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Domestic, Foreign or Common Shocks?

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Abstract

A stochastic general equilibrium model of the world economy is used to analyze the origin of international business cycles using data for Germany, Japan and the United States. The findings indicate that after 1973, common shocks play a major role in accounting for similarities in output fluctuations. However, trade interdependencies with the United States may have also played a very important role; more than 20 percent of output fluctuations of the German and Japanese economies could have been imported from the United States.

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Summary

The term "international business cycle" refers to the existence of common patterns in aggregate cyclical behavior across countries, which can be accounted for by two distinct factors. First, if it is accepted that a country-specific shock may be transmitted rapidly to other countries, the co-movements would arise from a significant economic interdependence. A second source of commonalities in aggregated economic variables could arise from the existence of common shocks that affect all countries similarly.

Although one would expect both sources of fluctuations to be important for the international business cycle, several studies have found that the main source of covariance between outputs can be accounted for by common shocks rather than by the transmission of domestic shocks--an empirical finding at odds with the view that trade has important macroeconomic effects.

This paper uses a general equilibrium model of the world economy to analyze the origin of international business cycles. The model differentiates between common and domestic shocks and allows the latter to be transmitted to the rest of the world over time. The implied restrictions of the theoretical model are then used to impose the relevant econometric restrictions on the empirical analysis.

The results suggest that although common shocks have played an important role in explaining the output fluctuations of Germany, Japan, and the United States (about 30 and 20 percent for Germany and the United States, respectively, and about 40 percent for Japan), trade interdependencies with the United States have also played a role in explaining the fluctuations of the German and Japanese outputs (more than 20 percent). In particular, for Germany the effects of common and transmitted shocks are very similar.

Overall, domestic shocks account for less than half of the fluctuations in German output and for less than one-third of the fluctuations in Japanese output. The locomotive role of the U.S. economy is indicated by the fact that U.S. domestic shocks account for about 75 percent of the fluctuations of U.S. output, and for more than 20 percent of the fluctuations of foreign output.

I. Introduction

The term international business cycle refers to the existence of common patterns in aggregate cyclical behavior across countries. Similarities in economic fluctuations in any set of countries can be accounted for by two distinct factors. Firstly, if it is accepted that a country-specific shock may be transmitted rapidly to other countries, the co-movements would arise from a significant economic interdependence. These sources of economic fluctuations, usually referred to as the locomotive theory, have received significant attention in economic theory in issues such as optimal exchange rate regimes or stabilization theory (see among others Huffman and Lothian (1984), Cantor and Marc (1988) and Cole and Obstfeld (1989)). In this case, the transmission mechanism could be explained through current account transactions of goods and services and through capital account transactions in assets.

A second source of commonalities in aggregated economic variables could arise from the existence of common shocks, such as an oil shock that affects all oil-dependent countries in a similar fashion, agreements leading to similar economic policies, common technological progress, etc. (see Stockman (1988)). Dellas (1986) studies several countries finding that the main source of covariance between output in the United States, United Kingdom, Germany and Japan could be accounted for by these kind of common shocks rather than by transmission. However, this empirical finding, as noted by Canova and Dellas (1993), is at odds with the view that trade has important macroeconomic effects and with the popular press argument that the United States is the locomotive of the world economy, that is, shocks to the U.S. economy should be transmitted to the rest of the world.

The issue of what generates business cycles has important economic implications. If output fluctuations are undesirable and demand disturbances are largely responsible for these fluctuations, there may be a role for government policies that try to mitigate the fluctuations. If instead, as the real business cycle literature emphasizes, output fluctuations can be explained by real factors, then the government should try to reduce uncertainties about its policies rather than trying to mitigate the fluctuations. Endorsing one view or another of the economy will also have some important implications in an international framework as, for example, in the study of flexible and fixed exchange rate regimes.

Whether fluctuations are primarily attributable to supply or demand factors is still an ongoing debate that often produces mixed and contradictory conclusions. Although real business cycle theories identify a plausible source of economic fluctuations, they have been subject to criticism given that the theoretical models are based on, possibly, an unrealistic frequency of productivity shocks. However, the introduction of a multi-country world economy can reduce the required frequency of the shocks. In fact, as we will see below, in a two country economy with trade, a single country specific productivity shock is sufficient to generate cycles in both countries. Or put in other words, in an open economy with trade a country without technological progress can be subject to real business cycles.

Another important issue is how business cycles are propagated. It is important to know whether the origin of the disturbance is domestic, foreign or common in order to, for example, design countercyclical policies in response to negative productivity shocks. In particular, if the origin is foreign, it is important to analyze and understand the channels through which shocks are transmitted. However, little statistical effort has been expended to evaluate the importance of the contribution of each type of shock to output fluctuations.

