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Abstract

This paper studies the generation and transmission of international business cycles in a multi–country model with production and consumption interdependencies. Two sources of disturbance are considered and three channels for propagation of shocks are compared. Simulations are performed for symmetric countries and for countries that differ either in preferences, technologies, fiscal policies or exogenous processes. Production interdependences determine to a large extent how technology shocks are propagated while consumption interdependencies largely account for the transmission of government shocks. Technology shocks, which are mildly correlated across countries, are more successful than government expenditure shocks in reproducing actual data.

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1 Introduction

The term "international business cycle" refers to the presence of common elements in the cyclical behavior of outputs across countries. Several authors, including Gerlach (1988), Baxter and Stockman (1989), Blackburn and Ravn (1992), Backus and Kehoe (1992) and Canova and Dellas (1993) among others, have documented the existence of commonalties in economic activity across countries using a variety of methods.[1] Economic similarities can be accounted for by the presence of economic interdependencies in either goods or asset markets, which spill country specific shocks across the world, by common exogenous disturbances or both. Within each category, demand and supply factors can induce international business cycles.

Whether cyclical movements in output are primarily attributable to demand or supply factors is a long standing question which has been tackled from many points of view in a closed economy (see e.g. Blanchard (1989), King, Plosser, Stock and Watson (1991), Cooley and Ohanian (1991), Christiano and Eichenbaum (1992) or Gali (1992) among the most recent ones). The answers however have been mixed and often contradictory. In an international context the generation and transmission of business cycles received substantial attention in the past (see e.g. Morgenstern (1959)) but has only been partially analyzed with the tools of modern dynamic theory.

The answer to the questions of what generates and what transmits cycles across countries has important policy implications. The issues surrounding the problem of generation are well understood. For example, if as widely perceived, output fluctuations are undesirable and demand shocks are largely responsible, there may be a role for aggregate Keynesian–type policies which cushion domestic or foreign disturbances. On the other hand, as often emphasized in the real business cycle literature, if cyclical fluctuations in output are the optimal response to unforeseen (demand and supply) disturbances, rather than mitigating fluctuations per se, a more appropriate role for the government is to reduce economically relevant uncertainties.

Identifying the channels of propagation is also crucial. For example, in designing aggregate demand policies to sterilize undesirable disturbances, it is important to know not only whether shocks have domestic or foreign origin but also whether transmission occurs through goods markets or financial markets. In addition, trade liberalizations or trade wars, which have both generated considerable debate in policy circles, will have different impacts on the cyclical properties of national output depending on how disturbances are transmitted. Finally, it is important to know whether the increased coordination of fiscal policies is responsible for the increased symmetry in business cycles across the world which has been particularly evident in the 80s.

[1]These include simple descriptive statistics (Backus and Kehoe, Stockman and Baxter), spectral analysis techniques to examine the coherence of national outputs at business cycle frequencies (Gerlach) and a variance decomposition of the forecast errors of domestic output to examine the percentage due to imported shocks (Canova and Dellas).

The empirical evidence regarding these issues is somewhat scant. Canova and Dellas (1993) document that trade interdependencies in intermediate goods are important factors in explaining the transmission of fluctuations in post WWII data. They also find that after 1973 the presence of common disturbances play some role in accounting for international cyclical output comovements. Cole and Obstfeld (1991), Backus, Kehoe and Kydland (1992) and Crucini and Baxter (1991) suggest that international risk sharing occurs primarily through the goods markets and that the loss in consumer welfare due to incomplete or autarkic financial markets appears to be small. Finally, Correira, Neves and Rebelo (1992) document an asymmetry in the stochastic processes characterizing fiscal variables in the US and UK for the period 1914–1950. Blackburn and Ravn (1992) show that this asymmetry, which seemed responsible for the different features of their business cycles, disappears from the 60s on.

This paper enters the debate by directly addressing the question of what generates and what propagates international business cycles. In section 2 I build a multicountry general equilibrium model where it is possible to distinguish the contribution of different types of disturbances as sources of output fluctuations and to quantify the importance of interdependencies in both intermediate and final goods in transmitting shocks across countries. One type of disturbance takes the form of exogenous government expenditure shocks (as e.g. in Christiano and Eichenbaum (1992)). These shocks leave the instantaneous marginal product of factors of production unchanged but generate dynamic responses in the system because they modify the flow of consumption services accruing to domestic households. Consequently, governments influence trade flows in final goods, as consumers substitute from domestic to foreign goods in response to disturbances, affect trade in intermediate goods, as consumers substitute leisure intertemporally and change investment patterns, and alter the production levels around the world because of the indirect effects on capital accumulation (see Ashauer (1989) for an empirical documentation of this effect in the US economy).

A second type of disturbances is modelled as exogenous technology disturbances, as is standard in the real business cycle (RBC) literature. These shocks affect the marginal product of factors of production and directly influence investment opportunities within each country. Moreover, because of income effects, these shocks also alter the flow of consumption services and trade flows of final goods across the world. The crucial difference between the two sources of exogenous disturbances is in the way they first impact on trade flows: government shocks immediately affect the value of net exports of consumption goods and later on the value of net exports of investment goods because of the induced changes in leisure choices. For technology shocks the order is reversed.

The model employed in the paper differs from those of Cantor and Mark (1988), Stockman and Tesar (1990), Mendoza (1991a), Backus, Kehoe and Kydland (1992) or Baxter and Crucini (1992) in at least four respects. First, each country specializes in the production of one good. Second, agents in each country consume an array of goods and government expenditure yields direct utility for domestic consumers.

Third, preferences, technologies and fiscal policies are allowed to differ across countries. Fourth, foreign capital is used in the production of domestic goods. Allowing for production interdependencies introduces an important and previously neglected channel through which shocks can be propagated across countries.

Information about the cyclical component of national outputs is summarized with statistics based on the impulse response function. Since the model of section 2 displays a deterministic trend specific to each country, the cyclical component of national outputs is computed after a country specific deterministic trend is extracted from the logarithm of GDPs. Section 3 provides empirical evidence for US, Germany and Japan and documents the presence of asymmetries in output responses depending on the origin of the disturbance.

Section 4 describes how technology and government disturbances generate international cycles in three cases — one where shocks are contemporaneously uncorrelated across countries and transmission occurs because of production interdependencies, one where shocks are contemporaneously uncorrelated and transmission occurs because of consumption interdependencies and one where shocks are contemporaneously correlated but no trade in either investment or consumption goods occur — and compares the properties of the spillover mechanism.

Section 5 asks whether a realistic parameterization of the model is able to reproduce features of the actual impulse response function of the data. In particular, I am interested in knowing whether the simulated impulse response function displays the same shape (in terms of peaks and troughs of the implied cycle) and the same magnitude of the cumulative dynamic multipliers of the actual impulse response function.

The results indicate that, when the model is symmetrically parametrized so that the three countries all resemble the US, the short run features of the transmission are best accounted for by contemporaneously correlated shocks regardless of the true source of disturbances. For the common elements of output fluctuations in the long run, on the other hand, production interdependencies play a major role when technology shocks drive the economy, while consumption interdependencies are crucial when government shocks are the sources of fluctuations in the economy. We find that although knowledge of the source of fluctuations is somewhat irrelevant in determining the qualitative features the propagation of output shocks across countries, the model driven by government disturbances is slightly more successful in reproducing salient features of the transmission of actual US output shocks. However, because the shape of the simulated impulse response function and the location of turning points are all somewhat sensitive to the choice of two "unmeasured" parameters, no strong quantitative conclusion regarding the relative importance of technology and government expenditure shocks in generating international cycles can be made.

The inclusion of cross country heterogeneity does not significantly improve the performance of the model. I find that the effect of common disturbances is still strong in the case of technology shocks but that the propagation of government shocks is now almost entirely due to trade in consumption goods. Also, although heterogeneity in the distribution of the exogenous processes is important in generating asymmetries in simulated total multipliers, such asymmetries do not bring simulated responses more in line with actual responses. Finally, while with a country specific parameterization a model with technology disturbances accounts for features of the propagation of US output shocks, the model with government disturbances has some merit in explaining the transmission of German output shocks.

Section 6 provides some conclusions and suggests possible answers to the policy questions discussed in this introduction.

2 The Model

The framework of analysis is an N country model with N consumption goods and each country specializing in the production of one good. We abstract from money, not because we believe that monetary aspects are unimportant in generating or transmitting business cycles, but because we do not have simple models of money which can produce quantitatively interesting real cyclical effects (see e.g. Danthine and Donaldson (1986) or Canova (1992)).

