59)	3.62 (0.47)
Std G/Std Y	1.04 (0.19)	0.90 (0.12)	1.24 (0.26)	0.85 (0.19)	1.24 (0.17)	1.00 (0.14)	1.84 (0.55)	2.36 (0.59)	0.93 (0.19)	1.17 (0.39)	0.77 (0.16)	*** 1.52 (0.21)	0.92 (0.13)	1.26 (0.17)	0.68 (0.11)	0.72 (0.14)	0.91 (0.18)	* 1.55 (0.30)
Std U/Std Y	9.18 (1.15)	7.32 (0.56)	5.75 (1.13)	4.02 (0.79)	NaN (NaN)	NaN (NaN)	3.59 (0.32)	*** 6.09 (0.73)	7.60 (0.94)	10.11 (1.30)	6.13 (0.53)	** 4.05 (0.64)	6.34 (0.72)	*** 10.16 (0.71)	4.53 (0.55)	** 8.18 (1.56)	9.78 (1.40)	** 14.39 (1.66)
Std Infl/Std Y	0.22 (0.03)	0.30 (0.04)	0.40 (0.08)	* 0.23 (0.05)	0.44 (0.07)	*** 1.43 (0.31)	0.22 (0.05)	** 0.40 (0.06)	0.39 (0.06)	0.50 (0.10)	0.18 (0.03)	*** 0.39 (0.06)	0.52 (0.09)	0.56 (0.08)	0.28 (0.06)	* 0.48 (0.10)	0.46 (0.08)	0.35 (0.06)
Std RX/Std Y	2.48 (0.40)	*** 0.34 (0.06)	4.91 (1.23)	*** 0.53 (0.12)	2.62 (0.28)	*** 0.79 (0.13)	1.34 (0.32)	* 0.67 (0.13)	1.97 (0.39)	*** 0.56 (0.12)	2.30 (0.41)	*** 0.57 (0.10)	1.50 (0.27)	*** 0.43 (0.06)	1.33 (0.33)	** 0.45 (0.09)	3.21 (0.43)	*** 0.47 (0.08)
Std NX/Std Y	0.23 (0.05)	0.27 (0.03)	0.57 (0.09)	0.37 (0.08)	0.46 (0.07)	*** 0.91 (0.16)	0.75 (0.16)	0.91 (0.16)	0.81 (0.12)	** 1.46 (0.30)	0.23 (0.04)	*** 0.62 (0.07)	0.92 (0.17)	0.90 (0.14)	0.21 (0.04)	0.27 (0.05)	0.36 (0.05)	0.32 (0.04)
Corr. Y Y*	0.42 (0.17)	** 0.85 (0.07)	0.69 (0.06)	0.82 (0.08)	0.79 (0.06)	0.91 (0.07)	0.76 (0.06)	0.59 (0.10)	0.93 (0.07)	0.91 (0.10)	0.36 (0.19)	** 0.85 (0.05)	0.81 (0.03)	0.78 (0.06)	0.83 (0.07)	0.90 (0.08)	0.62 (0.11)	* 0.86 (0.08)
Corr. C C*	0.36 (0.14)	0.62 (0.11)	0.74 (0.06)	0.69 (0.08)	0.83 (0.05)	0.82 (0.06)	0.32 (0.10)	*** 0.89 (0.08)	0.76 (0.05)	0.78 (0.09)	0.28 (0.16)	0.11 (0.14)	0.63 (0.10)	0.80 (0.06)	0.70 (0.08)	0.80 (0.06)	0.50 (0.12)	** 0.79 (0.05)
Corr. I I*	0.58 (0.10)	*** 0.85 (0.04)	NaN (NaN)	NaN (NaN)	NaN (NaN)	NaN (NaN)	0.83 (0.06)	*** 0.18 (0.18)	0.85 (0.07)	* 0.66 (0.08)	0.63 (0.09)	0.76 (0.06)	NaN (NaN)	NaN (NaN)	0.86 (0.05)	0.94 (0.06)	0.31 (0.15)	*** 0.81 (0.04)
Corr. G G*	0.35 (0.14)	** −0.10 (0.16)	0.54 (0.11)	** 0.08 (0.19)	0.17 (0.18)	−0.13 (0.21)	−0.04 (0.19)	** 0.50 (0.12)	0.29 (0.15)	0.16 (0.13)	0.03 (0.18)	−0.16 (0.23)	0.55 (0.10)	*** −0.12 (0.13)	0.53 (0.10)	*** −0.20 (0.18)	0.09 (0.14)	−0.07 (0.20)
Corr. U U*	0.73 (0.10)	0.83 (0.06)	0.55 (0.12)	0.63 (0.10)	NaN (NaN)	NaN (NaN)	0.72 (0.11)	0.69 (0.08)	0.92 (0.08)	0.87 (0.06)	0.54 (0.16)	0.68 (0.12)	0.63 (0.05)	*** 0.86 (0.05)	0.82 (0.07)	0.78 (0.04)	0.70 (0.06)	** 0.89 (0.07)
Corr. Infl Infl*	0.49 (0.13)	0.35 (0.11)	0.53 (0.10)	0.70 (0.06)	0.13 (0.16)	*** 0.59 (0.07)	0.36 (0.10)	0.55 (0.07)	0.47 (0.14)	0.58 (0.10)	0.38 (0.19)	0.69 (0.07)	0.57 (0.08)	** 0.80 (0.05)	0.51 (0.05)	*** 0.87 (0.06)	0.14 (0.14)	*** 0.68 (0.07)