In this paper we address the question of what generates and what transmits cycles across countries paying special attention to the origin of the fluctuations. We use a theoretical real business cycle model which extends those appearing in Stockman and Svensson (1987) and in Canova and Dellas (1993). The difference with that of Canova and Dellas is that productivity shocks are assumed to be of two types. One will be common to all the countries and will affect the productivity of the whole world economy. A second type will be a domestic shock (one for each country) that, over time, may be transmitted to the rest of the world. Canova and Dellas (1993) just consider one type of shock (domestic) and they allow shocks to be correlated. Both from a theoretical and an empirical point of view, the idea of introducing a new shock (common) and distinguishing between domestic and common shocks is appealing. From a theoretical point of view, it is simpler to differentiate common shocks (such as an oil crisis) from country specific shocks (such as bad crops due to natural events), which are independent of each other, than to consider only domestic shocks which are correlated. From an empirical point of view, the introduction of different shocks facilitates the decomposition of output fluctuations into fluctuations due to domestic, foreign and common shocks. Using the restrictions implied by the theoretical model, it is then possible to identify the effects of each type of shock. Otherwise, in order to evaluate the weight of imported shocks, the system should be orthogonalized with a Cholesky decomposition as a previous step to the computation of impulse responses or forecast errors. This decomposition, although well known in the econometric literature, suffers from an important problem, namely that the order of the countries in the estimated system matters. In other words, the empirical results would be subject to an additional assumption whose validity cannot be tested. Moreover, the interpretation of the empirical results can be especially complex, and for the first country in the system, it is impossible to differentiate between common and domestic shocks.

To anticipate the empirical results, we study output in the United States, Germany and Japan over the period 1974-1990, and we find that domestic plus common shocks account for approximately 75 percent of output variability in both Germany and Japan while for the United States, it accounts for around 95 percent of output fluctuations. The proportion of output fluctuations due to common shocks ranges from 20 percent in the United States to around 40 percent in Japan. When we add to Germany and Japan the fluctuations transmitted from the U.S. economy, the explained variance raises to 97 percent, reproducing the locomotive role of the United States in the world economy. Specific shocks to the German economy account for only 3 percent of the variance of the Japanese economy and do not significantly affect the U.S. economy. Shocks to the Japanese economy represent only 2 percent of the German fluctuations and around 5 percent of the U.S. fluctuations. Therefore, although common shocks account for a large proportion of output covariance, there are indications that trade links with the United States are an additional important source of this covariance.

The remaining of the paper is structured as follows. In Section II the set up of the model is presented and in Section III the properties of the model are analyzed. In Section IV the econometric methodology is presented. The empirical results are contained in Section V, and the concluding remarks close the paper in Section VI.

II. The model

This section presents a variation of the real business cycle model of trade in Canova and Dellas (1993). The modification is simple and allows for the identification of common and country-specific shocks. The set up of the model is as follows. The world economy is given by two countries which are identical except for the assumption that each one specializes in the production of a single good Y_i (i=1,2). In order to produce this single good, each country uses as inputs domestic and foreign production. We will denote by X_{ji} the required input of good j for the production of good i. Each country is inhabited by an infinitely lived representative agent which consumes both foreign and domestic goods. We will denote by C_{ji} the consumption of good j by individual i (i,j=1,2). The production of a single good for a given period of time is expressed as follows:

$$Y_j = C_{j1} + C_{j2} + X_{j1} + X_{j2}.$$

Introducing now the t to indicate the timing, the production functions are given by

$$\begin{aligned} Y_1(t) &= f_1(X_{11}(t-1), X_{21}(t-1), \eta(t), \theta_1(t)) \\ Y_2(t) &= f_2(X_{12}(t-1), X_{22}(t-1), \eta(t), \theta_2(t)), \end{aligned}$$

where $\eta(t)$ is a common productivity shock that affects the production of domestic and foreign goods and $\theta(t)$ is a country specific productivity shock that affects the production of good i. The function f_i represents the production function of country i, and it is assumed to satisfy standard regularity conditions. With this set up, an oil shock (widely considered as a common shock) would be captured by $\eta(t)$ whereas, for example, natural factors affecting one country in a given time period (considered as a country specific shock) would be captured by $\theta(t)$. We also assume that the productivity shocks are independent.

The timing of the production functions above will play an important role in what follows. Notice that the production processes require one period to be completed and are determined by the investment decisions taken at time t-1 and by two unknown productivity shocks at time t. It is assumed that inputs are completely perishable. As noted by Canova and Dellas (1993), assuming that inputs are completely perishable affects the persistence of the cycles at business frequencies, but it does not affect the transmission mechanism.

The problem for the firms is maximizing their values for the owners and that in turn is equivalent to maximizing the present value of the cash flows they generate. Each firm will be defined as a set of assets z_{ij} where i indexes the firms (i=1,2), and j the different assets j=1,2,3. The first two assets are contracts obligating the firm to deliver part of the current output to be used as input in the following period, while the third asset is just the dividend paid to the owner. Assuming a perfectly pooled equilibrium, agents who are risk adverse will choose to have half of the assets of each firm, pooling production risks in such a way that relative prices are not affecting the distribution of wealth. This assumption may be far from realistic given that the domestic individual will be indifferent between an increase in profitability at home and abroad. However, in order to have a tractable model, we would have to alternatively assume the absence of capital flows and balanced trade, something that the economic developments of the recent past have shown to be even further from a realistic assumption. On the other hand, a complete asset market equilibrium allows to focus on the effects of real trade links in the transmission of economic fluctuations rather than uniquely on the effects of common shocks.