Each country is populated by a large number of identical agents and labor is assumed to be immobile across countries. Preferences of the representative agent of country h, $h = 1, \ldots, N$ are given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c^*_{ht}, l_{ht}) = E_0 \sum_{t=0}^{\infty} \frac{\beta^t}{1-\sigma_h} [(\prod_{j=1}^{N} c^{*\theta_{hj}}_{hjt}) l_{ht}^{(1-\sum_{j=1}^{N} \theta_{hj})}]^{1-\sigma_h} \tag{1}$$

where

$$\begin{aligned} c^*_{hjt} &= c_{hjt} + \phi_h g_{ht} \quad \text{if } h = j \\ c^*_{hjt} &= c_{hjt} \quad\quad\quad\quad\ \text{if } h \neq j \end{aligned} \tag{2}$$

where c_{hjt} is the consumption of good j by the representative agent of country h. Agents value the services of up to N consumption goods: if good j is not enjoyed by residents of country h, $\theta_{hj} = 0$. Government consumption expenditure yields direct utility for the representative agents of their own country. When $\phi_h = 0$ government h consumption expenditure does not affect utility, while when $\phi_h = 1$, government and private domestic consumption are perfect substitutes so that changes in g_{ht} crowd out c^*_{hjt} but leave utility unaffected. One way to rationalize (2), is to think of the government as having a linear technology, $z_t = \phi_h g_{ht}$, which allows it to produce consumption goods using g_{ht}. If $\phi_h < 1$ it is costly for the society to have the government produce these goods.

Consumption goods are produced according to:

$$Y_{ht} = A_{ht} (\prod_{j=1}^{N} K^{\alpha_{hj}}_{hjt})(X_{ht} N_{ht})^{1-\sum_{j=1}^{N} \alpha_{hj}} \qquad \forall\, h,\ j \tag{3}$$

where $X_{ht} = \gamma_h X_{ht-1}$ with $\gamma_h \geq 1 \ \forall h$. X_{ht} represents a labor-augmenting Hicks-neutral deterministic technological progress. Production is subject to a technological disturbance A_{ht} and requires domestic labor and up to N intermediate capital inputs. If intermediate input of country j is not used in producing the output of country h, $\alpha_{hj} = 0$. Capital goods are accumulated according to:

$$K_{hjt+1} = (1 - \delta_j)K_{hjt} + \psi(I_{hjt}/K_{hjt})K_{hjt} \qquad \forall\ h,\ j \tag{4}$$

where $\psi(\frac{I_{hjt}}{K_{hjt}})$ satisfies $\psi > 0,\ \psi' \geq 0,\ \psi'' \leq 0$ and represents the cost of moving (or installing) intermediate good j from the location where it is produced to country h.

Mendoza (1991a), Backus, Kehoe and Kydland (1992) and Baxter and Crucini (1992) have shown that in a one good international model transaction costs help to avoid unrealistic unidirectional capital flights in response to technology shocks. The formulation adopted here is similar to Baxter and Crucini (1992) and was chosen because it retains simplicity, while linking transaction costs to the Tobin's Q. $\frac{1}{\psi'}$ is in fact Tobin's Q, i.e. the price of existing capital in location h relative to the price of new capital imported from location $j = 1, \ldots, N$. Note that because of production interdependencies, unidirectional capital flights need not occur in this model: capital may flow toward the country experiencing positive output disturbances but there may also be a contemporaneous flow in the opposite direction as foreign investments increase with the wealth of the country.

Leisure choices are constrained by:

$$0 \leq l_{ht} + N_{ht} \leq 1 \qquad \forall\ h \tag{5}$$

where I normalize the total endowment of time in each country to be equal to 1.

To insure that a balanced growth path with a stationary distribution of wealth obtains I assume that $\beta = \beta_h^* \mu_h$ and that $\gamma_h \mu_h = \gamma \ \forall h$ where μ_h is the growth rate of population in country h. Intuitively these conditions imply that, asymptotically, the more impatient country will not accumulate all of the world wealth.

Governments consume domestic goods, tax national outputs with a distorting tax and transfer what remains back to domestic residents. It is assumed that government expenditure is stochastic, while tax rates are parametrically given. Although the recent taxation literature (see e.g. Dotsey (1990) or Braun and McGrattan (1993)) models tax rates as stochastic processes, I adopt a parametric representation in order to isolate the contribution of government expenditure disturbances to the transmission mechanism of business cycles. The government budget constraint is given by:

$$g_{ht} = TR_{ht} + \tau_h Y_{ht} \qquad \forall\ h \tag{6}$$

where τ_h are tax rates and TR_h transfers in country h.

Economy wide resource constraints are given by:

$$Y_{ht} - g_{ht} - \sum_j c_{hjt} - \sum_j k_{hjt+1} \geq - \sum_j (1 - \delta_h) k_{hjt} \ \ \forall\ h \tag{7}$$

The economy is subject to a $2N \times 1$ vector of shocks $z_t = [A_{ht}, g_{ht}]$ and z_t is assumed to be a homoskedastic process with mean $\hat{z}_t = (A(\ell)z_{t-1})$ and variance Σ.

There is some empirical evidence (see e.g. Costello (1991)) that productivity disturbances have cross country lagged effects which are asymmetric. However, these lagged effects may be the result of misspecifications of the production function since foreign capital used in domestic production is not explicitly considered when calculating Solow residuals. For this paper I will specify a univariate law of motion for the shocks, in order to avoid mixing the transmission due to trade in goods and the one due to the presence of lagged feedbacks across shocks, but I allow each type of disturbance to be contemporaneously correlated across countries. There is also some evidence that technology and government expenditure shocks may be negatively correlated within countries (see Finn (1991) or Christiano and Eichenbaum (1992)). Because here I am interested in examining the dynamics generated by each of the two shocks separately, I will not consider this possibility and let $\Sigma = \text{blockdiag}(\Sigma_1, \Sigma_2)$.

Finally, I assume complete financial markets within countries and free mobility of financial capital across countries.

To find a solution to the model I first detrend those variables which drift over time by taking ratios of the original variables with respect to the labor augmenting technological progress and the population of each country (F_{ht}), e.g. $y_{ht} = \frac{Y_{ht}}{X_{ht}F_{ht}}$, etc. Second, since there are distortionary taxes in the model, the competitive equilibrium is not Pareto optimal and the competitive solution differs from the social planner solution. I therefore solve the problem faced by a pseudo social planner (a fictitious problem where distortionary taxes are eliminated) and modify the optimality conditions to take care of the distortions (see e.g. Appendix A of Baxter and Crucini (1992) for more details). The weights ω_h in the social planner problem will be chosen to be proportional to the initial population size of each country. The modified optimality conditions are then approximated with a log–linear expansion around the steady state as in King, Plosser and Rebelo (1988). Solutions for the variables of interest are computed analytically from the approximate optimality conditions. It is worthwhile to note that the resulting $22 * N \times 1$ system of equations is such that certain parameter configurations give rise to complex eigenvalues in the transition matrix of the states. Hence, contrary to RBC models driven by AR(1) shocks, which induce fluctuations without power at business cycle frequencies, the current model can generate business cycle behavior both in terms of variability and cross correlation and of power at business cycle frequencies.

Reynolds (1992) has used a similar model to study the properties of the transmission of productivity disturbances. There are two major differences between her framework and the one used here. First, she does not consider the impact of government expenditure disturbances. Second, she does not allow for transaction costs in the capital accumulation equation. Boileau (1992) also considers a model where production interdependencies play a role but the interdependence is created via an externality which affects all countries in the economy.

3 Some Empirical Evidence

This section documents some of the features of the transmission mechanism of output shocks across the US, Germany and Japan. To characterize the cyclical transmission of output shocks it is necessary to detrend the original output series and questions arise as to how best extract the long run component of the data. Canova (1991) indicates that, because alternative detrending methods impose different assumptions on the underlying structure of the time series, they induce different distributional properties for the cyclical components and, consequently, contrasting descriptions of the empirical evidence. Given the low power of the tests designed to inform us about the data's long run properties and the fact that no consensus view exists with regard to the appropriate choice of trend removal, I decided to use the model–based decomposition of national outputs implicit in the formulation of section 2. From the steady state properties of the model all variables in country h, except hours, grow at the rate of labor augmenting technological change γ_h. Therefore, I present statistics summarizing the features of international business cycles after a country specific deterministic trend is extracted from the log of raw output data. While this choice is arbitrary, in the sense that without precise knowledge about the long run properties of economic variables an alternative assumption about the statistical properties of exogenous technological progress (say, a unit root assumption) may be as sensible, it provides useful restrictions on the cyclical properties of actual data and it imposes discipline in the simulations.

