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Germany and the European Business Cycle – An Analysis of Causal Relations in an International Real Business Cycle Model

by

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Abstract

This paper studies the role of the German economy for the existence of the so called European business cycle, a term referring to the regularly observed synchronization of the national business cycles in Europe. Using a three-country general equilibrium model, we are able to simulate impulse response functions mimicking the important features observed in the data. Focusing on the importance of shocks affecting the German GDP we show that trade-related transmission from Germany to the other European economies is only of minor importance for the synchronization of national business cycles. On the contrary, our findings suggest that the influence of common shocks and of technology spillovers accounts for most of the parallels in economic performance.

Keywords: European business cycle; Transmission; Open economy macroeconomics; Real business cycles

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1. Introduction

The constitution of the European Monetary Union has brought back to light an issue, that has been discussed in a global context for a long time – the existence of common elements in national business cycles.[1] As, among others, Bayoumi and Eichengreen (1993) and Tavlas (1993) have noted, monetary integration in case of insufficient similarities between the participating countries may lead to high costs of the integration process due to improper coordination between national economic fluctuations and supranational monetary policy. Whether there exists what might be called a "European business cycle" therefore plays a crucial role for success or failure of the union.

While there appears to be a consensus in the literature that the European economies indeed share some common elements in their aggregate cyclical behavior (see Artis et al., 1998, or Lumsdaine and Prasad, 2003), opinions diverge concerning the question whether or not this common component gained importance for the national economies. Most econometric studies however suggest increasing similarities between the national business cycles with on-going European integration.[2] Reasons for this phenomenon still remain unrevealed though.

Two major sources of economic synchronization tendencies have been discussed in a global context: common shocks and the transmission of country specific shocks. Several authors, including Dellas (1986) and Canova and Marrinan (1998), have shown that in order to simulate realistic output fluctuations in an international business cycle model, transmission alone is not sufficient. Instead, the presence of a common exogenous shock appears to be necessary to quantitatively match the data gathered in empirical studies. Other authors (see, among others, Anderson et al., 1999, or Laxton and Prasad, 2000) however point out the importance of trade linkages for the synchronization of international business cycles.

Given the extraordinary economic and political integration of the European economies one might expect transmission effects to be of predominant importance for synchronizing the European business cycles. From this point of view, the German economy might well have an exposed position in Europe due to its economic weight and its intense inner-European trade linkages. The presumption, that Germany might have a similar role in Europe as the often cited "locomotive" USA in the world economy, seems quite plausible; German economic fluctuations thus were comparatively independent and influenced (in a boom as well as a recession) the other European economies' business cycles.

Following the work of Canova and Marrinan (1998), this paper presents a multi-country general

[1] See e. g. Mitchell (1927, 424f.) for an early study. For recent empirical documentation of parallels among international business cycles see, for example, Backus and Kehoe (1992) or Gregory et al. (1997).

[2] See e. g. Artis and Zhang (1997, 1999), or Dueker and Wesche (2001); sceptical: Inklaar and de Haan (2000).

equilibrium model, essentially due to Zimmermann (1997), allowing to quantify the importance of trade interdependencies for transmitting shocks across countries. Using this model as a tool to simulate output time series of an artificial world economy, we contribute to the growing literature dealing with the European business cycle some insights about sources and mechanisms of this phenomenon.

Our findings can be summarized like this: Focusing on the importance of shocks affecting the German GDP we show that trade-related transmission from Germany to the other European economies is only of minor importance for the observed synchronization of national business cycles. On the contrary, our findings suggest that the influence of common shocks and of technology spillovers between the countries accounts for most of the parallels in economic performance.

The paper is structured as follows. In order to provide a benchmark for the model and to offer some first insights into the driving forces of synchronization tendencies, section 2 derives some empirical regularities of the European business cycle. Section 3 explains the model economy. Section 4 presents the derivation of steady state equilibria. The methods used to calibrate the model are described in section 5. Section 6 gives an overview of the computational procedures used to calculate the simulated time series. In section 7 we present the results of our simulations and compare them with the empirical findings. Section 8 offers some further interpretation and discusses our results. Section 9 concludes. An appendix presents the sources of the data.

2. Empirical regularities of the European business cycle

In the following, the influence of Germany's economic fluctuations on the business cycles of its European neighbors shall be analyzed by estimating a multi-country vector autoregressive model and retrieving impulse response functions for a shock affecting the German economy.[3]

Such an analysis obviously requires an operationalization of the term "business cycle". Following the definition by Lucas (1977) of the business cycle as "co-movements among different aggregative time series" and specifically as "movements about trend in gross national product," the business cycle will here be represented by fluctuations of output series (GDP) around their trend. The trend is identified using the HP (1600) filter, thus considering the long-run growth component to be a smooth but non-deterministic process.[4]

The study is based on quarterly data taken from the IMF's International Financial Statistics covering the sample from 1970:1 to 2001:4. We estimate a VAR on the log of detrended real GDP of

[3] A similar analysis is carried out by Canova and Marrinan (1998) for interdependencies between Germany, Japan and the US.

[4] Application of the HP filter has been discussed controversially, as it is subject to the Nelson-Kang (1981) critique to create spurious periodicity in the data. Additionally, there is no upper bound for the frequencies passing the filter, thus short time variations in the data are left as part of the cyclical component. See Baxter and King (1999) for a detailed discussion.

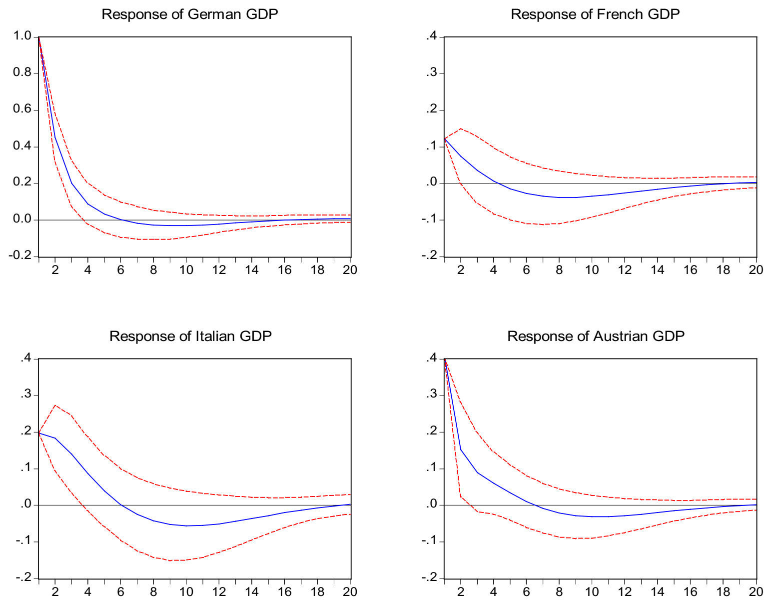

Figure 1: Impulse response functions of a 1% shock on German GDP with 95% confidence bands.

Austria, Germany[5], France, Italy, Japan, UK and the US. Additionally included are a (highly significant) dummy for the boom phase in Germany induced by the reunification (1991:1 until 1992:4) and the oil price growth rate as exogenous variable. According to the usual information criteria the lag length has been set to 1.

The impulse response functions have been simulated using the following Cholesky ordering: US, Germany, UK, France, Italy, Austria and Japan. With the exception of Japan this ordering follows the economic weight as indicated by the GDP in 1985 and can – given that bigger countries tend to influence smaller countries and not vice versa – be regarded as economically quite plausible. The exception of Japan seems justified in view of its less important economic linkages with the European countries.

Fig. 1 plots the mean estimate of the impulse response functions to a 1% shock on German GDP with 95% confidence bands.[6] Obviously, German output shocks have significantly large and positive contemporaneous effects on the European economies, with the reaction in Austria clearly being higher than in the other countries. As a whole, a positive interdependence between German business cycles and those of the included European economies can be assumed.

To get an impression of changes in the relationship leading to unreliabilities in the presented results, in a next step VARs will be estimated for different subsamples. The first subsample ("70ies")

[5]To avoid a jump in the data an artificial series has been created by writing back all-German values with West German growth rates from 1992:1 backwards.

[6]Economic dependencies between Germany and Europe shall here be analyzed focusing on France, Italy and Austria, as their economic relationship to Germany has been relatively stable over the examined period and data is readily available for these countries.

covers the period 1970:1 – 1979:4, the second subsample ("80ies") the period 1980:1 – 1991:4,[7] and the third subsample ("90ies") the period 1992:1 – 2001:4.