	US Pre	US EMU	UK Pre	UK EMU	JAP Pre	JAP EMU	CA Pre	CA EMU	CH Pre	CH EMU	NOR Pre	NOR EMU	SWE Pre	SWE EMU	**Non-EMU Avg.** Pre	**Non-EMU Avg.** Post	**EMU Avg.** Pre	**EMU Avg.** Post
Std. Y * 100	0.92 (0.11)	0.95 (0.15)	1.43 (0.19)	*** 0.42 (0.06)	1.30 (0.14)	*** 0.84 (0.09)	1.56 (0.16)	*** 0.82 (0.16)	1.17 (0.20)	1.05 (0.12)	1.47 (0.16)	*** 0.81 (0.09)	1.54 (0.29)	** 0.86 (0.16)	1.10 (0.09)	* 0.87 (0.11)	1.20 (0.11)	** 0.87 (0.09)
Std C/Std Y	0.89 (0.08)	*** 0.65 (0.04)	1.24 (0.11)	1.28 (0.21)	0.66 (0.08)	0.55 (0.08)	0.76 (0.06)	0.61 (0.09)	0.55 (0.11)	0.58 (0.08)	1.40 (0.22)	1.21 (0.10)	1.07 (0.17)	1.06 (0.11)	0.87 (0.04)	*** 0.70 (0.04)	0.93 (0.07)	0.84 (0.05)
Std I/Std Y	3.57 (0.41)	4.51 (0.45)	3.85 (0.46)	* 6.15 (1.14)	3.61 (0.27)	3.82 (0.30)	3.26 (0.31)	2.68 (0.63)	NaN (NaN)	NaN (NaN)	5.11 (0.64)	6.60 (1.10)	5.35 (0.51)	5.12 (0.60)	3.63 (0.22)	* 4.45 (0.40)	3.01 (0.13)	** 3.48 (0.18)
Std G/Std Y	1.16 (0.24)	0.90 (0.14)	0.88 (0.13)	*** 2.16 (0.46)	1.32 (0.25)	0.89 (0.15)	0.72 (0.11)	0.84 (0.23)	1.29 (0.21)	1.18 (0.18)	1.35 (0.18)	1.81 (0.32)	0.64 (0.16)	* 1.16 (0.24)	1.14 (0.17)	1.03 (0.14)	1.02 (0.09)	0.95 (0.12)
Std U/Std Y	8.66 (1.17)	9.86 (1.05)	6.69 (0.98)	8.80 (1.88)	4.46 (0.49)	4.45 (0.49)	5.36 (0.31)	6.16 (0.65)	26.54 (2.56)	*** 11.61 (0.88)	11.11 (1.19)	14.48 (2.75)	12.82 (1.70)	11.30 (2.65)	7.76 (0.72)	8.51 (0.78)	6.96 (0.62)	7.37 (0.75)
Std Infl/Std Y	0.35 (0.07)	0.39 (0.09)	0.60 (0.12)	** 1.15 (0.19)	0.31 (0.04)	0.25 (0.05)	0.29 (0.06)	** 0.67 (0.18)	0.42 (0.07)	0.56 (0.11)	0.27 (0.04)	*** 0.84 (0.17)	0.54 (0.10)	0.61 (0.14)	0.36 (0.05)	0.46 (0.08)	0.33 (0.04)	* 0.48 (0.07)
Std RX/Std Y	4.80 (1.16)	3.97 (0.78)	4.09 (0.75)	*** 8.55 (1.56)	7.72 (1.24)	6.32 (0.96)	2.42 (0.37)	4.17 (1.10)	6.51 (1.46)	4.60 (0.30)	2.75 (0.49)	*** 5.52 (0.84)	4.53 (0.70)	7.50 (1.85)	5.23 (0.95)	5.00 (0.68)	2.74 (0.41)	*** 0.48 (0.07)