Quarterly real GDP data for the US, Germany and Japan is taken from OECD tapes, covers the sample 1960,1–1990,4 and is converted into indices using 1980,1 values. The slope coefficients of the deterministic time trends are respectively 0.008, 0.0077 and 0.016 per quarter with the slope for Japanese output significantly different from the other two.

I summarize the information contained in the cyclical component of GDPs via the impulse response function. Although there are other statistics which may serve the purpose, the impulse response function is a simple "window" which allows us to draw conclusions on the transmission of shocks across countries without any need to directly identify the behavioral sources of disturbances in the economy. To compute it, I estimate a VAR with 9 lags and a constant on the cyclical components of the log of outputs. Results are presented when the contemporaneous correlation matrix of shocks is triangularized in the order US GNP, Germany GNP and Japan GNP.

Two potential problems should be mentioned before the evidence can be interpreted: the impulse response function may not be stable over the sample (due e.g. to structural breaks) and the properties of the transmission mechanism may not be robust to the chosen ordering of the triangularization. Evidence (available on request) shows that (i) apart from Japanese output at 1974,1, the VAR residuals have no visible outliers and satisfy both normality and the white noise assumption over the entire sample, (ii) the qualitative features of the impulse response function are approximately stable across subsamples and (iii) the properties of the transmission of shocks are independent of the ordering chosen for the triangularization.

Figure 1 plots the mean estimate of the impulse response function together with the upper and lower limits of a 95% band computed with a Monte Carlo integration. Table 1 reports two statistics which summarize the features of transmission presented in figure 1 (the size and the location of the peak response of the three variables and the magnitude of the cumulative multipliers). Three features emerge from figure 1. First, US output shocks have a significantly large and positive impact on the outputs in the other countries while this is not the case for Japanese and German output shocks. Second, it usually takes time for a shock to be fully transmitted across countries and the return to the trend line is very slow in both cases. For example, the peak response of German output following a shock in US output lags three quarters and the peak response of Japanese output lags eighteen quarters. Third, the point estimates of the cumulative multipliers are very asymmetric. For example, while a 1% surprise increase in the log of detrended US output generates a 10.91% cumulative responses in US output after 24 periods, a 9.72% cumulative response in German output and a large 19.33% cumulative response in Japanese output, a 1% increase in the log of detrended German output generates negative cumulative responses in all three countries. Finally, a 1% surprise increase in the log of detrended Japanese output has a large domestic impact (14.99% after 24 quarters) but very modest international repercussions.

Two conclusions can be derived from the evidence. First, there exists an international transmission of cyclical disturbances but, except for the case of US output shocks, it is not overwhelming in terms of magnitude and it is somewhat asymmetric. Roughly speaking, US output shocks drive the international cycle, the popular press argument that the US economy is a "locomotive" for the world economy, German output shocks crowd out foreign outputs in the medium-long run, while Japanese output shocks have modest international impacts. Second, the propagation of shocks across countries takes time, with the lag in the peak response varying from 2 to 18 quarters.

4 The Transmission Properties of the Model

The transmission mechanism of economic fluctuations of the model is more complex than the one obtained in one good economies (see e.g. Backus, Kehoe and Kydland (1992) or Baxter and Crucini (1992)) and in multigood economies where only domestic capital is used in domestic production (see e.g. Schlagenhauf (1989)). In a one good world with uncorrelated but persistent technology shocks, a disturbance in one country raises the productivity of domestic factors of production, induces an increase in domestic investment and domestic output, domestic hours worked and, to a lesser extent, in domestic consumption because of permanent income considerations. Because of the one good assumption, capital will flow to the most productive location (and the extent of this flow depends on the cost of moving capital) inducing a current account deficit in the country experiencing the shock and a decline in investment, output and labor demand in the other countries in the world. With perfect capital markets, risk sharing implies that consumption across countries will be perfectly correlated and that, once the initial inflow of capital goods is exhausted, the trade balance of the country experiencing the shocks will display positive net exports.

A positive government shock, which yields no utility for domestic consumers and leaves marginal product of capital unchanged, crowds out domestic consumption, affects the intertemporal allocation of leisure and therefore future production possibilities (see e.g. Aiyagari, Christiano and Eichenbaum (1992)) but has limited effects on the capital accumulation in any country (see e.g. Backus, Kehoe and Kydland (1991)). Note that, because of risk sharing, foreign consumption is also affected.

These features of the transmission mechanisms appear to be robust to several modifications of the basic framework. For example, Backus, Kehoe and Kydland (1992), Baxter and Crucini (1991) and Mendoza (1991b) show that dispensing with complete capital markets slightly reduces the cross country consumption correlations without affecting the other features of the transmission (in line with Cole and Obstfeld (1991)). The same authors also show that making agents more risk averse, increasing the transaction costs of moving capital, introducing time to ship or changing the size of the countries changes the magnitude of the foreign responses but not their qualitative features. Finally, Costello (1991) separates the production of consumption and investment goods, assumes that trade takes place entirely in capital goods and generates an identical international transmission of technology shocks.

In the model considered by Schlagenhauf (1989) investment dynamics do not drive the cycle because the investment good is nontraded (see also Stockman and Tesar (1990) and Ricketts and McCurdy (1992)).[2] Instead, shocks are propagated to the world economy because of consumption interdependencies. When a positive and persistent disturbance increases domestic output, consumption by domestic residents increases and part of the increase is diverted to foreign goods. The increase in demand and the risk sharing agreement across countries imply that consumption of the foreign goods will go up in all countries, depressing foreign investments and future foreign output. Hence, although foreign outputs are negatively correlated with domestic shocks as in the one good economy, the transmission occurs through a countercyclical net trade in consumption goods as opposed to a countercyclical net trade in investment goods. Mendoza (1991a) and Cardia (1991) show that, with minor modifications, the same mechanism takes place in small open economy which faces exogenous productivity disturbances.

In the model of this paper there are three reasons why shocks in one country may result in temporary displacement of foreign outputs from their trend. One is because shocks may be correlated across countries. The second is because indepen-

[2]The model by Stockman and Tesar is more complex, considers tradable and nontradable sectors but maintains the assumption that capital in the tradable sector is immobile. Also, in addition to technology shocks they consider the case of preference shocks, which shares some aspects with the government shocks I consider in this paper. Ricketts and McCurdy, on the other hand, have a model where consumption goods need to be purchased with money.

dent shocks may be transmitted through production interdependencies. The third is because independent disturbances may be transmitted through consumption interdependencies. Figure 2 displays how the transmission mechanism works in each of these cases when either technology disturbances are present (first three panels) or when government disturbances which have no direct affect on agents' utility are present (last three panels) for the case of three symmetric countries. In all cases time series of length T=6000 were generated from the model, a VAR with 9 lags was fit to the data, impulse responses are computed using a triangularization in the order country 1, 2 and 3.[3]

Consider first the case of a common disturbance to an economy where no trade in either consumption or investment goods takes place. Here a positive output shock in country one implies a positive response of outputs in other countries and a slow return to the steady state position. Two facts need to be noted. First, technology and government disturbances generate the same short–medium run dynamics and they may be differentiated only by examining the pattern of long run responses and, to some extent, the smoothness of the convergence to the steady state. Second, for both types of shocks the three countries experience a peak response which is lagged with respect to the initial shocks by 3–6 quarters.

Next consider the case of uncorrelated shocks which are propagated to other countries through production interdependencies. Here I assume that domestic residents consume only domestic goods. The situation is similar to the one examined by Backus, Kehoe and Kydland (1991) except that production requires domestic and foreign *capital* goods while Backus, Kehoe and Kydland do not distinguish between consumption and investment goods in their model.

A positive output shock in one country increases total investments (domestic and foreign), consumption and hours in the country experiencing the shock. However, contrary to the one good case, the features of the transmission across countries depend on the relative size of capital inflows from the rest of the world (substitution effect) and of capital outflows due to the spillover of the shock (wealth effect). In turn, the net effect of these two opposing forces depends on the weights of various capital goods in the production functions. If the domestic inputs are more intensively used in domestic production, the substitution effect dominates and cross country output dynamics are similar to those of the one good economy. If foreign inputs are more intensively used, the wealth effect prevails generating positive, although lagged, foreign output responses.