The impulse response functions for the subsamples (see fig. 2) reveal some interesting features of the European economic system. While in the 1970ies and 1990ies positive shocks on the German GDP have positive contemporary impacts on the other European economies, business cycle interdependencies between Germany and France as well as Italy appear to be negative and relatively weak during the 1980ies.[8]

This pattern of German influence on the French and the Italian business cycle seems rather unusual for an economic integration process that one would expect to lead to an increase in correlation. Having in mind that economic synchronization might be the outcome of transmission as well as common exogenous shocks, interpretation is straightforward though: In the 1970ies, economic fluctuations were influenced by oil price shocks leading to a synchronization of business cycles worldwide. By contrast, in the 1980ies such symmetric shocks were absent. Instead, business cycle fluctuations were rather weak and marked by different economic policies: while, e. g., the French socialist government reacted to the emerging recession in the early 1980ies with expansive fiscal policy, a consolidation policy was implemented in Germany. Already in the early 1990ies, but still as part of the 80ies subsample, Germany experienced an upswing after its reunification, that coincided with a recession in the rest of Europe.[9] During the 1990ies European economic integration finally led to a reenforcement of economic interdependencies and thus synchronicity.

In contrast, the influence of Germany on the Austrian business cycle has remained qualitatively unchanged over time. For all subsamples we observe a positive contemporary reaction of the Austrian GDP in response to a shock leading to a deviation of the German GDP from its trend. While the French and Italian GDP's peak response in the 1970ies and 1990ies subsample lag for 1 quarter behind the German shock (a feature not observed in the full sample analysis), Austria's peak response in the 80ies and 90ies arises without delay. While this might be interpreted as a sign of the influence of common exogenous shocks on both the German and the Austrian economy, we by no means can rule out the existence of economic linkages transmitting Germany's economic fluctuations to Austria.[10] Assuming that the transmission between highly integrated economies might be rather fast (having in mind e. g. the capital markets as a transmission channel), the use of quarterly data could be too coarse to allow a clear distinction between the influence of common shocks and transmitted asymmetric shocks. On the other hand, the observed lag between Germany's and the French and Italian peak response can not necessarily be interpreted as an indication for the

[7]This upper bound is chosen in order to match the break in the data due to the German reunification.
[8]This has been previously noted. See e. g. Seifert (1999) for an analysis of correlation coefficients in different periods.
[9]Application of the HP filter induces additional negative correlation. As a result of the strong expansion process after the German unification, the cyclical component of German GDP in the late 1980ies, even though following an upswing, is assessed rather low, while the other European economies experienced a boom period.
[10]While it seems plausible to expect the main influence to be directed from Germany to Austria, an influence from Austria on Germany shall clearly not be precluded.

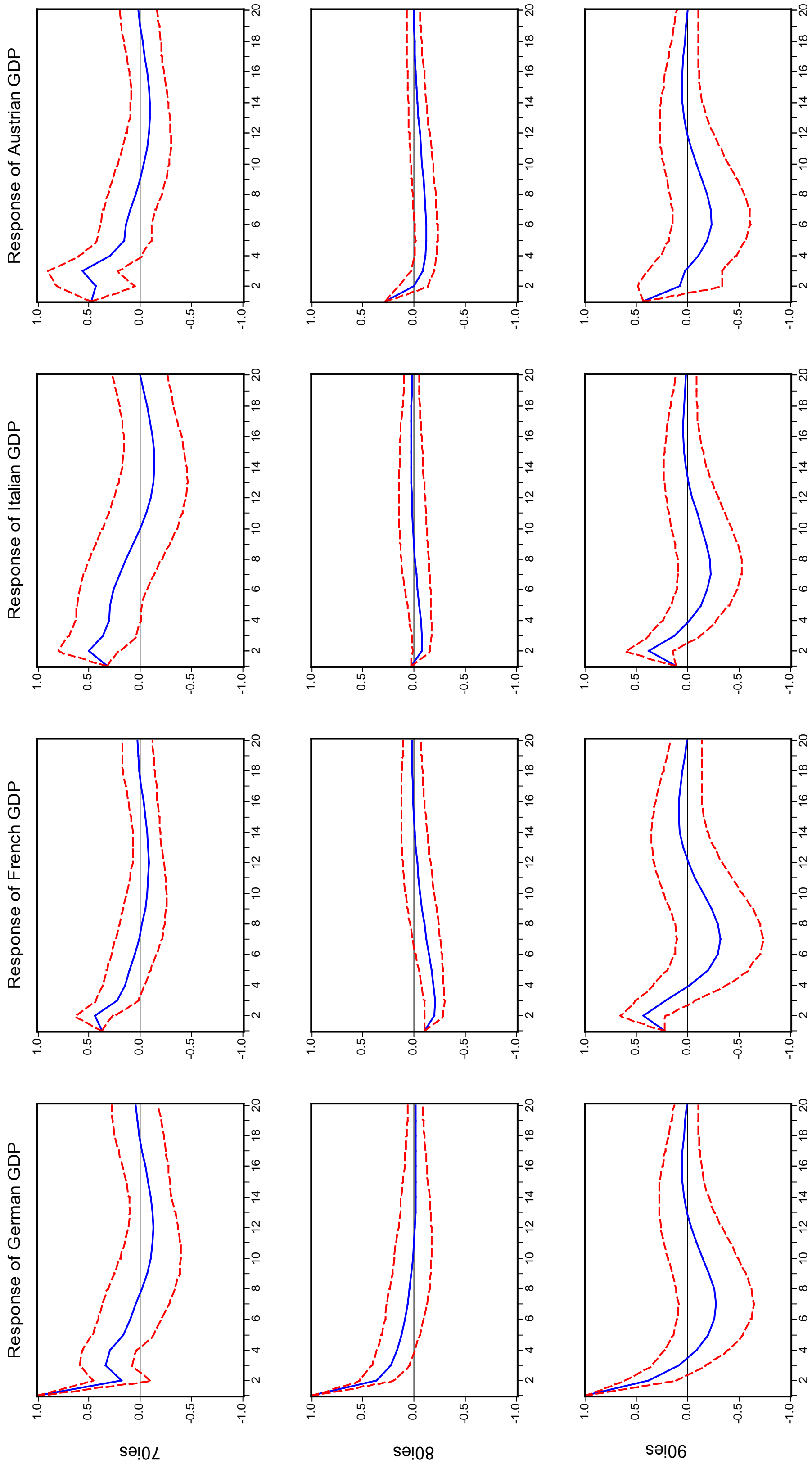

Figure 2: Impulse response functions of a 1% shock on German GDP with 95% confidence bands.

absence of common exogenous shocks and for high importance of transmissive effects. As Mills and Holmes (1999, 560) note, even if countries experience a common shock, their response might well be temporarily spread due to differing economic structures or different ways of dealing with the shock, thus leading to an impulse response function similar to the one obtained in the case of a transmitted idiosyncratic shock.

Therefore, the possibilities to further investigate the influence of Germany's economic fluctuations on the European business cycle on basis of the empirical findings presented above are quite limited, as a clear distinction between the importance of transmissive effects and common shocks for the synchronization of the national cycles is not feasible. Our analysis confirms the previously observed strong correlation between the output fluctuations in Germany and the other economies especially in the 1970ies and 1990ies. Evidence of reasons for this close connection remains unreliable though. There might be some weak indication of an increase in transmission between Germany and France as well as Italy in the 1990ies compared to the 1970ies, as the contemporaneous correlation decreased (thus indicating a diminished influence of common shocks), while the lagged reaction of either country's GDP increased. A confirmation of the hypothesis that German economic fluctuations influence the business cycle of the other European countries by means of transmission has yet to be given, though.

In the following sections we present an international real business cycle model, that is capable to simulate the observed regularities of the European business cycle. By modifying the model's mechanisms and using the empirical findings presented above as a benchmark, we are able to assess the importance of different driving forces of the national cycles.

3. The model

The model employed here to further investigate the influence of German business cycles on the economic fluctuations of its European neighbors, corresponds in its characteristic features to the basic real business cycle models presented in the seminal papers by Kydland and Prescott (1982) and Long and Plosser (1983). Apart from rational expectations and cleared markets due to an efficient price mechanism, this is in particular the assumption of a pure supply sided stochastic shock (technology shock) as impulse for economic fluctuations. There is no monetary sector and no governmental influence on the economy. The fundamental extension of this model compared to the baseline models is the opening of the economy to international goods markets.[11] In contrast to the international models decisively developed by Backus et al. (1992) and Baxter and Crucini (1993), heterogeneities among the countries are taken into account by Zimmermann (1997). The following exposition is chiefly based on his work.