Std NX/Std Y	0.22 (0.03)	** 0.13 (0.02)	0.34 (0.07)	* 0.61 (0.12)	0.26 (0.06)	0.18 (0.02)	0.44 (0.07)	*** 1.20 (0.25)	0.29 (0.06)	0.30 (0.05)	1.33 (0.17)	1.66 (0.30)	0.42 (0.10)	* 0.67 (0.11)	0.27 (0.03)	0.27 (0.03)	0.38 (0.04)	0.45 (0.05)
Corr. Y Y*	0.69 (0.07)	0.69 (0.07)	0.70 (0.08)	0.72 (0.08)	−0.02 (0.20)	0.33 (0.22)	0.83 (0.04)	0.71 (0.08)	0.48 (0.15)	0.64 (0.09)	−0.04 (0.23)	** 0.50 (0.11)	0.61 (0.11)	* 0.85 (0.08)	0.54 (0.08)	0.62 (0.07)	0.66 (0.06)	** 0.86 (0.06)
Corr. C C*	0.57 (0.08)	0.46 (0.21)	0.46 (0.13)	0.41 (0.18)	−0.15 (0.18)	−0.22 (0.18)	0.82 (0.07)	0.49 (0.19)	0.30 (0.26)	0.55 (0.14)	−0.05 (0.21)	*** 0.62 (0.08)	0.30 (0.23)	0.68 (0.07)	0.41 (0.08)	0.32 (0.14)	0.60 (0.05)	* 0.72 (0.05)
Corr. I I*	0.28 (0.18)	*** 0.89 (0.05)	0.67 (0.11)	** 0.21 (0.18)	−0.01 (0.23)	** 0.56 (0.16)	0.55 (0.14)	** 0.92 (0.07)	NaN (NaN)	NaN (NaN)	0.07 (0.17)	0.42 (0.14)	0.44 (0.14)	*** 0.84 (0.06)	0.27 (0.17)	*** 0.75 (0.04)	0.67 (0.05)	*** 0.85 (0.03)
Corr. G G*	−0.31 (0.16)	*** 0.50 (0.14)	0.17 (0.22)	0.13 (0.16)	−0.55 (0.10)	*** 0.37 (0.13)	0.11 (0.21)	0.38 (0.16)	−0.07 (0.17)	0.13 (0.16)	0.14 (0.17)	0.27 (0.12)	0.29 (0.13)	0.46 (0.14)	−0.28 (0.13)	*** 0.42 (0.11)	0.38 (0.08)	*** −0.07 (0.11)
Corr. U U*	0.89 (0.08)	0.90 (0.07)	0.82 (0.07)	*** −0.02 (0.23)	−0.09 (0.25)	** 0.50 (0.17)	0.92 (0.08)	0.90 (0.08)	0.88 (0.09)	0.71 (0.11)	−0.18 (0.22)	*** 0.55 (0.09)	0.79 (0.06)	0.65 (0.09)	0.66 (0.08)	0.72 (0.05)	0.71 (0.04)	0.77 (0.03)
Corr. Infl Infl*	0.42 (0.15)	0.57 (0.07)	0.17 (0.12)	0.33 (0.15)	0.36 (0.16)	0.30 (0.14)	0.30 (0.13)	* 0.57 (0.07)	0.43 (0.08)	0.53 (0.11)	−0.07 (0.15)	** 0.31 (0.08)	0.23 (0.12)	*** 0.77 (0.06)	0.37 (0.12)	0.49 (0.06)	0.43 (0.06)	*** 0.61 (0.03)