In the second and fifth panels of figure 2 I present an intermediate case where domestic and foreign intermediate inputs have equal intensity in each of the three production functions. Two features need to be noted. First, while initially a positive output shock induces a negative response in the output of other countries, as capital moves to country one, in the medium–long run the spillover effect dominates and net capital outflows from the country experiencing the shock become positive.

[3]To examine the properties of theoretical economies, it is typical to compute "population" impulse responses (see e.g. King, Plosser and Rebelo (1988)). Here instead I consider "empirical" impulse responses to maintain comparability with the responses presented in figure 1.

Second, once again, the shape of the responses to a one standard error shock in country one does not depend on whether the economy is driven by technology or government shocks. These results agree with those of Backus, Kehoe and Kydland (1991) who showed that both shocks induce positive domestic output responses and a negative net export response in the country experiencing the shocks. However, because their model has no distorting taxation, the magnitude of the changes is not directly comparable.

Finally, consider the case of uncorrelated shocks which are transmitted to the world economy because of consumption interdependencies. Here I assume that the production requires only domestic intermediate goods. When technology disturbances drive the economy, the dynamics are essentially the same as those of Schlagenhauf (1989) or Stockman and Tesar (1990). Depending on the parameters of the utility function we may have no transmission, if the utility function heavily weighs domestic goods, or a substantial one, if domestic consumers prefer foreign goods relative to the domestic one. The third and sixth panels of figure 2 report results for the case where domestic and each of the foreign goods have the same weight in the utility function. It is evident that in the case of technology disturbances this channel of transmission is minor.

When government disturbances drive the economy, the dynamics of the transmission of output shocks is more interesting and are very similar to those presented in panel 5 in the medium run. A negative government shock increases current output available for private use, current consumption of the domestic goods and current consumption of goods from other countries. Because the level of foreign output is given at the time of the shock, the increased domestic demand for foreign goods is accommodated through reductions in foreign investments. Since foreign hours increase, output increases temporarily and then falls as the decline in foreign investment reduces foreign capital stocks. Because, following a cut in domestic government expenditure, part of the resulting increase in private consumption falls on foreign goods, the increase in domestic investments is larger than the one that would take place in a closed economy. This increase in domestic investment boosts domestic production, leading to the lagged peak domestic response observed in the sixth panel of figure 2. Hence, temporary cuts in government expenditure generate positive domestic multiplier effects, as resources are moved from current to future consumption, but have negative effects on the output of other countries, as resources are moved from future to current consumption. Eventually, the cross country effect is reverted and positive spillovers obtain in the medium run when the wealth effect dominates.

Two main conclusions can be derived from studying the dynamics of the model. First, since the transmission of technology and government shocks looks very similar in two out of the three cases, it is not always possible to distinguish which source of disturbance buffets the system using the dynamic responses of GDPs. Second, while shocks which are contemporaneously correlated induce short run positive cross country output responses which die out in the medium–long run, shocks which are contemporaneously uncorrelated and transmitted via trade in goods induce an immediate negative response in foreign outputs and a positive spillover in the medium–long run.

5 Does the Model Reproduce the Data?

The next question I ask is whether with a realistic parameterization the model can indeed produce the features of the impulse responses presented in figure 1. To start with I consider a situation where the world is composed of three identical countries with parameter values based on US data. This step is useful for two reasons: to clarify which of the channels is dominant in transmitting disturbances and to make the analysis comparable with previous works by e.g. Cantor and Mark (1988), Stockman and Tesar (1990) or Backus, Kehoe and Kydland (1992), which primarily consider the case of identical countries.

5.1 The Parameterization of the Model

The parameters of the model are $\sigma_h, \theta_{hj}, \beta, \gamma_h, \alpha_{hj}, \tau_h, A_h(\ell), \phi_h, \delta_h, \Sigma$, the steady state values of Tobin's Q, η_{hj}, the elasticity of the investment–capital ratio to changes in Tobin's Q plus steady state ratios (c/y; g/y; i/y) and the social planner weights ω_h. The selected values are reported in table 2.

As in all calibration exercises, the first test for a model trying to explain the cyclical properties of the data is that it fits long run observations. This parameter selection procedure is equivalent to the method of moment approach suggested by Christiano and Eichenbaum (1992) when only first moments of the data are used to form orthogonality conditions. Once the model fits the long run properties of the data, the parameters which are specific to business cycle frequencies are selected on the basis of existing studies or, absent such literature, they are fixed a–priori and a sensitivity analysis is performed to assess the robustness of the results.

According to this logic I choose $\theta_{hj}, \alpha_{hj}, \tau_h, \gamma_h$, the steady state ratios and the steady state value of Tobin's Q so that the steady states of the endogenous variables match the long run averages in the data. I directly estimate $A_h(\ell), \Sigma$, while $\beta, \delta_h, \phi_h, \eta_{hj}, \sigma_h$ are fixed a–priori or selected within a reasonable range of existing estimates.

Long run averages are computed using data from several sources. Various issues of Eurostat External Trade Analytic Tables and the United Nation International Trade Statistics Yearbook report data on the value of imports and exports toward a particular country and on its composition by category of goods. The Yearbooks of Labor Statistics provide data on hours worked per week (Establishment Surveys). The Statistical Abstract of the US, the Japan Statistical Yearbook and the Monthly Reports of the Bundesbank provide time series for the shares of labor compensation in GDP. These three sources are used to construct the θ_{hj} and α_{hj} parameters. IMF Government Finance Statistics Yearbooks provide data on the tax revenues for the three countries which is used to select τ_h. The OECD Economic Outlook, Historical Statistics provide data on the average growth rate of GDP in the three countries for the sample 1960–1989, which is used to pin down γ_h. Various issues of the Statistical Abstract of the US, Japan Statistical Yearbook and the Monthly Reports of the Bundesbank provide the composition of GDP by categories of absorption. Steady states ratios are computed averaging the composition of GDP by categories over the sample 1960–1989. The steady state Tobin's Q is set equal to 1 so that the model with adjustment costs has the same steady state as a model without adjustment costs.

The time series properties of government expenditure are estimated using an AR(1) model on OECD data for the period 1960,1–1990,4 while the time series properties of the technology shocks are estimated using a univariate AR(1) model on the Solow residuals of the three countries. It is worth noting that government expenditure may contain a component which is endogenously responding to the developments in the economy. In this situation it is typical to use military expenditure to proxy for the exogenous component of government expenditure (see e.g. Rotemberg and Woodford (1992)). In the present context this solution does not seem appropriate because military expenditure is only a very small fraction of total government expenditure (and of GDP) in Japan and Germany, so that the resulting properties for g_{ht} process may have very little to do with its truly exogenous component.

Many estimates of the coefficient of relative risk aversion exist for the US but evidence for the other two nations is scant. To provide a range for selecting σ_h, for each $h = 1, 2, 3$, I estimate this parameter over five different samples using the three procedures suggested by Brown and Gibbons (1985) and comparable wealth and consumption aggregates. The ranges of estimates are [1.09, 2.06] for the US, [1.48, 1.97] for Germany, [0.67, 2.23] for Japan. The values presented in the table refer to exactly identified GMM estimates.

Many of the values for US parameters presented in table 2 are standard. For the other two countries the values are similar to those previously employed in the literature (see e.g. Stockman and Tesar (1990), Parente and Prescott (1991), Cardia (1991) or Reynolds (1992)). The values of tax rates are slightly lower than those used by e.g. Baxter and Crucini (1992) but this may be due to the presence of measurement errors in tax revenues.

The table contains estimates of parameters which have not been previously used (the share of foreign capital in production) while partially new are the estimates of the share of foreign consumption in total consumption. To construct the share of total intermediate foreign goods in total output I add imports of industrial supplies, fuels and machinery equipment in each country and divide the total by current GDP. To decompose the total share by country of origin I calculate the share of intermediate goods coming from each of the two other countries, normalize the sum to one and divide the share of total intermediate goods using the relative weights obtained. This normalization is necessary because the percentage of intermediate imports from countries other than the two considered is, in general, large. The share of foreign goods in total consumption is obtained by summing up the value of imports of food, beverages and nondurables goods and dividing by the value of consumption of nondurable goods and services in each economy. The share of foreign consumption goods by country of origin is computed using the same procedure used to obtain each country's share of intermediate imports.