The model's world economy consists of three countries differing in size and trade related vari-

[11] International capital markets are not explicitly modeled here. See e. g. Baxter and Crucini (1995) or Cantor and Mark (1988).

ables. The countries are populated by a constant[12] number of representative agents maximizing their lifetime utility by consuming or investing goods and varying their labor supply over time. While goods are freely traded internationally, labor is internationally immobile.

The representative agent in country $i = 1 \dots 3$ maximizes his expected lifetime utility $\mathrm{E}\{U_i\}$, which is assumed to be representable by

$$U_i = \sum_{t=0}^{\infty} \frac{\beta^t}{\gamma} \left({c_{i,t}}^{\mu} \cdot (1 - n_{i,t})^{1-\mu} \right)^{\gamma}, \qquad 0 < \beta < 1, 0 < \mu < 1, \gamma < 1, \tag{1}$$

where $c_{i,t}$ is the agents consumption at time t, $n_{i,t}$ his working time and thus $1 - n_{i,t}$ his leisure, β the discount factor, and γ the coefficient of relative risk aversion.

Each country produces one good $y_{i,t}$ according to a Cobb-Douglas production function using capital $k_{i,t}$ and labor $n_{i,t}$.[13] Production is influenced by a stochastic technology parameter $z_{i,t}$:

$$y_{i,t} = z_{i,t} \cdot {k_{i,t}}^{\theta} {n_{i,t}}^{1-\theta}, \qquad 0 < \theta < 1. \tag{2}$$

The technology parameter $z_{i,t}$ follows a first order vector autoregressive process:

$$z_{t+1} = \left[z_{1,t+1} \; z_{2,t+1} \; z_{3,t+1} \right]^T = Z + A z_t + \varepsilon_{t+1}, \tag{3}$$

where $\varepsilon_{t+1} = \left[\varepsilon_{1,t+1} \; \varepsilon_{2,t+1} \; \varepsilon_{3,t+1} \right]^T \sim \mathrm{N}(0, V)$ is a vector of normally distributed serially independent technology shocks with mean 0 and variance-covariance matrix V.[14]

Capital is accumulated according to

$$k_{i,t+1} = (1 - \delta) k_{i,t} + x_{i,t}, \qquad 0 < \delta < 1, \tag{4}$$

where $x_{i,t}$ is gross investment and δ the depreciation rate.

Total production of country i, $y_{i,t}$, is used domestically and abroad. Exports from country i to country j per capita of country j are symbolized by $y_{i,j,t}$. Thus, if the population of country i is given as α_i:

$$\alpha_i y_{i,t} = \alpha_i y_{i,i,t} + \alpha_j y_{i,j,t} + \alpha_k y_{i,k,t}, \qquad i \neq j \neq k. \tag{5}$$

Goods are used for consumption $c_{i,t}$ and investment $x_{i,t}$, where a limited substitutability between goods of different origin is handled by introducing an Armington (1969) aggregator $G(\cdot)$ into the household's problem. This function attaches different weights $\omega_{i,j}$ to goods of different origin and

[12]As the model is used to simulate business cycles rather than growth tendencies we refrain from growth in population.
[13]All variables are in per capita terms of the respective country.
[14]Contemporary correlation of the technology shock in the respective countries is thus taken into account by the matrix V and lagged correlation (e. g. due to technological spillovers) by the matrix A.

aggregates them to a single homogeneous good being consumed or invested:

$$c_{i,t} + x_{i,t} = G(y_{i,i,t}, y_{j,i,t}, y_{k,i,t}) = \left(\omega_{i,i} y_{i,i,t}{}^{-\rho} + \omega_{j,i} y_{j,i,t}{}^{-\rho} + \omega_{k,i} y_{k,i,t}{}^{-\rho}\right)^{-\frac{1}{\rho}}, \quad \text{with } \omega_{i,i}, \omega_{j,i}, \omega_{k,i} \geq 0, \rho \geq 1. \tag{6}$$

4. The steady state

In the steady state the trade balances and all markets are in equilibrium. The influence of technology shocks is set to zero ($\varepsilon_{i,t} = 0$). The technology parameters' equilibrium value $\bar{z}$ is then $\bar{z} = (I - A)^{-1} Z$.

The producer's maximization problem is

$$\max_{\{k_i, n_i\}} z_i k_i{}^{\theta} n_i{}^{1-\theta} - w_i n_i - (r + \delta) k_i, \tag{7}$$

where r is the interest rate and w_i the wage. The first order conditions are then

$$\bar{y}_i = \bar{z}_i^{\frac{1}{1-\theta}} \left(\frac{\theta}{r+\delta}\right)^{\frac{\theta}{1-\theta}} \bar{n}_i, \quad \bar{k}_i = \theta \frac{\bar{y}_i}{r+\delta}, \quad \bar{w}_i = (1-\theta)\frac{\bar{y}_i}{\bar{n}_i}, \quad \bar{x}_i = \frac{\delta\theta\bar{y}_i}{r+\delta}. \tag{8a–d}$$

Households maximize their utility subject to their budget constraint:

$$\max_{\{c_i, n_i\}} \frac{1}{\gamma}\left(c_i{}^{\mu}(1-n_i)^{1-\mu}\right)^{\gamma}, \qquad \text{s. t. } w_i n_i + (r+\delta) k_i = c_i + x_i. \tag{9}$$

This leads to

$$\bar{n}_i = \frac{(1-\theta)\frac{\mu}{1-\mu}}{1 + (1-\theta)\frac{\mu}{1-\mu} - \frac{\delta\theta}{(r+\delta)}} \qquad \text{and} \qquad \bar{c}_i = \frac{\mu}{1-\mu}(1-\theta)\frac{\bar{y}_i}{\bar{n}_i}(1-\bar{n}_i). \tag{10a,b}$$

If $p_{i,j}$ or $p_{i,k}$ is the respective price of the foreign good valued in units of the domestic good (price ratio, bilateral terms of trade), the household's maximization over the three goods $y_{i,i}$, $y_{j,i}$ and $y_{k,i}$ according to the Armington aggregator, complete markets assumed, leads to

$$p_{i,j} = \frac{\partial G / \partial y_{j,i}}{\partial G / \partial y_{i,i}} = \frac{\omega_{j,i}}{\omega_{i,i}} \left(\frac{y_{i,i}}{y_{j,i}}\right)^{1+\rho}, \tag{11a}$$

$$\text{and } p_{i,k} = \frac{\partial G / \partial y_{k,i}}{\partial G / \partial y_{i,i}} = \frac{\omega_{k,i}}{\omega_{i,i}} \left(\frac{y_{i,i}}{y_{k,i}}\right)^{1+\rho}. \tag{11b}$$

The trade balance is defined as value of exports less value of imports (expressed in prices of country

i's goods). Per capita of country i, it is

$$tb_i = \frac{\alpha_j}{\alpha_i} y_{i,j} + \frac{\alpha_k}{\alpha_i} y_{i,k} - p_{i,j} y_{j,i} - p_{i,k} y_{k,i}. \tag{12}$$

In the steady state, the trade balance is in equilibrium ($tb_i = 0$) and the terms of trade are equal to one. For the trade flows, this leads to

$$\bar{y}_{i,i} = \frac{\bar{y}_i}{1 + \left(\frac{\omega_{j,i}}{\omega_{i,i}}\right)^{\frac{1}{\rho+1}} + \left(\frac{\omega_{k,i}}{\omega_{i,i}}\right)^{\frac{1}{\rho+1}}}, \tag{13a}$$

$$\bar{y}_{j,i} = \frac{\bar{y}_i}{\left(\frac{\omega_{i,i}}{\omega_{j,i}}\right)^{\frac{1}{\rho+1}} + 1 + \left(\frac{\omega_{k,i}}{\omega_{j,i}}\right)^{\frac{1}{\rho+1}}}, \tag{13b}$$

$$\bar{y}_{k,i} = \frac{\bar{y}_i}{\left(\frac{\omega_{i,i}}{\omega_{k,i}}\right)^{\frac{1}{\rho+1}} + \left(\frac{\omega_{j,i}}{\omega_{k,i}}\right)^{\frac{1}{\rho+1}} + 1}. \tag{13c}$$

This completes the description of the model's steady state.