Each individual maximizes expected lifetime utility

$$\max E_0 \sum_{t=0}^{\infty} \beta^t U_i(C_{1i}(t), C_{2i}(t))$$

subject to the budget restriction imposed by the asset property.

If we now specialize the following familiar functional forms for both utility and production functions

$$U(C_1(t), C_2(t)) = \psi_1 \log C_1(t) + \psi_2 \log C_2(t)$$
$$\log Y_i(t) = \sum_{j=1}^{2} \alpha_{ji} \log X_{ji}(t-1) + \log\eta(t) + \log\theta_i(t),$$

where

$$0 \le \psi_i \le 1; \sum_{j=1}^{2} \alpha_{ij} < 1,$$

and we assume that the log of productivity shocks follow a white noise process, the problem can be solved analytically as

$$\begin{aligned} C_j(t) &= (\psi_j/\gamma_j)\,Y_j(t) \\ X_{ji}(t) &= (\beta\gamma_i\alpha_{ji}/\gamma_j)\,Y_j(t) \\ \gamma_i &= \psi_i+\beta\textstyle\sum_{i=1}^{2}\gamma_j\alpha_{ji} \end{aligned}$$

(i,j=1,2) (see Canova and Dellas (1993)). Clearly, the assumption of a white noise productivity shock is not realistic. However, on the one hand it is useful to find an analytical solution to the model, and on the other, it has no effects on the transmission properties of the model (although it will affect the long run responses of outputs to a shock, given that outputs present no trend in this model).

The solution above indicates that an increase in domestic output will produce an increase in consumption (domestic and foreign) of the domestic good. It is also important to notice that an increase in domestic output will increase the amount of domestic good used in the domestic and foreign productive sectors. That is, other things equal an increase at time t of domestic output will produce an increase of domestic and foreign consumption at time t and an increase of domestic and foreign outputs at time t+1. As noted above, a single shock can produce cycles in both countries.

Finally, substituting the expression for the inputs in the production function, we obtain

$$y(t)=\mu+Ay(t-1)+1_2w(t)+v(t),$$

where $y(t)=\log([Y_1(t)\ \ Y_2(t)]')$, $w(t)=\log(\eta(t))$, $v(t)=\log([\theta_1(t)\ \ \theta_2(t)]')$, 1_2 is a (2x1) vector of 1's,

$$A=\begin{bmatrix}\alpha_{11} & \alpha_{21}\\ \alpha_{12} & \alpha_{22}\end{bmatrix},$$

and μ is a constant term involving parameters of the model. Given our assumption of independent productivity shocks $\eta(t)$ and $\theta(t)$, w(t) and v(t) will also be independent.

III. Properties of the Model

In this model there are two reasons why outputs can show positive covariance. One is because of the existence of common shocks, as reflected by the term w(t). The second is because country specific shocks may be transmitted through trade interdependencies, as reflected by the non-diagonal elements in the matrix A which account for bilateral relations between countries. Observe that these elements, measuring bilateral trade dependencies, are those controlling the transmission features of the model. Notice also that, if any non-diagonal element of the matrix A is equal to zero, domestic output will not be affected by foreign shocks.

Let us first consider the effects of a foreign shock abroad. An increase in foreign output will increase domestic imports increasing domestic consumption of the foreign good and, if part of the imports are used in the productivity activity ($\alpha_{21}>0$), will in turn increase domestic output. Because domestic output rises, aggregate consumption of the domestic good will also increase. The more intensively foreign output is used in domestic production (the larger α_{21}) the larger the increase in domestic output. Intuitively, the foreign productivity shock will reduce the relative price of the foreign input with respect to the domestic input, and the domestic firm will profit more than when domestic inputs are more intensively used. If alternatively $\alpha_{21}=0$, and foreign goods are not used in domestic production, then an increase in foreign output will increase domestic imports but they will be matched by an increase in domestic consumption of the foreign good. Aggregate consumption of the domestic good will remain the same. We recall here that the distribution of wealth is not affected.

An important result from above is that, even when only country specific shocks abroad are considered, the overall world output (domestic plus foreign) will increase more in the case of important bilateral trade flows. Or put it in other words, a country without significant technological shocks can display business cycles due to foreign real factors. The effects of a common shock do not differ by much from those of a country specific shock if trade takes place. However, contrary to the previous case, even in absence of trade, both domestic and foreign outputs increase. Consequently, both domestic and foreign aggregate consumption will increase. The lagged effects will, however, depend on the trade ties and the transmission mechanism works as in the country specific shock. Notice also that now there are feedback effects since there are two different effects for the domestic output; one produced by the common shock and one exported from the domestic country via trade. Overall, and as expected, the effects will tend to be larger than in the country specific shock.