The value for the share of nondurable goods and services coming from abroad used by Schlagenhauf (1989) (= 0.157) is higher than the one employed here. However, his measure uses total imports and it is biased upward since it also contains items like transport equipment which cannot be considered either nondurable or final goods. One should also note that the values used here are somewhat downward biased because no direct measure of the flow of services from foreign produced durable goods is available. This may be an important source of misspecification at least for the US, where consumption of Japanese and German durables is substantial.[4]

As in Christiano and Eichenbaum (1992) and Backus, Kehoe and Kydland (1991), I consider primarily the case of ϕ=0 but I examine the sensitivity of the results to modifications of this parameter. Similarly, $\eta_{i,j}$ are chosen so that the investment–capital ratio is sensitive to changes in Tobin's Q but I experiment with two other specifications where the investment capital ratio is less responsive. In principle, one could estimate this elasticity parameter from moment conditions involving the variability of investment. However, because the model contains multiple investment goods and because no disaggregated investment data exist, no fruitful estimation seems possible.

Finally, I assume that the three countries receive weights in the social planner problem which are approximately proportional to their population in 1960. Because the size of the country in the world economy has some effect on the time series correlations of saving and investment within countries (see Baxter and Crucini (1992) or Head (1992)), I also examine how the properties of transmission are affected when these weights change.

5.2 Some Simulation Results

Figure 3 presents the responses of the three outputs to a one standard error output shock in country 1 when the economy is driven by technology shocks (panel 1) or when it is driven by government shocks (panel 2) for the case of three identical countries. In each case I present the point estimate of response. To reduce the importance of small sample biases, the length of the simulated time series is T=6000. To facilitate the comparison with the actual data, I superimpose on these responses the same 95% confidence band depicted in figure 1 when US GDP is shocked. The parameters selected for this baseline situation are those presented in table 2 for the US and the social planner weights are the same for each country.[5]

[4]Luckily, it turns out that the results of the simulations are essentially insensitive to the exact setting of utility parameters within the range of existing values used in the literature.

[5]For technology shocks the standard error is 0.0102, the serial correlation 0.95 and the cross country contemporaneous correlation 0.25. For government shocks the standard error is 0.0156,

When the economy is driven by technology shocks the effect due to the common contemporaneous correlation of shocks is strong in the short run and features of the transmission via production interdependencies play some role in determining the shape of the responses in the medium–long run. Not surprisingly, given the small share of foreign goods in consumption, consumption interdependencies play a negligible role.

When government expenditure shocks are the source of fluctuations, the effect due to common disturbances is responsible for the initial dynamics but the transmission via trade in final goods is dominant. In particular, we observe a lagged peak response in the country experiencing the shock, a delayed peak in country 2 and a sizable cyclical response in countries 2 and 3.

But apart from these differences, the two model specifications generate impulse responses which are qualitatively very similar. As a consequence, both the model driven by technology or government expenditure shocks can qualitatively account for aspects of the "locomotive role" of the US economy. Positive output shocks in country 1 are in fact associated with instantaneous positive foreign responses, a lagged peak response in country 2 and significant multiplier effects in two of the three countries. In addition, a model driven by government disturbances generates a lagged peak response in the country experiencing the shock, a feature which appears to be important in the case of actual US output shocks. Note also that, quantitatively, the responses for all three countries are not significantly different from the actual ones. Both specifications, however, are poor in other dimensions. The most obvious one is the inability of the model to account for the large and positive response of Japanese output to US output shocks. Quantitatively speaking, the current specification of the model is also unable to capture cycle lengths and the turning points of the cycle as depicted in figure 1: the cycles in simulated data are somewhat too short and the timing of turning points is off by a few quarters.[6]

5.3 Sensitivity Analysis

To examine whether the features of the propagation of output shocks just described are robust, I next undertake a sensitivity analysis on those parameters which are chosen a–priori or measured with substantial error. Summary statistics for the baseline case discussed in section 5.2 and for 7 other experiments are presented in table 3.

Experiment 1 considers a situation where private and public consumption are imperfectly substitutable in the utility of domestic agents, i.e., $\phi = 0.5$. Experiment 2 examines the situation where consumers are very risk averse, i.e., $\sigma = 10$. Experiment 3 covers the case of a lower discount factor, i.e., $\beta = 0.96$, so that the

the serial correlation 0.98 and the cross country contemporaneous correlation 0.20.

[6]To be fair one should note that because of the large standard error bands surrounding actual mean responses, the peak in the mean response of Japanese output at lag 18 is not significantly different from zero or from 2.5. Also, because of this uncertainty, turning points can be identified only with a 3–4 quarter error.

annualized steady state real interest rate is 7.75 % (up from 4.56 % in the baseline case). In experiment 4 no distortionary taxes are levied on output, i.e., $\tau_h = 0.0\ \forall h$. Experiment 5 considers an economy where exogenous shocks are serially uncorrelated, i.e., $\rho_g = \rho_a = 0.0$. Experiment 6 presents the case when the elasticity of the investment–capital ratio to Tobin's Q is lower, i.e., $\eta(h,j)^{-1} = -0.005,\ \forall h,j$. Experiment 7 covers a situation where installing capital in the location where it is produced entails lower costs than moving it from another location, i.e., $\eta(h,j)^{-1} = -0.01, \eta(h,h)^{-1} = -0.0001$. Finally, in experiment 8 we present a situation where two of the three countries trade their own capital goods more easily. In this case, i.e., $\eta(h,j)^{-1} = -0.0001$ if h,j=1,2 or h=j=3 and $\eta(h,j)^{-1} = -0.01$ otherwise.

Making government expenditure a better substitute for private consumption changes the magnitude of domestic and foreign responses but the qualitative features of the transmission are maintained. In particular, shocks are less persistent over time and output responses across countries display smaller swings. Intuitively this occurs because, an increase in government expenditure has two effects on consumption. The first one is through the resource constraint, as in the case $\phi = 0.0$. The second occurs because an increase in government expenditure increases current utility of domestic agents therefore reducing the incentive to substitute leisure and the magnitude of increases in future outputs. This implies that, ceteris paribus, shocks are less persistent and have smaller international repercussions both in terms of total multipliers and amplitude of the fluctuations. The changes in agents' leisure profile obviously depend on the persistence of government expenditure shocks. For the highly persistent shocks we have input into the model the relative importance of this second effect is rather small for values of ϕ up to 0.7. Hence this modification produces minor changes on the transmission of disturbances from the baseline case.

Increasing σ_h or decreasing β has similar effects on the transmission of shocks. When σ_h is high, the dynamics which follow an output shock are reduced because agents are less willing to substitute intertemporally. Hence, positive technology or negative government shocks result in lower total investment than otherwise, less persistent domestic responses and a weaker and less persistent spillover to other countries. Similarly, with a lower β agents are less patient relative to the baseline case and wish to consume more today relative to the future. As a result, when a positive technology shock hits the economy more impatient agents will invest less and when a negative government shock occurs the intertemporal substitution from current to future leisure is magnified resulting in a lower profile of future output growth as compared to the baseline case. In both instances, higher impatience in consumption desires induces weaker persistence, smaller own multiplier and a reduced international transmission of disturbances. In practice, both of these effects appear to be small and apart from minor numerical differences (primarily due to a drop in country 1's investments to the other countries), none of the qualitative features of the results is sensitive to the choice of these parameters.

Changes in τ from 0 to 50% have essentially no effects on the persistence of output responses and on their transmission across countries when the economy is driven by technology shocks. When government spending disturbances are the source of fluctuations and there are no distorting taxes, agents tend to enjoy good times domestically so that the wealth effect due to the spillover of the shocks to other countries is smaller than in the baseline case. But also in this case the differences in the qualitative features of the propagation of shocks are small.

When shocks are serially uncorrelated, the impulse response function is substantially modified: shocks die out quickly, spillovers are small, apart from the initial contemporaneous effect, multiplier effects are insignificant and the location and magnitude of turning points change. Note that when government shocks are zero $\forall t$, $\delta = 1.0$, $\alpha_{hj} = \theta_{hj} = 0 \ \forall j \neq h$ and $\sigma_h = 1.0$, this economy is similar to the one examined by Long and Plosser (1983) in a domestic framework and Cantor and Mark (1988) in an international framework. They assert that with iid technology shocks, the model can generate output comovements across sectors or countries. This experiment demonstrates that although output disturbances are not transmitted over time or across countries, comovements in the cyclical component of output do exist (the contemporaneous correlation of outputs is around 0.70). But they are a high frequency not a business cycle phenomena.