5. Calibration

As common in RBC theory, the model's parameters are determined by calibration (see e. g. Kydland and Prescott, 1996). Following Zimmermann (1997) and most of the literature the (quarterly) interest rate in all countries is set to $r = 1\%$. This yields $\beta = \frac{1}{r+1} \approx 0.99$. The quarterly discount rate is fixed at $\delta = 0.025$, the capital income share θ is set to 0.35.[15] Rearranging (10a) and setting $\bar{n}_i = 0.3$ as well as $\frac{\bar{c}_i}{\bar{y}_i} = 0.75$, leads to $\mu = \frac{1}{1+\frac{\bar{y}_i}{\bar{c}_i}(1-\theta)\frac{1-\bar{n}_i}{\bar{n}_i}} \approx 0.33$. For the measure of risk aversion $\gamma = -1$ is assumed.

The $\omega_{i,j}$ are determined by setting $\frac{\bar{y}_{i,i}}{\bar{y}_i}$ according to the average domestic production share of the respective country's GDP as recorded in the IMF's International Financial Statistics.[16] Additionally $\frac{\bar{y}_{j,i}}{\bar{y}_i}$ and $\frac{\bar{y}_{k,i}}{\bar{y}_i}$ are set such that the countries import ratios from the two other countries match the average import proportions as reported in the IMF's Direction of Trade Statistics. Taking into account, that in the long run $\bar{c}_i + \bar{x}_i = \bar{y}_i$ and the terms of trade in the steady state are equal to one, one can derive the weights in the Armington aggregator as $\omega_{j,i} = \left(\frac{\bar{y}_{j,i}}{\bar{y}_i}\right)^{1+\rho}$.

The calibration of the technology parameter is based on the estimation of Solow (1957) residuals. Using time series of employment, real output and capital formation for the respective countries, we derive a time series for the Solow residual of each country.[17] As assumed in the model, z_t evolves according to a VAR(1) process. We thus use the series of the Solow residuals to estimate

[15] Assuming that factors are paid according to their marginal product, it follows from the production function that the households' income share from capital equals θ.
[16] Averages cover the period from 1970 to 2000. See the appendix for details.
[17] See the appendix for sources and details of the aggregation procedure.

the parameters of this VAR process (coefficient matrix A and variance-covariance matrix V) by ordinary least squares.

6. Synopsis of the computational procedures

As most RBC models, the model discussed in this paper can not be solved analytically due to the functional forms of preferences and production.[18] It will therefore be evaluated numerically using a dynamic programming technique explained by Hansen and Prescott (1995) and Díaz-Giménez (1999). This technique requires the optimization problem underlying the consumers and producers behavior to be written in terms of a social planning problem.[19] This allows us to exploit the recursive structure of the dynamic optimization problem, as the social planner's problem is structurally the same in each period: given a fixed capital stock k_t and technology parameter z_t, he decides about labor, consumption, investment and imports such that the expected value of the agents' discounted life time utility is maximized. This will be the case if the social planner maximizes a weighted sum of the representative agents' utility, where the weights are given by the country size α_i.

The social planner's optimization problem is thus given by

$$\max \sum_{i=1}^{3} \alpha_i \sum_{t=0}^{\infty} \frac{\beta^t}{\gamma} \left({c_{i,t}}^{\mu} (1 - n_{i,t})^{1-\mu} \right)^{\gamma} \tag{14}$$

$$\text{s.t.} \quad c_{i,t} = G\left(y_{i,i,t}, y_{j,i,t}, y_{k,i,t}\right) - x_{i,t} \tag{15a}$$

$$\alpha_i y_{i,i,t} = \alpha_i y_{i,t} - \alpha_j y_{i,j,t} - \alpha_k y_{i,k,t} \tag{15b}$$

$$y_{i,t} = z_{i,t} {k_{i,t}}^{\theta} {n_{i,t}}^{1-\theta} \tag{15c}$$

$$z_{t+1} = \left(z_{i,t}, z_{j,t}, z_{k,t}\right)^T = Z + A z_t + \varepsilon_t \tag{15d}$$

$$k_{i,t+1} = (1-\delta)\, k_{i,t} + x_{i,t} \tag{15e}$$

for all $i \neq j \neq k$ and $i, j, k \in \{1, 2, 3\}$. Substituting (15a)–(15c) in (14) leads to the global utility function, which serves as the social planner's objective function in the dynamic programming problem:

$$\max_{\{n_{i,t}, x_{i,t}, y_{i,j,t}\}} \sum_{i=1}^{3} \alpha_i \sum_{t=0}^{\infty} \frac{\beta^t}{\gamma} \left(\left[G\left(z_{i,t} {k_{i,t}}^{\theta} n_{i,t}^{1-\theta} - \frac{\alpha_j}{\alpha_i} y_{i,j,t} - \frac{\alpha_k}{\alpha_i} y_{i,k,t}, y_{j,i,t}, y_{k,i,t} \right) - x_{i,t} \right]^{\mu} \left(1 - n_{i,t}\right)^{1-\mu} \right)^{\gamma} \tag{16}$$

[18]Analytical solutions can be found for models with very strict assumptions, e. g. a depreciation rate of 100% and logarithmic utility as in Long and Plosser (1983).

[19]According to the Second Welfare Theorem, the decentral maximization problem of consumers and producers can equivalently be analyzed in terms of a social planning problem, if there are no externalities such as distorting taxes in the considered model.

$$\text{s.t.}\quad z_{t+1} = Z + Az_t + \varepsilon_t, \tag{17a}$$

$$k_{i,t+1} = (1-\delta)\, k_{i,t} + x_{i,t}. \tag{17b}$$

In order to simplify the computations, the global utility function (16) is approximated by a second order Taylor series around the steady state. Dynamic programming techniques are then used to derive decision rules from this quadratic function under the linear constraints given in (17a) and (17b). Using these decision rules we are able to simulate the model economy's reaction in response to a numerically defined or a stochastic shock affecting the technology parameter z_t.

7. Simulation of impulse response functions

In a next step the model will be used to simulate output series. In analogy to the empirical analysis carried out in section 2 of this paper these series are detrended using the HP filter.[20] Subsequently, a VAR is estimated on the detrended series and impulse response functions are determined. The simulated series are thereby chosen to have a length of 5000 periods, thus reducing the influence of singular observations.

The model is simulated under two different scenarios concerning the calibration of the country-specific parameters ("Model A" and "Model B", respectively). Country 1 in both scenarios shall be Germany, as the main objective of this work is to isolate transmissive effects from Germany to the rest of Europe. Country 2 in model A is calibrated to mimic the main features of the French economy, in model B country 2 corresponds to the Austrian economy. Country 3 ("Rest of the World", RoW) is parameterized according to an aggregate consisting of the remaining countries used in section 2.[21]

As has been noted in section 5, the country specific calibration of the model's parameters is limited to features concerning the respective country's integration and dependencies in an international context. Specifically, these parameters are the weights in the Armington aggregator (determined, as described above, by the respective import share $\frac{y_{j,i}}{y_i}$ of the country) and the matrices affecting the level and motion of the technology parameter. Table 1 and 2 report these parameters' values for the two model specifications based on data from 1970:1 to 2000:4.[22]

The parameters are broadly in line with other estimates in the literature. Some remarkable features arise, though: First, the coefficients describing the spillover effects (matrix A), are generally rather low compared with the estimates presented in the literature. This is especially surprising for

[20] Detrending the simulated series might seem redundant, as due to the model's construction the series by definition don't have a growth trend. In order to maintain comparability with our empirical results, filtering the series is indispensable anyway, because the filtering process removes longer-term fluctuations as trend, even though they are not to be regarded as trend in the model's context. Zimmermann (1997) applies the same procedure in order to allow direct comparison of data and simulated histories.

[21] RoW A = {AT,IT,JP,UK,US}; RoW B = {FR,IT,JP,UK,US}.

[22] See the appendix for a detailed description of sources and methods.

Table 1.a: Import shares.