It is also interesting computing the unconditional variances of the fluctuations due to different shocks. Observe that, given that common and country specific shocks are independent, the output variance can be decomposed into the variance due to w(t) and the variance due to v(t). Denoting by W(t) and V(t) the (2x1) vectors of unobserved components which capture the evolution of output due to w(t) and v(t) respectively,

$$var(y(t))=var(W(t))+var(V(t)),$$

where

$$W(t)=AW(t-1)+1_2 w(t)$$

and

$$V(t)=AV(t-1)+v(t).$$

It is not difficult to show that

$$var(W(t)) = \sigma_w^2(I-A)^{-2}$$
$$var(V(t)) = (I-A)^{-1}B(I-A)^{-1'}$$

where $\sigma_w^2 = E(w(t)^2)$ and $B=E(v(t)\ v(t)')=diag(\sigma_{v1}^2\ \sigma_{v2}^2)$. Denoting $(det(I-A))^2$ by D, it follows that

$$var(W_1(t)) = D^{-1}\sigma_w^2((1-\alpha_{22})^2+2\alpha_{21}(1-\alpha_{22})+\alpha_{12}^2)$$
$$var(W_2(t)) = D^{-1}\sigma_w^2((1-\alpha_{11})^2+2\alpha_{12}(1-\alpha_{11})+\alpha_{21}^2)$$
$$cov(W_1(t),W_2(t)) = D^{-1}\sigma_w^2((1-\alpha_{22})\alpha_{12}+(1-\alpha_{11})(1-\alpha_{22})+\alpha_{21}\alpha_{12}+(1-\alpha_{11})\alpha_{21})$$

and

$$var(V_1(t)) = D^{-1}(\sigma_{v1}^2(1-\alpha_{22})^2+\sigma_{v2}^2\alpha_{12}^2)$$
$$var(V_2(t)) = D^{-1}(\sigma_{v2}^2(1-\alpha_{11})^2+\sigma_{v1}^2\alpha_{21}^2)$$
$$cov(V_1(t),V_2(t)) = D^{-1}(\sigma_{v1}^2(1-\alpha_{22})\alpha_{12}+\sigma_{v2}^2(1-\alpha_{11})\alpha_{21})$$

Notice that the derivatives of the expressions for the covariances of W(t) and V(t) with respect to α_{ij} (i,j=1,2) are always larger than zero for i different from j. That is, as the bilateral ties become more important (α_{12} and α_{21} become larger), the covariance between outputs increases. In particular, the more intensively foreign inputs are used in domestic production, the larger the covariance between outputs; the more intensively domestic inputs are used in domestic production, the smaller the covariance between outputs.

Summing up, under the assumptions above, the model predicts that outputs will present positive covariance either by the common shock effect or by the transmission effect. The question is what proportion of output fluctuations can be attributed to each type of shock. Or, put in other words, how much output variance is being imported from abroad. The next section addresses this issue where the above model is used in order to impose the relevant identifying restrictions in the econometric model.

IV. Econometric Analysis

This section reviews the econometric methodology used to answer the question posed above. In the previous section we have presented a model which allows to decompose the productivity shocks between country-specific and common. The main identifying restriction implied by the model is that when a country imports other country-specific shocks, this is done with one lag. From an econometric point of view, we will also relax the above vector autoregressive (VAR) specification of order 1 to allow for more general dynamics, since it is possible that the transmission of economic disturbances takes a longer time that the one lag implied by the model. Notice also that the above economic model implies no trends in output. In other words, it can be considered a model for the cyclical components or detrended output.

Let y(t) denote a (Nx1) vector of time series containing the observed cyclical components of log output for N countries, and assume the following Wold representation:

$$y(t)=C(L)e(t), \tag{1}$$

where L is the lag operator such that L^n e(t)=e(t-n), e(t) is a vector white noise process of one period ahead forecast errors with zero mean and covariance matrix Ω, and the matrix polynomial $C(L)=I-C_1L-C_2L^2...$ satisfies standard assumptions.

On the basis of the model in Section 2, we could express the cyclical components of log output as

$$y(t)=F(L)(1_N w(t)+v(t)), \tag{2}$$

where $F(L)=I-F_1L-F_2L^2...$ and w(t) and v(t) are defined as above. It is straightforward to show that if equations (1) and (2) hold, then F(L)=C(L) and $e(t)=1_N\, w(t) + v(t)$.

While the equality F(L)=C(L) does not present any particular problem, the equality between the one-period-ahead forecast error of the reduced form model and the sum of common and country specific shocks could be subject to an identification problem. If for example N=2, there is no identification problem, since Ω contains 3 independent moments and we should have to estimate 3 moments (the variance of w(t) and the 2 variances of the (2x1) vector v(t)). For the general case with N countries, Ω will contain N(N+1)/2 independent moments while the moments to estimate continue to be N+1. However, if both (1) and (2) hold, it implies that the covariance between any two different elements of e(t), say $e_i(t)$ and $e_j(t)$, will be the same with independence of i and j. In such a case, the number of independent moments in Ω reduces to N+1 and the shocks would be exactly identified.