Variations in η change substantially the features of the propagation of output disturbances. When the elasticity of the investment–capital ratio to changes in Tobin's Q is smaller positive output shocks result in less investment both domestically and abroad, independently of the source of disturbance. This is intuitive. If the cost of installing new capital is higher, agents prefer to consume more now and less in the future to avoid incurring the deadweight loss caused by the higher cost. Once again this reduces the persistence of the shocks and their international impact. Also, this feature of the model is independent of the exact value of η employed. For values up to the one of Baxter and Crucini, i.e. $\eta^{-1} = -0.075$, output dynamics are similar.

When installation costs are asymmetric and higher costs have to be paid to install new foreign capital domestically, the features of the transmission are altered but the impact of this modification depends on the source of disturbances of the economy. If technology shocks are responsible, output swings in country 1 are magnified in the medium run as compared with the baseline case. If government shocks drive the economy, minor differences with the baseline case emerge. This is not a surprise since, in this case, production interdependencies play a minor role in the transmission of shocks.

Finally, when two of the countries (say, country 1 and 2) enjoy some kind of proximity which allows them to incur lower transaction costs in importing each other's capital goods, we observe a substantial asymmetry in output responses in country 2 and 3 when technology disturbances drive the economy, with the responses of country 3 fairly close to zero at all horizons. This is to be expected because, as we have seen, investment dynamics are responsible for the international cycle when technology disturbances drive the economy. When we consider government expenditure disturbances, the modification with respect to the baseline case is minor. As in the previous experiment, production interdependences play only a minor role in transmitting government expenditure shocks and the gross flow of capital across borders is of an order of magnitude smaller than the case when technology disturbances drive the economy.

It is worthwhile to note that in these last three experiments the dominant root of the state equations is complex and has a modulus very close to 1. This induces strong cyclical behavior in the three output series and increases the frequency of the swings in the impulse response function.

In sum, although the quantitative results are somewhat sensitive to the choice of parameters, the qualitative properties of the transmission are primarily affected in two cases: when shocks are serially uncorrelated and when the sensitivity of the investment capital ratio to changes in Tobin's Q is high or asymmetric. The first case is of minor empirical relevance since the driving forces of actual economies appear to be strongly serially correlated but the second is more disturbing and suggests the need for a more accurate measurement of the parameters of the adjustment cost functions.

5.4 Heterogeneous Countries

Since a model with three identical countries does not account for some of the features of the output responses presented in figure 1, I next examine its performance when some source of country specific heterogeneity is included. I first consider an experiment where countries differ only in the serial and contemporaneous correlation properties of the shocks. Then I proceed to six additional experiments, which maintain country specific distributions in the exogenous process and add differences in country size (experiment 2), differences in preferences — both in terms of θ_{hj} and σ_h — (experiment 3), differences in fiscal policies (experiment 4) and differences in technologies and growth patterns (experiment 5). Finally, to maintain comparability with other studies I also consider a case when exogenous disturbances display asymmetric, one period cross country feedbacks (experiment 6). Table 4 contains summary statistics. Figure 4 plots the point estimates of the impulse response for the case of technology shocks and figure 5 plots the point estimates of the impulse response for the case of government expenditure shocks for the data generated in experiment 5. To facilitate the comparison with actual data, I superimpose in both pictures the same 95% confidence bands presented in figure 1. Finally, to downplay the importance of sampling variability, I set the length of the simulated time series to T=6000.

When technology shocks drive the economy, the presence of asymmetries in the distribution of disturbances does not dramatically affect the properties of transmission relative to the case where countries are symmetric. The effect due to common shocks still prevails in the short run and the transmission via production interdependencies is dominant in the medium–long run. German and Japan output responses to German shocks are strong and persistence but no sizable effect on US output is notable. Japan output shocks, on the other hand, die out quickly domestically, induce a lagged peak response in the other two countries and generate total multipliers which are small in all three countries. Responses to US output shocks are qualitatively similar to the case of three symmetric countries but some numerical differences emerge.

When government shocks drive the economy, transmission via trade in consumption goods is important, especially in the case of Japanese output shocks. Important asymmetries in output responses and total multipliers are present in this case. For example, positive US output shocks are very persistent domestically, induce jagged responses in German output and the same type of output responses in Japan observed in the case of three symmetric countries. German output shocks have a strong contemporaneous impact on Japan and generate output swings of wide amplitude in that country while inducing strong negative and persistent US responses. Finally, Japan output shocks generate an own lagged peak response, a positive displacement in US output after 5–6 quarters and a minor medium run impact on German output.

It is also important to underscore that the remarkable similarity in the qualitative features of the responses we observed when we have symmetric countries and alternative sources of shocks drive the economy disappear in this case. One major difference is in the response of US and Japanese outputs to a German output shock. US output responses are strongly negative when government disturbances drive the economy, while they are negligibly different from zero when technology shocks do. Japanese output responses are much more cyclical when government disturbances are present.

Another major difference is that when asymmetries in the distribution of exogenous shocks are present, the model with government expenditure shocks fails to generate the type of transmission of US output shocks we see in the data.

Changing the social planner weights from 1/3 for each country to those contained in table 2 has very little influence on the propagation of output shocks across countries. The major difference, as expected, is in the magnitude of US output responses to foreign output shocks, which display fluctuations of somewhat reduced amplitude. Similarly, the addition of country specific preferences, fiscal policies and technologies have only minor impacts on total multipliers and on the location of the turning points when technology shocks drive the economy. When government shocks drive, differences in fiscal policies and in production are somewhat important in determining the magnitude of the peaks and troughs of the cycle, in particular when German output is shocked. But apart from the negative total multiplier effects in US and Japan output following German output shocks, no major change appears.

These results should not come as a surprise: preferences and technologies across countries are too alike to induce substantial differences from the homogeneous case. The case of heterogeneity in fiscal policies is different. Fiscal variables do differ across countries both in terms of steady state percentage of output accounted by government consumption and average tax rates. However, the results appear to be insensitive to differences of these parameters within the cross country range presented in table 2.

Finally, I consider a case where exogenous disturbances display one period cross country feedbacks which are allowed to be asymmetric. Although the distinction between sources and propagation becomes unclear, it is useful to consider this case to maintain comparability with current literature which allows shocks to have a lagged impact across countries. In the appendix I provide estimates of the magnitude of the cross country one period feedbacks of the shocks. Once we include these feedbacks into the model, many features of the results are affected. In particular, the magnitude and, in some cases, the sign of total multipliers, the location and the magnitude of turning points change. The most visible effects are the existence of very strong negative long run output responses when technology shocks drive the economy and of a magnified cross country effect of Japan output shocks when government shocks drive the economy. In general, the presence of feedbacks across shocks does not improve the ability of the model to reproduce the data and creates additional discrepancies between simulated and actual data in some dimensions where the model was sufficiently adequate.

In sum, the presence of heterogeneities does not substantially augment the ability of the model to fit the data and, in some cases, it even worsens the model performance. The transmission effect via trade in final goods dominates the features of the propagation of government shocks, while the transmission effect via trade in intermediate goods still dominates in the case of technology disturbances in the medium–long run. The presence of heterogeneities in the distribution of the exogenous shocks across countries induces some asymmetries in the impulse response functions but such asymmetries are either insufficient to rationalize the wide variety of total multiplier effects which emerge in real data or go in the opposite direction of what one would like. In particular, none of the asymmetries introduced can generate the large domestic response coupled with the modest international effects which we observe following Japan output shocks.

5.5 Consumption Correlations

The relevance of the results so far presented depends on whether the theoretical implications for other variables are also born out by the data. While there is a wealth of information on prices and quantities which can be used for this comparison, here I limit the attention to consumption correlations and leave a more detailed comparison with other aspects of the data to a subsequent paper (Canova (1993)).

The magnitude of the cross country consumption correlations has been the object of intense study in recent years. Backus, Kehoe and Kydland (1992) and Deveraux, Gregory and Smith (1992) have documented that consumption correlations across countries tend to be low and, in general, lower than output correlations, regardless of the way the series are detrended. The inability of a standard two–country–one–good model with complete markets to replicate this fact has prompted Backus, Kehoe and Kydland (1993) to term the magnitude of this correlations an unexplained puzzle. Limiting the type of assets that can be traded across countries helps in reducing theoretical consumption correlations but does not reduce them to realistic levels (see e.g. Baxter and Crucini (1991)).