From: \ To:	Germany	France	RoW A
Germany	$\frac{y_{1,1}}{y_1} = 0.793$	$\frac{y_{1,2}}{y_2} = 0.065$	$\frac{y_{1,3}}{y_3} = 0.070$
France	$\frac{y_{2,1}}{y_1} = 0.048$	$\frac{y_{2,2}}{y_2} = 0.818$	$\frac{y_{2,3}}{y_3} = 0.035$
RoW A	$\frac{y_{3,1}}{y_1} = 0.159$	$\frac{y_{3,2}}{y_2} = 0.117$	$\frac{y_{3,3}}{y_3} = 0.895$
	$\sum_1$: 1.000	$\sum_2$: 1.000	$\sum_3$: 1.000

Table 1.b: The technology parameter.

$$A = \begin{bmatrix} \underset{(0.03467)}{0.881620} & \underset{(0.04505)}{-0.041001} & \underset{(0.06693)}{0.104630} \\ \underset{(0.01930)}{-0.039868} & \underset{(0.02507)}{0.943340} & \underset{(0.03725)}{0.082678} \\ \underset{(0.02195)}{-0.009231} & \underset{(0.02852)}{-0.057053} & \underset{(0.04237)}{0.917830} \end{bmatrix} \qquad V = \begin{bmatrix} 2.5431\text{E}{-05} & 5.8401\text{E}{-06} & 1.6281\text{E}{-06} \\ 5.8401\text{E}{-06} & 7.8998\text{E}{-06} & 1.8278\text{E}{-06} \\ 1.6281\text{E}{-06} & 1.8278\text{E}{-06} & 1.0199\text{E}{-05} \end{bmatrix}$$

Numbers in parentheses are standard errors.

Table 1: Calibration of the country specific parameters in model A.

Table 2.a: Import shares.

From: \ To:	Germany	Austria	RoW B
Germany	$\frac{y_{1,1}}{y_1} = 0.793$	$\frac{y_{1,2}}{y_2} = 0.187$	$\frac{y_{1,3}}{y_3} = 0.084$
Austria	$\frac{y_{2,1}}{y_1} = 0.047$	$\frac{y_{2,2}}{y_2} = 0.710$	$\frac{y_{2,3}}{y_3} = 0.026$
RoW B	$\frac{y_{3,1}}{y_1} = 0.160$	$\frac{y_{3,2}}{y_2} = 0.103$	$\frac{y_{3,3}}{y_3} = 0.890$
	$\sum_1$: 1.000	$\sum_2$: 1.000	$\sum_3$: 1.000

Table 2.b: The technology parameter.

$$A = \begin{bmatrix} \underset{(0.04008)}{0.856396} & \underset{(0.02561)}{-0.000865} & \underset{(0.06819)}{0.096106} \\ \underset{(0.05970)}{0.062181} & \underset{(0.03814)}{0.872364} & \underset{(0.10157)}{0.104022} \\ \underset{(0.02494)}{0.003042} & \underset{(0.01593)}{-0.028566} & \underset{(0.04243)}{0.891018} \end{bmatrix} \qquad V = \begin{bmatrix} 2.6572\text{E}{-05} & 5.6809\text{E}{-06} & 2.2685\text{E}{-06} \\ 5.6809\text{E}{-06} & 5.8956\text{E}{-05} & 1.8182\text{E}{-06} \\ 2.2685\text{E}{-06} & 1.8182\text{E}{-06} & 1.0288\text{E}{-05} \end{bmatrix}$$

Numbers in parentheses are standard errors.

Table 2: Calibration of the country specific parameters in model B.

the model B scenario, where one would expect Austria's technology level to be more dependant on German technology shocks. The second remark concerns the negative coefficients in the spillover matrix. Though not significant at the 10% level, this point calls for attention. Following Zimmermann (1997, 330f), it might be interpreted as the outcome of a competitive advantage emerging from a positive technology shock in one country, inducing a negative effect on output and productivity in the other country. Although this interpretation appears reasonable, we want to point out, that these estimates are rather unusual compared to similar studies dealing with other countries' business cycles. We leave to future research an assessment of the stability of these results in a European context.

Basically, the model allows for two different reasons why technological disturbances in one country lead to fluctuations in the time series of the other countries. Following Canova and Marrinan (1998), we distinguish between production interdependencies on the one hand and consumption interdependencies on the other hand, with production interdependencies being characterized by contemporary and lagged correlation of the technology parameter, i. e. a direct transmission of the technology shock.[23]

In contrast, consumption interdependencies are generated by international trade: a technology shock in one country leads to a sharp rise in productivity and, due to increasing marginal products, a rise in labor, investment and output. Additionally, the households, now calculating with a higher permanent income, increase their consumption. Since the increase in consumption and investment is higher than the increase in output, imports will rise, which leads in the short run (given initially unchanged productivity and output) to a decrease in investment in the foreign country. This is followed by a reduction of the capital stock and a decline of output abroad. In the long run, the rise of output in the country experiencing the shock leads to a decline of the relative price of this country's production and an increase of exports, thus in turn resulting in a rise of investment and production in the foreign country.

In order to assess the relevance of these two kinds of interdependencies, for each specification of the model three time series are simulated. In a first run, the model is simulated as described above, i. e. with all transmission mechanisms in effect. In a second run the importance of trade for the international transmission of cycles shall be evaluated. Therefore, the off-diagonal elements of the matrices A and V are set to zero, thus eliminating the direct international effects of technology shocks and leaving consumption interdependencies as the only remaining transmission channel. In a third run, a model reduced by trade linkages (but with restored matrices A and V) is simulated, i. e. no import goods are demanded. The direct international effects of the technology shock are then the sole reason for international transmission.

Impulse response functions based on these simulated time series are depicted in figure 3 and 4.

[23] Note, that in contrast to Canova and Marrinan (1998) the term "production interdependencies" shall here be extended such that it covers contemporary correlation and is not limited to lagged spillover effects as in Canova and Marrinan (1998).

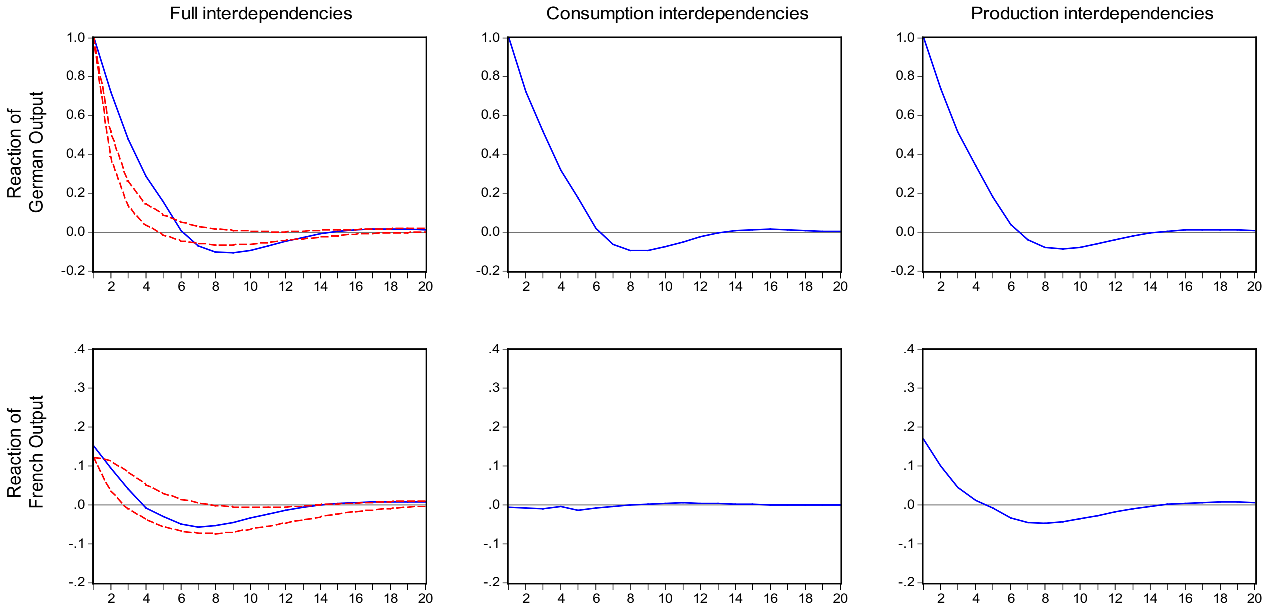

Figure 3: Simulated impulse response functions in model A: Output of the model's economies after a technology shock increasing German output by 1%. Depicted are the reactions with all transmission mechanisms in effect (additionally pictured are the 95% confidence bands of the empirical analysis), with pure consumption interdependencies and with pure production interdependencies.