From an empirical point of view, a way to tackle this problem is testing for the number of independent moments in the matrix Ω. In order to test the hypothesis of just N+1 independent moments in Ω against the unrestricted hypothesis of more than N+1 independent moments, one way is first obtaining a consistent estimate of the covariance matrix of the one period ahead forecast errors, and then testing for equal covariances. The consistent estimate of Ω, denoted by S, can be obtained by first fitting a VAR(p) to the cyclical components of output, obtaining estimated residuals u(t), and then computing

$$S=T^{-1}\sum_{t=p+1}^{T} u(t)u(t)'.$$

As Lütkepohl (1991) shows,

$$plim(S)=\Omega$$

and

$$T^{1/2}(vech(S-\Omega)) \sim N(0,\Sigma) \tag{3}$$

with

$$\Sigma = 2(DM'DM)^{-1}DM'(\Omega\otimes\Omega)DM(DM'DM)^{-1},$$

where DM is a standard (NxN(N+1)/2) duplication matrix, and vech is the column stacking operator which eliminates elements above the main diagonal. For the case N=3, a Wald test can be built by defining the following matrix

$$Z=\begin{bmatrix} 0 & 1 & -1 & 0 & 0 & 0 \\ 0 & 1 & 0 & -1 & 0 & 0 \end{bmatrix}.$$

Observe now that

$$Zvech(\Omega) = [\Omega_{12}-\Omega_{13} \quad \Omega_{12}-\Omega_{23}]' \tag{4}$$

and therefore the hypothesis to test is Z vech(Ω)=[0 0]'. Next, it follows from (3) and (4) that

$$T^{1/2}Z(vech(S-\Omega)) \sim N(0,Z\Sigma Z')$$

and consequently, under the null hypothesis of just 4 independent moments in Ω,

$$T(Z(vech(S)))'(Z\Sigma Z')^{-1}(Z(vech(S))) \sim \chi^2(2).$$

Clearly, in practice even if we do not reject the null hypothesis, the estimates of Ω_{12} will differ from that of Ω_{13}, etc. Nevertheless, this problem can be easily solved by taking the average of the covariances and using this value as the common covariance.

Given that the empirical analysis heavily relies on the above test, and given that these tests are not widely used in the econometrics literature, we have performed a small Monte Carlo experiment to highlight the finite sample properties of the test. We have generated a trivariate white noise process with covariance matrix

$$\Omega=\begin{bmatrix} 1 & a & .5 \\ a & 1 & .5 \\ .5 & .5 & 1 \end{bmatrix}$$

with a=.5 in order to evaluate the finite sample size properties of the test, and with a=.4,.2,.6,.8 to evaluate the finite sample power. We have considered three different sample sizes, T=60,100,200 which correspond to 15, 25 and 50 years of quarterly data. Table 1 reports the results of the Monte Carlo experiment.

One first relevant result in Table 1 is that the size of the test is quite close to the theoretical 5 percent in any sample size. As expected, when a is close but different from the value under the null hypothesis (.5), the power is low but it increases with T and with the difference $| a-.5 |$. Overall, there are indications that the test is reliable enough to proceed with the analysis, although in small samples it will have a tendency to frequently accept the null hypothesis even if it is false.

If the test does not reject the null hypothesis, then we can proceed to compute the different components for each series. Let us partition the C(L) matrix polynomial as

$$C(L)=\begin{bmatrix} C(L)_{11} & C(L)_{12} & C(L)_{13} \\ C(L)_{21} & C(L)_{22} & C(L)_{23} \\ C(L)_{31} & C(L)_{32} & C(L)_{33} \end{bmatrix},$$

where $C(L)_{ij}$ is now a polynomial in the lag operator L, where the parameter for the element L^0 is 1 if i=j, and zero otherwise. From above it follows that

$$y_i(t)=(\textstyle\sum_{j=1}^{3} C(L)_{ij})\,w(t)+C(L)_{i1}v_1(t)+C(L)_{i2}v_2(t)+C(L)_{i3}v_3(t)$$
$$y_i(t)=C(L)_i w(t)+C(L)_{i1}v_1(t)+C(L)_{i2}v_2(t)+C(L)_{i3}v_3(t)$$
$$y_i(t)=P_i(t)+S_{i1}(t)+S_{i2}(t)+S_{i3}(t),$$

where $P_i(t)$ denotes the component driving $y_i(t)$ due to common shocks, and $S_{ij}(t)$ denotes the component driving $y_i(t)$ due to country specific shocks to country j. Given the assumption of independent shocks, the variance of $y_i(t)$ will be the sum of these four components. Finally, it can also be of interest to evaluate the contribution of each shock to the forecast error variance of each series for different horizons. Observe that, as the horizon approaches infinite, the forecast error variance due to a given shock will just reduce to the unconditional variance of the series due to the relevant shock.