The model presented in this paper has potentially two channels which may change this results. First, note that the optimality conditions of the social planner problem equalize the marginal utility of consumption bundles across countries. However, because government expenditure enters the utility function of the agents, consumption correlations need not to be perfect since government expenditure affects only domestic residents and therefore plays the role of a non–traded good. The more heavily agents weight domestic goods in consumption and the higher is the substitutability of government expenditure in private consumption, the lower would be consumption correlations unless government consumption expenditures are very highly contemporaneously correlated across countries.[7]

A second channel through which the model may generate low consumption correlations is when there are higher costs to be paid to install foreign capital goods, consumption interdependencies are small and independent technology shocks drive the economy. In the situation we have just described there is no channel to spread the wealth gains induced by positive productivity disturbances across countries since consumers favor domestic goods in consumption and production interdependencies are limited by the presence of asymmetric installation costs. Note that in both these two situations financial markets are still assumed to be complete. Hence, small frictions in the goods markets may be sufficient to prevent an effective risk sharing to take place even when financial markets are complete.

To illustrate numerically these possibilities we have run two experiments: one where uncorrelated government expenditure shocks drive the economy and one where uncorrelated technology shocks drive the economy. In both cases, the parameters are as in table 2 except that in the case of technology disturbances we assume that $\eta_{h,h}^{-1} = -0.0001$ and $\eta_{h,j}^{-1} = -0.1$, and in the case of government expenditure disturbances we assume that $\phi_h = 0.5$. Table 6 presents the results of the two experiments. For the sake of comparison the table also reports the consumption correlations obtained in the baseline experiment presented in table 4 and the actual consumption correlations, after the three consumption series have been linearly detrended.

It is easy to see that in the baseline experiments the simulated correlations are essentially perfect and there is a large discrepancy between simulated and actual correlations. In the two other experiments, the theoretical consumption correlations are smaller. If we push ϕ_h toward 1, consumption correlations are, approximately, of the same order of magnitude as the actual ones. Hence, although the assumption of perfect substitutability of g_{ht} and c_{hht} may not be very realistic, it is clear that the model has the potential to solve this previously unexplained puzzle.

[7]It is however worthed noting that although the correlation of private consumption across countries may be lower, the correlation of aggregate consumption (inclusive of private and government consumption) will be perfect.

6 Conclusions

In this paper I study the generation and the transmission of international business cycles across countries with the aid of a multi-country general equilibrium model with production and consumption interdependencies. The model features two sources of fluctuations and three types of propagation mechanism which may transmit exogenous disturbances across countries. I show how each of the three channels of transmission works for both types of disturbances and find that regardless of the sources of disturbances, the model produces similar output dynamics across countries. The paper then asks whether, with a realistic parameterization, the model can account for the transmission of output shocks which characterizes actual data. I show that both government and technology shocks which are moderately correlated across countries can account for some aspects of the "locomotive" role of the US economy but that government disturbances, which are primarily transmitted via trade in final goods, can replicate the impulse response function of German output shocks better. Sensitivity analysis demonstrates that although the qualitative characteristics of propagation are largely independent of the parameterization, the quantitative features are not. In the experiments with heterogeneous countries I find that either the three countries are too similar to make a difference or that, when there are important differences, they do not bring simulated data more in line with actual ones. I also show that the model has at least two built–in features which have the potential to explain the magnitude of actual cross country consumption correlations.

There are at least three modifications which may improve the ability of the model to account for the data. The first is the inclusion of monetary factors. In the model, changes in government expenditure are matched by changes in lump sum taxes while in the real world either the monetary base or the amount of outstanding nominal bonds is typically varied. In addition, at least in the case of German output shocks, monetary policy may play an important role in altering the features of the transmission. The introduction of country specific monetary policies may therefore improve our understanding of how international business cycles are generated and propagated across countries (see Ricketts and McCurdy (1992) for such an attempt). Second, in the current model technology shocks incorporate both disturbances to the production function and to the terms of trade. If countries respond differently to changes in the terms of trade because of their relative size in the world economy, an explicit modelling of terms of trade disturbances may give a more useful characterization of the sources of international cycles. Third, in the real world labor market agreements substantially differ across countries. In the model, however, a competitive market is assumed in each country and the lack of heterogeneity in labor market characteristics may miss an important channel of asymmetries in the transmission of shocks.

Because the paper has concentrated attention primarily on output dynamics across countries, I have neglected a wealth of empirical information contained in terms of trade, real interest rates, net export and hours data, which may allow us to distinguish which of the two sources of disturbance is responsible for the actual pattern of international business cycles. The model presented in the paper in fact implies that although the two shocks generate similar output dynamics, the responses of terms of trade, net exports and hours will differ depending on the source of disturbances. We examine these implications in detail in a companion paper (see Canova (1993)).

Finally, the model provides answers to the policy questions discussed in the introduction. First, the removal (or the introduction) of trade barriers between US, Japan and Germany is unlikely to change the way outputs comove across countries and how recessions and expansions spread, at least in the first two years of the cycle. Obviously, this does not imply that the changes in trade practices have no effect on the growth patterns of the three countries. Second, and as a consequence of the above, restricting trade practices may not necessarily stabilize domestic fluctuations and may reduce consumer's welfare. Third, the increased fiscal coordination does not seem to be responsible for the increased symmetry in world business cycles in the 80s. According to the model such a change would produce a higher contemporaneous correlation of outputs but it would not change the medium–long run features of the propagation of output responses.

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Table 1
Features of the Transmission of International Business Cycles
Actual Data: Sample 1960,1–1990,4

		US Shocks	German Shocks	Japan Shocks
Peak	US	3 1.32	1 0.00	4 0.20
Response	Germany	3 0.71	1 1.00	5 0.43
	Japan	18 1.36	2 0.12	3 1.00
Total	US	10.91	-5.69	1.53
Multiplier	Germany	9.72	-1.63	4.36
(24 quarters)	Japan	19.33	-16.67	14.99

Note: For peak responses each cell reports first the location and second the magnitude of the peak. The statistics refer to the mean responses obtained using 1000 replications.

Table 2
Parameters of the Model

	US variables	German variables	Japanese variables
	Utility Parameters		
$\theta_{.,1}$	0.29	0.03	0.04
$\theta_{.,2}$	0.01	0.30	0.03
$\theta_{.,3}$	0.01	0.03	0.35
$\theta_{.,4}$	0.69	0.64	0.58
σ	1.97	1.68	2.12
β	0.99	0.99	0.99
ϕ	1.00	1.00	1.00
	Production Parameters		
$\alpha_{.,1}$	0.3200	0.105	0.045
$\alpha_{.,2}$	0.0245	0.272	0.017
$\alpha_{.,3}$	0.0245	0.030	0.408
$\alpha_{.,4}$	0.6310	0.593	0.530
γ	1.008	1.0077	1.016
δ	0.025	0.025	0.025
	Government Parameters		
τ	0.180	0.161	0.120
s_g	0.170	0.180	0.090
	Social Planner Weights		
ω	0.50	0.25	0.25
	Adjustment Cost Parameters		
$\eta_{.,1}^{-1}$	-0.00001	-0.00001	-0.00001
$\eta_{.,2}^{-1}$	-0.00001	-0.00001	-0.00001
$\eta_{.,3}^{-1}$	-0.00001	-0.00001	-0.00001
	Parameters of the Shocks		
ρ_a	0.97	0.95	0.94
ρ_g	0.98	0.81	0.88
$\nu_{a_{1,.}}$		0.28	0.20
$\nu_{a_{2,.}}$			0.39
$\nu_{g_{1,.}}$		0.23	0.10
$\nu_{g_{2,.}}$			0.72
σ_a	0.0102	0.0097	0.0133
σ_g	0.0156	0.0171	0.0375

Note: When government expenditure shocks are considered, $\rho_a = \sigma_a = \nu_{a_{h,j}} = 0.0$. When productivity disturbances are considered, $\rho_g = \sigma_g = \nu_{g_{h,j}} = 0.0$. When we consider symmetric countries, $\rho_a = .95$, $\nu_{a_{i,j}} = 0.25$, $\sigma_{a_1} = 0.0102$ or $\rho_g = .98$, $\nu_{g_{i,j}} = 0.20$, $\sigma_{a_1} = 0.0156$.