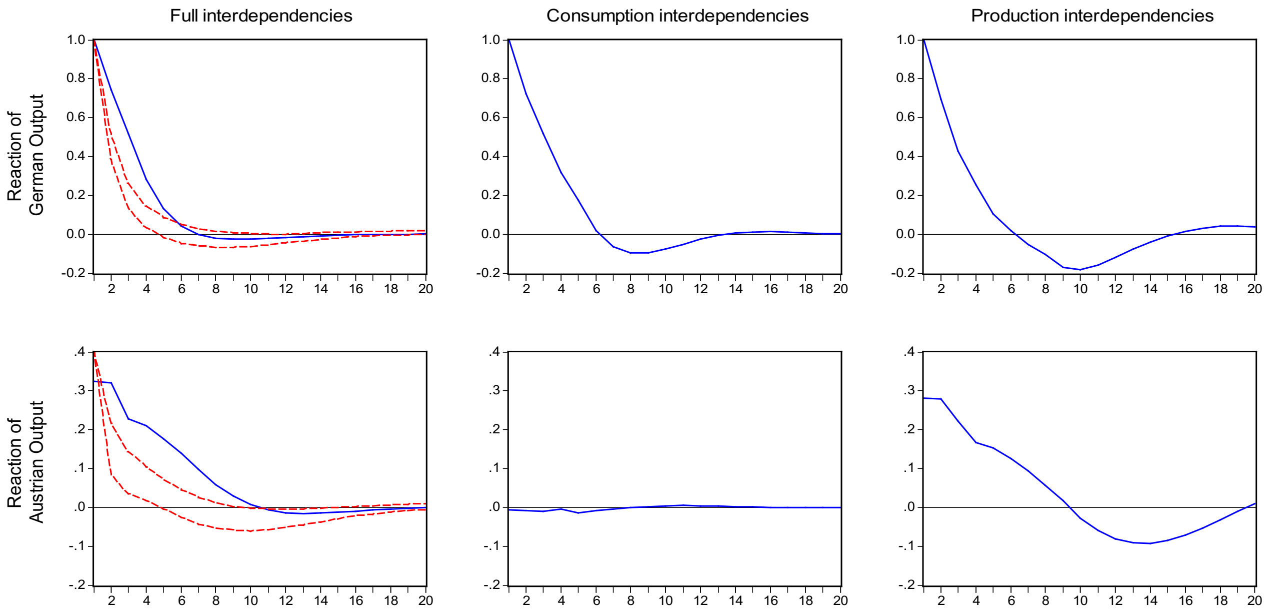

Figure 4: Simulated impulse response functions in model B: Output of the model's economies after a technology shock increasing German output by 1%. Depicted are the reactions with all transmission mechanisms in effect (additionally pictured are the 95% confidence bands of the empirical analysis), with pure consumption interdependencies and with pure production interdependencies.

As is apparent when comparing the graphs with the additionally pictured 95% confidence interval of the empirical analysis, the base model (with all transmission mechanisms in effect) resembles rather well the broad features of the European business cycle transmission as documented in section 2, figure 1. In Germany, the shock's influence fades out rather quickly and the economy reaches its long-run growth path after approximately 7 quarters, which is slightly more than the empirically estimated persistence of a 1% shock on the German GDP. For France, the model's result shows a persistence somewhat too small, with the model economy returning to its steady state within 4 quarters, while in the non-structural VAR model of section 2 it takes the French GDP about 5 quarters to reach its trend. In contrast, the model's prediction for the Austrian output is plainly too persistent in comparison to the empirical regularities documented above.

In contrast to the model's predictions concerning the persistency of a shock, the model's simulation of the contemporary reaction of the European countries' fits the empirical data impressively well. As a whole, the model is rather successful in mirroring the differences between the respective country's reaction on a shock: Austria experiences a fairly strong and long lasting reaction on a German technology shock, while the reaction in France is quite weak and dies out quickly.

The modifications of the model as described in the paragraph further above turn out to be interesting with regards to the question of the German economy's role for the European business cycle (see fig. 3 and 4). As becomes unambiguously clear, international trade plays only a minor role for the transmission of business cycles within the framework of the model. In scenario A as well as in scenario B production interdependencies are crucial for transmitting impulses across borders. Despite of strong trade linkages especially between Germany and Austria the trade channel does not appear to promote business cycles on a large scale.

The importance of production interdependencies suggests a deeper analysis. For this purpose we distinguish additionally between contemporary correlation according to matrix V and lagged spillovers according to matrix A (see fig. 5 and 6).[24] Thus, the model is simulated first with A's off-diagonal elements and second with V's off-diagonal elements set to zero.

For both model specifications apparently neither lagged nor contemporary production interdependencies are the decisive mechanism to shape the impulse response function. On the contrary, in both cases contemporary as well as lagged correlation of the technology parameter is necessary to model the economies' behavior in order to match the empirical results.

8. Implications and discussion of results

The findings presented above allow us to give some concluding assessment of the influence of different synchronization mechanisms: In view of our theoretical analysis the importance of trade (consumption interdependencies) for the relations between European business cycles is to be as-

[24] Note that the graphs are plotted by directly simulating the model's reaction on the technology shock, not, as before, by estimating a VAR on HP-detrended simulated time series.

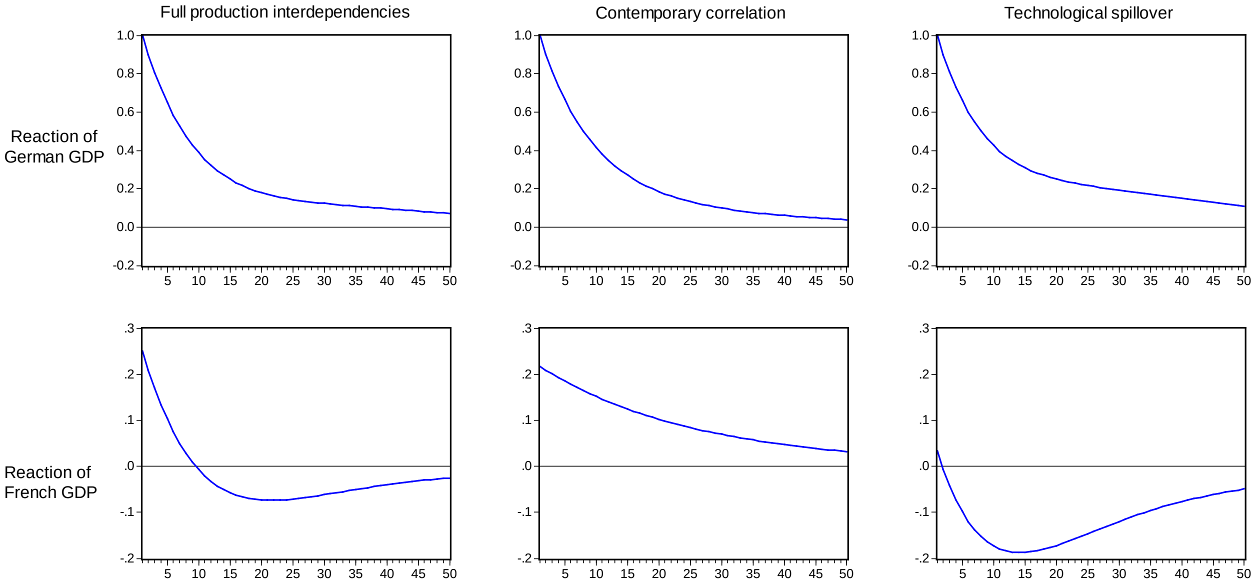

Figure 5: Detailed analysis of production interdependencies in model A: Output responses following a 1% shock on German GDP with full production interdependencies, with isolated contemporary correlation and lagged technological spillovers.