V. Empirical Analysis

In this section we study the cyclical components of output for three countries, Germany, Japan and the United States. The time period for the analysis extends from the first quarter of 1974 to the fourth quarter of 1990. The sample covers a period which goes from after the first oil crises to before the German reunification. Figure 1 shows the plot of the logs of the original data. Preliminary analysis of the series (not reported but available upon request) indicated that the hypothesis that the series are I(1) cannot be rejected on the basis of Augmented Dickey and Fuller tests, and that the series are not cointegrated on the basis of Johansen cointegration tests.

Since in this model the outputs have no trend, we first proceed to detrend the series. For the extraction of cyclical components, we use the Hodrick-Prescott filter. As noted by Canova (1991), the different available detrending methods tend to produce different results. However, the

Hodrick-Prescott filter is widely used in the empirical macroeconomics literature and therefore our results can be easily compared to others. Figure 2 plots the cyclical components of the outputs and Table 2 reports some descriptive statistics for the same components with consistent standard errors for heteroskedasticity and autocorrelation.

A relevant fact shown in Table 2 is that Japanese fluctuations are smaller in magnitude than German and U.S. fluctuations. The U.S. series presents the most accentuate fluctuations. Basically, the standard deviations of the series indicate that the country with the most regulated economy of this system (Japan) is the one with the smallest output fluctuations, whereas the least regulated country (United States) is the one displaying the most accentuate fluctuations. The skewness and excess of kurtosis statistics do not suggest any outstanding problem with outliers, and for the three series, the values can be accepted to be the typical values of a Normal distribution. Table 3 shows contemporaneous cross-correlation coefficients for the three cyclical components with consistent standard errors. Table 3 also reports the autocorrelation coefficients of each cyclical component under the heading -n, (n=1,2,3). For example, the cross between the column headed by -1 and the row headed by GE contains the first autocorrelation coefficient for the German series.

Table 3 indicates that the cyclical components of these three countries present a positive correlation being always significantly different from zero. Moreover, there are indications that the cyclical components tend to co-move together, as shown by the correlation coefficients which are always larger than .5. Inspection of Table 3 also reveals that the correlation coefficients are very similar for every pair of countries. With respect to the autocorrelation structure, the Japanese series displays the lowest persistence with a third autocorrelation coefficient point estimate very close to zero. The series displaying the largest persistence is, as in the case of the variance, the U.S. series.

Another important set of descriptive statistics is that reported in Table 4, the lead-lag cross correlation statistics. For example the heading GE,JA-n indicates the correlation between the current value of the German series and n lags of the Japanese series.

Figures in Table 4 indicate the presence of a strong temporal dependence between the series. The results also suggest that the highest correlations are those between the lagged series of the United States and the series of the other two countries. These results indicate that the current behavior of the series of the United States would be strongly related with the future behavior of the series of the other two countries, suggesting a possible locomotive role of the U.S. economy. However, these results must be interpreted very carefully, since in general correlation does not imply causality.

At this point we proceed to fit a VAR. Given the number of observations, we initially fit a VAR(2) model producing the following covariance matrix for the error term

$$\Omega=10^{-4}\begin{bmatrix} .92 & .20 & .30 \\ .20 & .43 & .18 \\ .30 & .18 & .72 \end{bmatrix}.$$

The residuals do not present any indication of serial correlation. The univariate Ljun-Box statistics for serial correlation take values, 8.85, 7.56 and 3.95. Under the null hypothesis of independent residuals, these statistics are asymptotically distributed as a $X^2(6)$ (critical value, 12.59). We have also computed the multivariate version of this statistic which is asymptotically distributed as a $X^2(90)$ (critical value 112.7) taking a value of 83.7. With respect to the normality statistics, the univariate Jarque and Bera statistics take values 4.87, 3.54 and .56, which under the null hypothesis of normal errors are asymptotically distributed as $X^2(2)$ (critical value 5.99). Finally, we have also calculated the multivariate version of this statistic (equal to 8.99), which under the null hypothesis is asymptotically distributed as $X^2(6)$ (critical value 12.19). Since the statistics are always smaller than the 5 percent critical values, we do not reject the hypothesis of independent and normal errors.

The next step is to compute the test statistic for equal covariances as described in the previous section. In this case the value of the statistic is 1.339, which under the null hypothesis of equal covariances is distributed as a $X^2(2)$. Since $1.339<5.99$ we do not reject the null hypothesis. On these grounds, the variance for the common shock series would be .23, while the variance for the country specific shock series of Germany, Japan and the United States would be .68, .20 and .48 respectively. Table 5 reports the forecast error variance decomposition (in percentages) at different horizons. We recall that at an infinite horizon the components of the forecast error variance decomposition are equivalent to the relative components of the unconditional variance decomposition.