Table A-1: For GE, NE, and BE: relative variables are towards EA6. Other countries: relative variables are towards (remaining) EA9. Time-varying (4 quarters rolling window) trade shares were used as weights. All variables are expressed in logs (except Infl and NX) and HP-filtered. Standard errors are given in small fonts. Asterisks denote 10%, 5%, and 1% significant difference. Averages are weighted with long-run PPP-adjusted GDP.

Table A-2: Structural decomposition of change

	PreEMU	NoUIP	EMUgov	EMUrules	EMUshocks	EMU
Domestic						
Std Y * 100	1.17	1.18	1.18	0.92	0.92	0.89
Std C/Std Y	0.85	0.84	0.83	0.81	0.81	0.89
Std I/Std Y	2.84	2.88	2.84	2.94	2.93	2.94
Std G/Std Y	1.08	1.08	0.74	0.96	0.96	0.99
Std U/Std Y	9.10	9.18	9.18	8.77	8.79	9.48
Std π/ Std Y	0.04	0.04	0.04	0.07	0.07	0.10
Foreign						
Std Y * 100	0.77	0.78	0.79	0.71	0.73	0.70
Std C/Std Y	0.74	0.74	0.73	0.69	0.71	0.64
Std I/Std Y	2.96	3.01	2.97	3.10	3.04	3.19
Std G/Std Y	0.57	0.58	0.32	0.36	0.35	0.37
Std U/Std Y	4.11	4.13	4.06	5.31	5.18	4.71
Std π/ Std Y	0.11	0.11	0.11	0.10	0.12	0.14
Trade						
Std RX/Std Y	1.79	0.43	0.43	0.45	0.39	0.31
Std NX/Std Y	0.12	0.04	0.04	0.04	0.04	0.04
Cross-country						
Corr Y Y^*	0.52	0.53	0.53	0.55	0.62	0.70
Corr C C^*	0.41	0.42	0.42	0.42	0.53	0.72
Corr I I^*	0.51	0.46	0.46	0.49	0.54	0.46
Corr G G^*	0.16	0.12	0.06	0.04	0.04	0.04
Corr U U^*	0.59	0.57	0.56	0.58	0.61	0.68
Corr $\pi\pi^*$	0.49	0.51	0.53	0.56	0.67	0.21

Notes: for computation of statistics see table 4; left and right columns replicate results for PreEMU and EMU calibration, respectively. Middle columns from left to right simulate gradual transition from PreEMU to EMU: no UIP shocks, fiscal rules/shocks as under EMU, independent monetary policy rules but with EMU coefficients, monetary policy shocks occur symmetrically (volatility as under EMU).

B Data sources and issues

B.1 Sources

Data are taken from the OECD Economic Outlook 84, the Main Economic Indicators vol. 2008 release 12, Monthly Statistics of International Trade Vol. 2008 release 11, and the Quarterly National Accounts vol. 2008 release 12 databases, all in OECD (2008a). We also use the STAN database in OECD (2008b) and the AMECO database in European Commission DG ECFIN (2008).