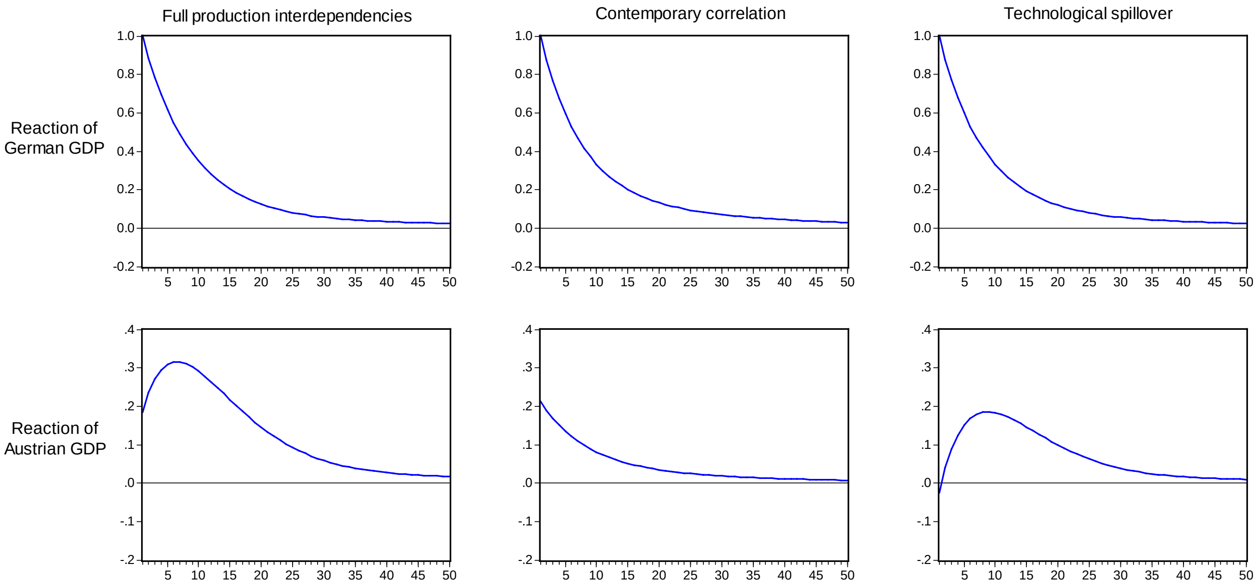

Figure 6: Detailed analysis of production interdependencies in model B: Output responses following a 1% shock on German GDP with full production interdependencies, with isolated contemporary correlation and lagged technological spillovers.

sessed rather low. The role of technological interdependencies demands a more sophisticated examination. As we have shown in the preceding section, contemporary as well as lagged correlation of the technology parameter is required in order to simulate realistic impulse response functions.

We follow Canova and Marrinan (1998, 144) in interpreting contemporary correlation as a sign of common exogenous shocks influencing the national economies. Our results therefore imply, that exogenous shocks are highly relevant for the existence of synchronization tendencies among the European economies.

The interpretation of lagged correlation is not as forthright though. High off-diagonal elements of matrix A might well be interpreted as an indication for the transmission of technology, e. g. through the export of technically advanced intermediate goods, international knowledge transfers or imitation of foreign goods. In this sense, the model provides some indication for an influence of Germany's economic developments on the other European nations'. This is not to say that this influence necessarily points just in one direction. On the contrary, a comparison of the coefficients of matrix A does not confirm an unidirectional effect in the case of France, where the influence appears to be relatively balanced. The existence of a "German locomotive", that increases the foreign productivity by technological spillovers, might be affirmed in the case of Austria, though. Still, we can not deny the problem already discussed in section 2, that the impression of lagged correlation might simply be induced by different economic policies to deal with a common (exogenous) shock or by different structural conditions. This problem is as relevant for the estimation of the technology shock's parameters as it was relevant for the estimation of the VARs on GDPs in section 2.

Concluding, we can state that from a theoretical point of view the European business cycle is mainly based on common exogenous shocks and mutual supply side dependencies. Given, that the model and the chosen parameter values are a correct description of reality, the importance of trade related transmission effects is rather low.

This result corresponds to the findings presented by Canova and Marrinan (1998) for the international component of business cycles in Germany, Japan and the US. We can not provide an indication for a diverging result due to the special economic situation in Europe. Neither can we confirm the thesis of Germany having due to its size a dominant and thus synchronizing influence on the European business cycles, nor does the deep integration of European national economies via trade appear to have a harmonizing effect.

However, the central role of production interdependencies in the model might at least in part be provoked by a common (and controversially discussed) characteristic of real business cycle models: the indefiniteness of the Solow residual. The interpretation of this "measure of our ignorance" (Abramovitz, 1956, 11) as an indicator for a country's technology level appears inappropriate. As notes Mankiw (1989), the observed high correlation between the Solow residual and GDP is not necessarily to be interpreted as an indicator for the important role of technological disturbances for business cycles, but might well have its reasons in an insufficient separation of technology shocks from other influences when estimating the Solow residual. King and Rebelo (1999) argue similarly, when they point out, that the unreasonable – but for the quantitative fit of standard RBC models necessary – large volatility of the Solow residual and its central role in business cycle theory is not reflected by a corresponding public perception of these shocks: “If these shocks are large and important why can’t we read about them in the *Wall Street Journal*?” (King and Rebelo, 1999, 962). In this sense, the Solow residual, being additionally biased by measurement problems e. g. due to changes in capacity utilization, appears quite unsuitable to be a realistic indicator for technology shocks. According to King and Rebelo (1999), models relying on the Solow residual as driving process are therefore just with caution to be regarded as useful for actual business cycle analysis.

In the model presented here the dominance of the Solow residual leads almost inevitably to an overestimation of technological disturbances as a source of economic fluctuations. Trade-related transmission effects are thus pushed in the background. Our assessment of Germany’s economic fluctuations being rather irrelevant for the synchronicity of the European economies’ business cycles is therefore to be taken with caution.

9. Conclusion and final remarks

This paper investigates the sources of the so called European business cycle, a term referring to the regularly observed synchronization of the national business cycles in Europe. We concentrate on the role of Germany and examine, whether or not German economic fluctuations have an important influence on the synchronization of national cycles by causing transmissive effects leading to an adjustment of the other nations’ cycles.

Using a calibrated multi-country general equilibrium model featuring three heterogenous countries connected by trade linkages, we are able to reproduce the important characteristics of empirically estimated impulse response functions. The model offers basically two mechanisms, why economic fluctuations in one country might lead to a similar development in another country: consumption interdependencies and production interdependencies. While consumption interdependencies, namely dependencies due to trade on international goods markets, are strikingly irrelevant for the synchronization of our model economies’ output fluctuations, we show that the central mechanism to mimic the empirically derived impulse-response functions relies on lagged and contemporary correlation of technology disturbances.

By identifying contemporary correlation as the outcome of the influence of common shocks and interpreting lagged correlation as technological spillovers, we finally conclude that the European business cycle is mainly based on exogenous factors. Inner-European synchronization mechanisms are limited to technological interdependencies. The hypothesis, that Germany might influence the other European countries due to its large economic weight, has thus to be rejected. In contrast, we find that the European business cycle owes its existence to a large scale to outside influences. It shall be noted, that the relevant exogenous influences are not limited to obvious impulses as the oil price shocks in the 1970ies, but that e. g. the US’ business cycle can be regarded as a major source of exogenous disturbance (Canova and Marrinan, 1998; SVR, 2001). From this point of view, an increase in synchronization has to be attributed mainly to an approximation of policies in response to shocks and a harmonization of structural conditions in Europe.

The model is subject to the regular criticism of real business cycle theory, though. Due to the restriction to technology shocks as source of economic fluctuations, we allow for a limitation shedding some doubt on our results. An integration of fiscal shocks in the model might improve its reality considerably. Additionally, the high degree of abstraction rules out the possibility to simulate governmental actions. Appropriate modifications of the model promise interesting implications in view of the further integration of the European economies.

Appendix

Sources of the data

The data for the GDP series presented in section 2 were taken from the IMF's International Financial Statistics database. We used quarterly index data at constant prices from 1970:1 to 2001:4. If necessary, the data was seasonally adjusted using the US Census Bureau's X12 method. For the determination of oil price growth rates we also used the time series provided by the IMF.

The import shares ($\frac{y_{j,i}+y_{k,i}}{y_i}$) were derived on the basis of annual IMF data from 1970 up to 2000. We used data of real GDP and of Imports of goods and services, both in national currencies. To determine the import and GDP figures for RoW, values were converted in US dollar and summarized. We then removed internal trade according to the IMF's Directions of Trade Statistics. From this data, we calculated the import share and their mean value for the period $[1970, 2000]$. The domestic production share $\frac{y_{i,i}}{y_i}$ is then calculated by subtracting this value from 1.

To determine the relative import shares $\frac{y_{j,i}}{y_i}$, the import shares are split up according to IMF data. The Directions of Trade Statistics provide the necessary figures to calculate each country's sum of imports to be considered in our model economy in terms of US dollar. Relating the import value from one country j to the total sum of imports and multiplying the resulting quota with the import share derived above leads to the relative import share $\frac{y_{j,i}}{y_i}$. In the case of the aggregated country RoW we removed internal trade prior to the calculations.