As indicated in Table 5, a large part of the variability of the three output series at short horizons is accounted for by domestic shocks. After one quarter, domestic shocks explain 75, 47, and 68 percent of the total variability of the German, Japanese, and U.S. output respectively. However, at longer horizons the contribution of domestic shocks increases only for the U.S. economy to around 75 percent, whereas for the other two economies the contribution of domestic shocks decreases by 25 percent for Germany, and 15 percent for Japan.

Foreign shocks account for a small part of the total variability of the three series at short horizons. However, they become more and more important at long horizons for both the German and Japanese economies. For the Japanese series, imported shocks account for approximately 10 percent after three quarters, 22 percent after five, and as the horizon increases they explain 25 percent of the total variability. Notice that 22 percent is accounted for by U.S. shocks, whereas only 3 percent by German shocks. For the German series, the contribution of Japanese shocks is very small at both short and long horizons, whereas imported shocks from the United States account for approximately 8 percent after three quarters, 18 percent after five quarters, and as the horizon increases they account for 22 percent of the total variability. The shocks imported by the U.S. economy from the other two countries explain only .2 percent of the total variability after three quarters, and as the horizon increases the percentage raises to only 4.6, with the Japanese shocks accounting for 4.5 percent.

Common shocks account for a large part of the variability of the series both at short and at long horizons. After one quarter, common shocks explain one fourth, one half, and one third of the variability of German, Japanese, and U.S. outputs respectively. These percentages reduce for the Japanese and the U.S. series at longer horizons by around 10 percentage points; at the infinite horizon (i.e. the unconditional variance of the series), the percentage of the total variance of the Japanese and the U.S. series explained by common shocks reduces to 43 and 21 percent respectively.

Table 5 also shows that the effects of imported shocks from the United States to the other two economies increase over time. After one quarter the effects of imported shocks from the United States to the other two countries are 0, but as the horizon increases their importance increases, accounting for more than 20 percent of the total variability of the output of the other two countries, indicating the locomotive role of the U.S. economy. We recall that the main channel of transmission of shocks is trade, through imports.

Therefore, there are indications that both common shocks and shocks imported mainly from the United States are very important in explaining output co-movements. This result is consistent with the popular view that the United States is a locomotive for the world economy. It also indicates that in this system, the United States is the country less influenced by international developments whereas Japan is the most affected, and that Japanese domestic shocks explain less than one third of the variability of Japanese output.

VI. Conclusions

In this paper we have analyzed whether international business cycles arise from common shocks or from country specific shocks that are then transmitted to the world economy. We have used a multi-country real business cycle model with production interdependencies. The model is able to generate fluctuations attributable to common shocks captured by a term measuring the world's technological progress as well as by country specific shocks which are then transmitted. The main channel of propagation of the country specific shocks is trade.

The paper has empirically analyzed the three output series of Germany, Japan and the United States. The findings indicate that common shocks explain a large proportion of the variability of output in these countries, and that the transmission of U.S. specific shocks to the other two countries is also very relevant. In particular, more than 20 percent of the variance of the German and Japanese series can be attributed to imported shocks from the United States, and therefore the model is able to capture the locomotive role of the United States in the world economy.

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Table 1: Monte Carlo results.

T	a=.5	a=.4	a=.2	a=.6	a=.8
60	.04	.10	.69	.09	.58
100	.04	.15	.89	.16	.85
200	.04	.27	.99	.25	.99

Table 2: Descriptive statistics.

COUNTRY	MEAN	STD	SKEW	EKUR	MIN	MAX
GERMANY	.0	1.37	.05	.05	-3.32	3.48
s.e.	(.28)	(.35)	(.40)	(.73)	(.0)	(.0)
JAPAN	.0	.82	-.04	-.57	-1.97	1.68
s.e.	(.15)	(.12)	(.34)	(.64)	(.0)	(.0)
US	.0	1.84	-.47	-.16	-4.55	3.39
s.e.	(.42)	(.52)	(.50)	(.94)	(.0)	(.0)

Table 3: Cyclical components' contemporaneous cross-correlation coefficients and autocorrelation coefficients; (GE=Germany, JA=Japan, and US=United States).

	GE	JA	US	-1	-2	-3
GE	1			.64	.42	.23
s.e.	(.0)			(.09)	(.15)	(.18)
JA	.59	1		.47	.34	.07
s.e.	(.11)	(.0)		(.11)	(.14)	(.18)
US	.66	.60	1	.84	.60	.35
s.e.	(.13)	(.13)	(.0)	(.07)	(.15)	(.19)

Table 4: Lead-lag cross-correlation statistics.

n	GE,JA-n	GE,US-n	JA,GE-n	JA,US-n	US,GE-n	US,JA-n
1	.42	.61	.47	.57	.52	.43
s.e.	(.14)	(.12)	(.13)	(.11)	(.14)	(.15)
2	.36	.54	.28	.51	.32	.21
s.e.	(.15)	(.14)	(.15)	(.12)	(.17)	(.17)
3	.12	.35	.19	.37	.15	.0
s.e.	(.18)	(.17)	(.17)	(.14)	(.19)	(.18)

Table 5: Forecast error variance decomposition.