For Canada, Finland, France, Germany (Western Germany before 1991), Ireland, Italy, Norway, Japan, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States, we take the following series from the Economic Outlook: 'Gross domestic product - volume - market prices'; 'Private final consumption expenditure - volume'; 'Private total fixed capital formation - volume'; 'Government final consumption expenditure - volume'; 'Government gross fixed capital formation -

volume'; 'Consumer price index'; 'Unemployment rate'; 'Exchange rate'; 'Gross domestic product - volume - at 2000 PPP - USD'; 'Interest Rate, ShortTerm'; 'OECD crude oil import price - CIF - USD per barrel'; 'Total trade in value by partner countries'. Note that government spending is defined as the sum of government investment and consumption where data on government investment is available.[36]

For the same countries we obtain the following series from the STAN database: 'Production (gross output), volumes' as well as 'Production (gross output), current prices' in 'Manufacturing' and 'Total services'; and the following series from from the AMECO database: 'Net capital stock per unit of gross domestic product at constant market prices: Capital output ratio: total economy (AKNDV)' and 'Adjusted wage share: total economy: as percentage of GDP at current factor cost (Compensation per employee as percentage of GDP at factor cost per person employed.) (ALCD2)'.

The computation of Solow residuals is based on labor inputs only (as the capital stock adjusts only very little at high frequency and data on the capital stock is not generally available). We obtain the following series from the OECD Main Economic Indicators: 'Production of total industry sa'; 'Civilian employment: industry including construction sa' (where not available—GE, FR, and IR—series for 'Production in total manufacturing sa' and 'Weekly hours worked (paid): manufacturing' or 'Employees: manufacturing sa') and 'Civilian employment: services sa'. Where available, data for (Output of) 'Services' are from the OECD Quarterly National Accounts. We only consider data up to 2006, because the German series for labor employed ends at that point. We also include a dummy at the time of the re-unification in equations for Germany.

B.2 Foreign aggregate and parameter values

In order to avoid national basis effects, we construct the rest of the world series, i.e. the 'foreign' country for each 'home' country considered, by first calculating quarterly growth rates and aggregating the weighted series. Euro area growth rates include West-Germany until 1990Q4, and unified Germany from 1991Q1 onwards. Weights are calculated as the time-varying percentage shares of trade (imports+exports) with the respective country (lagged four-quarter rolling window).

The aggregated growth rates are then cumulated from the normalized base year in order to transform the series into levels. Relative variables are specific to the country under consideration and the respective foreign-country aggregate. For example, the real exchange rate is constructed using the corresponding data on nominal exchange rates and the CPIs of the specific country and the countries forming the foreign aggregate.

[36] The series for UK investment (private and public) was adjusted for the unusual transfer of nuclear reactors from the British Nuclear Fuels plc to the Nuclear Decommissioning Authority in April 2005, see National Statistics (2006) for details.

Concerning the values for the labor share, the capital-to-output ratio, and the price durations, the averages of the above mentioned time-varying trade weights were used as weights. These weights were adjusted for the fact that data for Ireland is missing in the case of price durations. The average capital-to-output ratio, the labor share, and government spending over GDP were calculated by aggregating the two long-run averages for Germany and EA6 using average PPP adjusted GDP weights, yielding values of 11.99, 0.66, and 0.21 respectively. We compute the average of the ratio of manufacturing relative to services output using the averages of the time-varying trade weights (adjusted for the missing data for Portugal, Spain, and Ireland).

B.3 Filtering

We generally apply the HP-filter with a smoothing parameter of 1600 to the time series data before computing statistics of interest. We apply the filter to the longest available sample (1970-2007) to remove the trend. Note that data used in the estimation of the Taylor rule is not filtered. Since the calculation of the UIP shocks relies on forecasts based on data available in each period, first differences were used instead of the two-sided HP-filter to remove trends.

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