The time series of the Solow residual were derived by using IMF quarterly data of real GDP from 1970:1 to 2000:4. We then multiplied each national series with a constant factor in order to match the real GDP in international prices compiled by Heston et al. (2002) in their Penn World Tables. We proceeded accordingly to derive the figures for the capital stock. To determine the employment time series, OECD data was used. If available, we used the civilian employment series provided in the Main Economic Indicators, otherwise we calculated approximate figures according to labor force and unemployment statistics. Data for the aggregated countries were added up. Each series has then been normalized to give it a sample mean of 1. According to $z_{i,t} = \frac{y_{i,t}}{{k_{i,t}}^{\theta} {n_{i,t}}^{1-\theta}}$ we calculated time series of the technology parameter. These series have been seasonally adjusted and linearly detrended (the model assumes a stationary technology parameter) and were then used to estimate the matrices A and V in a VAR(1) process.

References

Abramovitz, Moses (1956): Resource and Output Trends in the United States since 1870, *American Economic Review*, Vol. 46, No. 2, pp. 5–23.

Anderson, Heather, Noh-Sun Kwark and Farshid Vahid (1999): Does International Trade Synchronize Business Cycles?, Monash Econometrics and Business Statistics Working Paper Series No. 8/99, `http://www.buseco.monash.edu.au/Depts/EBS/Pubs/WPapers/1999/wp8-99.pd`.

Armington, Paul S. (1969): A Theory of Demand for Products Distinguished by Place of Production, *International Monetary Fund Staff Papers*, Vol. 16, pp. 159–178.

Artis, Michael J., Hans-Martin Krolzig and Juan Toro (1998): The European Business Cycle, CEPR Discussion Paper No. 2242, `http://www.economics.ox.ac.uk/research/hendry/paper/AKTcepr.pdf`.

Artis, Michael J. and Wenda Zhang (1997): International Business Cycles and the ERM: Is There a European Business Cycle?, *International Journal of Finance and Economics*, Vol. 2, pp. 1–16.

Artis, Michael J. and Wenda Zhang (1999): Further Evidence on the International Business Cycle and the ERM: Is There a European Business Cycle?, *Oxford Economic Papers*, Vol. 51, pp. 120–132.

Backus, David K. and Patrick J. Kehoe (1992): International Evidence on the Historical Properties of Business Cycles, *American Economic Review*, Vol. 82, No. 4, pp. 864–888.

Backus, David K., Patrick J. Kehoe and Finn E. Kydland (1992): International Real Business Cycles, *Journal of Political Economy*, Vol. 100, No. 4, pp. 745–775.

Baxter, Marianne and Mario J. Crucini (1993): Explaining Saving–Investment Correlations, *American Economic Review*, Vol. 83, No. 3, pp. 416–435.

Baxter, Marianne and Mario J. Crucini (1995): Business Cycles and the Asset Structure of Foreign Trade, *International Economic Review*, Vol. 36, No. 4, pp. 821–854.

Baxter, Marianne and Robert G. King (1999): Measuring Business Cycles: Approximate Band-Pass Filters for Economic Time Series, *The Review of Economics and Statistics*, Vol. 81, No. 4, pp. 575–593.

Bayoumi, Tamim and Barry Eichengreen (1993): Shocking Aspects of European Monetary Integration, in: Francisco Torres and Francesco Giavazzi (Eds.), *Adjustment and Growth in the European Monetary Union*, Chapter 7, Cambridge: Cambridge University Press, pp. 193–229.

Canova, Fabio and Jane Marrinan (1998): Sources and Propagation of International Output Cycles: Common Shocks or Transmission?, *Journal of International Economics*, Vol. 46, pp. 133–166.

Cantor, Richard and Nelson C. Mark (1988): The International Transmission of Real Business Cycles, *International Economic Review*, Vol. 29, No. 3, pp. 493–507.

Dellas, Harris (1986): A Real Model of the World Business Cycle, *Journal of International Money and Finance*, Vol. 5, pp. 381–394.

Díaz-Giménez, Javier (1999): Linear Quadratic Approximation: An Introduction, in: Ramon Marimon and Andrew Scott (Eds.), *Computational Methods for the Study of Economic Dynamics*, Oxford, New York: Oxford University Press, pp. 13–29.

Dueker, Michael and Katrin Wesche (2001): European Business Cycles: New Indices and Analysis of their Synchronicity, Federal Reserve Bank of St. Louis Working Paper Nr. 99-019B, `http://research.stlouisfed.org/wp/1999/1999-019.pdf`.

Gregory, Allan W., Allen C. Head and Jacques Raynauld (1997): Measuring World Business Cycles, *International Economic Review*, Vol. 38, No. 3, pp. 677–701.

Hansen, Gary D. and Edward C. Prescott (1995): Recursive Methods for Computing Equilibria of Business Cycle Models, in: Thomas F. Cooley (Ed.), *Frontiers of Business Cycle Research*, Princeton: Princeton University Press, pp. 39–64.

Heston, Alan, Robert Summers and Bettina Aten (2002): Penn World Table Version 6.1, Center for International Comparisons at the University of Pennsylvania (CICUP), October 2002.

Inklaar, Robert and Jakob de Haan (2000): Is There Really a European Business Cycle?, CESifo Working Paper Series No. 268.

King, Robert G. and Sergio T. Rebelo (1999): Resuscitating Real Business Cycles, in: John B. Taylor and Michael Woodford (Eds.), *Handbook of Macroeconomics*, Vol. 1B, Amsterdam, Lausanne, New York: Elsevier Science, pp. 927–1007.

Kydland, Finn E. and Edward C. Prescott (1982): Time to Build and Aggregate Fluctuations, *Econometrica*, Vol. 50, No. 6, pp. 1345–1370.

Kydland, Finn E. and Edward C. Prescott (1996): The Computational Experiment: An Econometric Tool, *Journal of Economic Perspectives*, Vol. 10, No. 1, pp. 69–85.

Laxton, Douglas and Eswar S. Prasad (2000): International Spillovers of Macroeconomic Shocks: A Quantitative Exploration, IMF Working Paper No. 00/101.

Long, John B., Jr. and Charles I. Plosser (1983): Real Business Cycles, *Journal of Political Economy*, Vol. 91, No. 1, pp. 39–69.

Lucas, Robert E., Jr. (1977): Understanding Business Cycles, in: Karl Brunner and Allan H. Meltzer (Eds.), *Stabilization of the Domestic and International Economy*, Carnegie Rochester Conference Series on Public Policy, Vol. 5, Amsterdam, New York, Oxford: North-Holland Publishing Company, pp. 7–29.

Lumsdaine, Robin L. and Eswar S. Prasad (2003): Identifying the Common Component in International Economic Fluctuations: A New Approach, *Economic Journal*, Vol. 113, No. 484, pp. 101–127.

Mankiw, N. Gregory (1989): Real Business Cycles: A New Keynesian Perspective, *Journal of Economic Perspectives*, Vol. 3, No. 3, pp. 79–90.

Mills, Terence C. and Mark J. Holmes (1999): Common Trends and Cycles in European Industrial Production: Exchange Rate Regimes and Economic Fluctuations, *The Manchester School*, Vol. 67, No. 4, pp. 557–587.

Mitchell, Wesley C. (1927): *Business Cycles: The Problem and Its Setting*, Studies in Business Cycles No. 1, New York: National Bureau of Economic Research.

Nelson, Charles R. and Heejoon Kang (1981): Spurious Periodicity in Inappropriately Detrended Time Series, *Econometrica*, Vol. 49, No. 3, pp. 741–751.

Seifert, Michael (1999): Zum Konjunkturverbund zwischen integrierten Volkswirtschaften, *Forschungsreihe des Institut für Wirtschaftsforschung Halle*, Nr. 4/1999, pp. 3–36.

Solow, Robert M. (1957): Technical Change and the Aggregate Production Function, *Review of Economics and Statistics*, Vol. 39, No. 3, pp. 312–320.

SVR, Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung (2001): *Jahresgutachten 2001/02: Für Stetigkeit – Gegen Aktionismus*, Stuttgart: Metzler-Poeschel.

Tavlas, George S. (1993): The ‘New’ Theory of Optimum Currency Areas, *World Economy*, Vol. 16, No. 6, pp. 663–685.

Zimmermann, Christian (1997): International Real Business Cycles among Heterogenous Countries, *European Economic Review*, Vol. 41, No. 1, pp. 319–355.