HORIZON=1	COMMON	GE	JA	US
GERMANY	25.3	74.7	0	0
JAPAN	53.5	0	46.5	0
US	32.4	0	0	67.6
HORIZON=3				
GERMANY	29.3	62.2	.1	8.1
JAPAN	51.8	2.1	37.6	8.5
US	26.3	.1	.1	72.7
HORIZON=5				
GERMANY	28.9	53.3	.1	17.4
JAPAN	46.4	2.9	31.8	18.9
US	21.6	.1	2.8	75.1
HORIZON=7				
GERMANY	27.7	50.4	.1	21.0
JAPAN	44.1	2.9	30.8	22.1
US	20.8	.1	4.2	74.5
HORIZON=10				
GERMANY	27.4	49.8	1.3	21.4
JAPAN	43.8	2.9	30.9	22.3
US	20.1	.1	4.5	73.9
HORIZON=∞				
GERMANY	27.5	49.6	1.3	21.5
JAPAN	43.6	2.9	31.0	22.3
US	20.9	.1	4.5	73.9

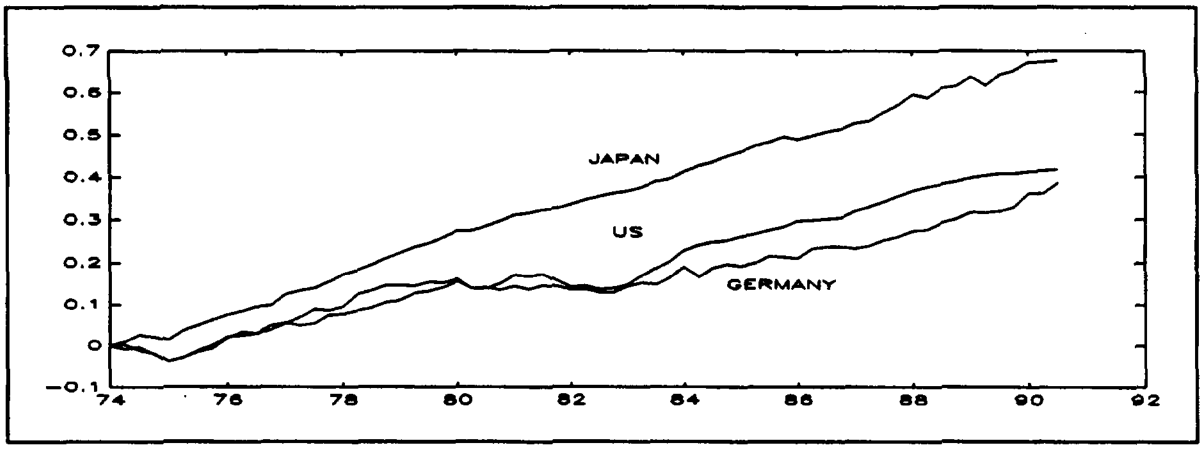

Figure 1, GNP SERIES, LOG-INDEX

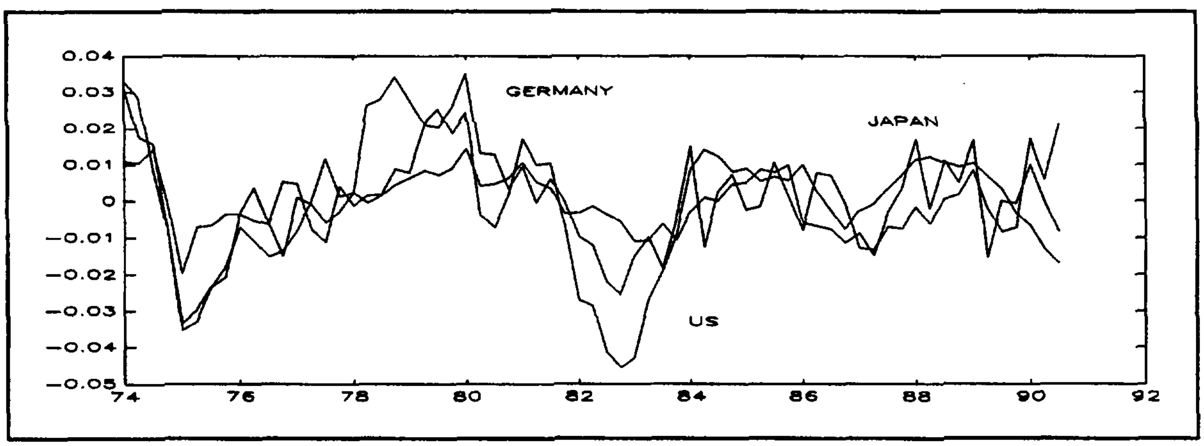

Figure 2, CYCLICAL COMPONENTS