Table 3
Features of the Transmission of International Business Cycles
Symmetric Countries

		Technology Shocks	Government Shocks ($\phi = 0.0$)	Government Shocks ($\phi = 0.5$)
		Baseline Case		
Peak Response	Country 1	1 1.00	3 1.54	3 1.41
	Country 2	19 0.40	5 0.45	3 0.62
	Country 3	1 0.27	1 0.31	1 0.36
Total Multiplier (24 quarters)	Country 1	2.30	11.75	9.65
	Country 2	7.08	6.90	3.12
	Country 3	-1.50	-6.63	-4.51
		Experiment 2: $\sigma = 10$		
Peak Response	Country 1	1 1.00	3 1.50	
	Country 2	4 0.50	5 0.34	
	Country 3	1 0.34	1 0.23	
Total Multiplier (24 quarters)	Country 1	2.56	10.85	
	Country 2	7.47	4.52	
	Country 3	-1.44	-4.74	
		Experiment 3: $\beta = 0.96$		
Peak Response	Country 1	1 1.00	3 1.53	
	Country 2	4 0.42	5 0.41	
	Country 3	1 0.29	1 0.21	
Total Multiplier (24 quarters)	Country 1	2.52	9.89	
	Country 2	6.52	5.94	
	Country 3	-1.81	-6.77	
		Experiment 4: $\tau = 0.0$		
Peak Response	Country 1	1 1.00	3 1.53	
	Country 2	19 0.40	17 0.40	
	Country 3	1 0.28	1 0.29	
Total Multiplier (24 quarters)	Country 1	2.38	14.86	
	Country 2	7.15	5.71	
	Country 3	-2.11	-8.09	

Table 3
Features of the Transmission of International Business Cycles
Symmetric Countries

		Technology Shocks	Government Shocks ($\phi = 0.0$)
Experiment 5: $\rho = 0.0$			
Peak	Country 1	1 1.00	1 1.00
Response	Country 2	4 0.23	3 0.24
	Country 3	1 0.25	1 0.18
Total	Country 1	0.48	1.22
Multiplier	Country 2	0.13	0.07
(24 quarters)	Country 3	-0.16	-0.35
Experiment 6: $\eta_{h,j}^{-1} = -0.05$			
Peak	Country 1	1 1.00	1 1.00
Response	Country 2	1 0.27	9 0.50
	Country 3	4 0.46	5 0.35
Total	Country 1	0.97	5.31
Multiplier	Country 2	0.75	-3.82
(24 quarters)	Country 3	-0.43	0.64
Experiment 7: $\eta_{h,h}^{-1} = -0.00001; \eta_{h,j}^{-1} = -0.01$			
Peak	Country 1	1 1.00	2 2.64
Response	Country 2	19 0.83	4 1.63
	Country 3	5 0.20	1 1.34
Total	Country 1	3.92	10.96
Multiplier	Country 2	-1.68	5.40
(24 quarters)	Country 3	-4.00	-1.39
Experiment 8: $\eta_{h,j}^{-1} = -0.00001, \text{ ifh, j} = 1, \text{2orh} = \text{j} = 3 \eta_{h,j}^{-1} = -0.01$ otherwise			
Peak	Country 1	1 1.00	2 1.37
Response	Country 2	14 0.78	3 0.92
	Country 3	5 0.05	1 0.12
Total	Country 1	4.87	8.09
Multiplier	Country 2	3.45	6.36
(24 quarters)	Country 3	-0.13	-0.29

Note: For peak responses each cell reports first the location and second the magnitude of the peak.

Table 4
Features of the Transmission of International Business Cycles
Heterogeneous Countries

		Technology Shocks			Government Shock		
		US Shocks	German Shocks	Japan Shocks	US Shocks	German Shocks	Japan Shocks
Experiment 1: Differences in Exogenous Shocks							
Peak	US	1 1.00	14 0.12	10 0.34	3 1.73	1 0.19	5 0.26
Response	Germany	4 0.46	1 1.00	4 0.13	1 0.19	1 1.00	16 0.02
	Japan	1 0.27	3 0.65	1 1.00	1 0.19	1 2.03	3 1.26
Total	US	2.37	1.26	2.10	25.82	-23.33	-1.92
Multiplier	Germany	5.09	12.02	-2.32	1.44	4.19	-1.05
(24 quarters)	Japan	-0.93	7.91	3.04	-6.52	4.17	8.29
Experiment 2: Differences in Exogenous Shocks and Social Planner Weights							
Peak	US	1 1.00	14 0.16	10 0.38	3 1.67	1 0.00	5 0.05
Response	Germany	4 0.37	1 1.00	4 0.13	1 0.23	1 1.00	2 0.03
	Japan	24 0.26	3 0.60	1 1.00	3 0.37	1 2.00	3 1.25
Total	US	2.38	2.14	1.89	25.67	-19.48	-3.09
Multiplier	Germany	5.06	12.98	-3.35	0.93	4.82	-1.30
(24 quarters)	Japan	-0.89	8.76	2.29	-5.30	3.11	8.17
Experiment 3: Differences in Exogenous Shocks and Preferences							
Peak	US	1 1.00	14 0.12	10 0.35	3 1.59	1 0.00	5 0.14
Response	Germany	4 0.44	1 1.00	4 0.12	1 0.18	1 1.00	16 0.05
	Japan	1 0.30	3 0.59	1 1.00	3 0.26	1 1.46	3 1.27
Total	US	1.94	1.49	1.88	23.96	-22.40	-4.87
Multiplier	Germany	5.32	11.32	-2.50	- 0.03	5.23	-0.69
(24 quarters)	Japan	-0.66	8.55	2.13	-4.87	2.57	8.52

... contd.

(... contd. Table 4)
Features of the Transmission of International Business Cycles
Heterogeneous Countries

		Technology Shocks			Government Shock		
		US Shocks	German Shocks	Japan Shocks	US Shocks	German Shocks	Japan Shocks
Experiment 4: Differences in Exogenous Shocks and Fiscal Policies							
Peak	US	1 1.00	14 0.15	10 0.32	3 1.68	1 0.00	5 0.51
Response	Germany	4 0.47	1 1.00	4 0.10	1 0.19	1 1.00	7 0.12
	Japan	1 0.33	3 0.71	1 1.00	1 0.12	1 0.98	3 1.38
Total	US	2.26	1.71	1.72	25.64	-19.83	-6.07
Multiplier	Germany	5.98	12.80	-2.90	0.54	4.43	-0.53
(24 quarters)	Japan	-1.69	9.58	2.30	-5.03	1.67	10.14
Experiment 5: Differences in Exogenous Shocks, Technologies and Growth							
Peak	US	1 1.00	14 0.14	10 0.39	4 1.75	1 0.00	1 0.00
Response	Germany	4 0.37	1 1.00	4 0.13	1 0.12	1 1.00	7 0.11
	Japan	24 0.27	3 0.64	1 1.00	3 0.33	1 1.21	2 1.31
Total	US	2.17	1.13	2.27	27.35	-19.55	-9.87
Multiplier	Germany	5.78	13.39	-3.98	-2.03	6.66	0.19
(24 quarters)	Japan	-1.22	4.17	2.04	-4.20	-1.25	9.15
Experiment 6: Feedbacks in the Exogenous Processes							
Peak	US	1 1.00	9 0.04	12 0.66	3 1.63	1 0.00	7 0.14
Response	Germany	8 0.67	1 1.00	24 0.36	3 0.448	1 1.00	5 1.04
	Japan	6 0.14	1 0.74	4 1.10	17 0.54	1 1.82	5 2.57
Total	US	-3.93	-4.74	9.73	20.92	-15.49	-21.16
Multiplier	Germany	9.47	10.11	5.39	3.86	4.41	13.00
(24 quarters)	Japan	-5.78	0.37	14.32	0.41	12.29	38.80

Note: For peak responses each cell reports first the location and second the magnitude of the peak.

Table 5: Consumption Correlations

	Corr(C_{US}, C_{WG})			Corr(C_{US}, C_{JAP})			Corr(C_{WG}, C_{JAP})		
	-1	0	1	-1	0	1	-1	0	1
Actual	0.26	0.31	0.12	0.09	0.20	-0.01	0.56	0.67	0.54
Baseline 1	0.92	0.93	0.91	0.95	0.97	0.96	0.92	0.92	0.91
Baseline 2	0.98	0.99	0.99	0.99	0.99	0.99	0.98	0.99	0.98
$\phi_h = 0.5$	0.48	0.56	0.46	0.40	0.50	0.40	0.84	0.92	0.86
$\eta_{h,j} = -0.1$	0.62	0.72	0.69	0.80	0.85	0.91	0.88	0.88	0.89

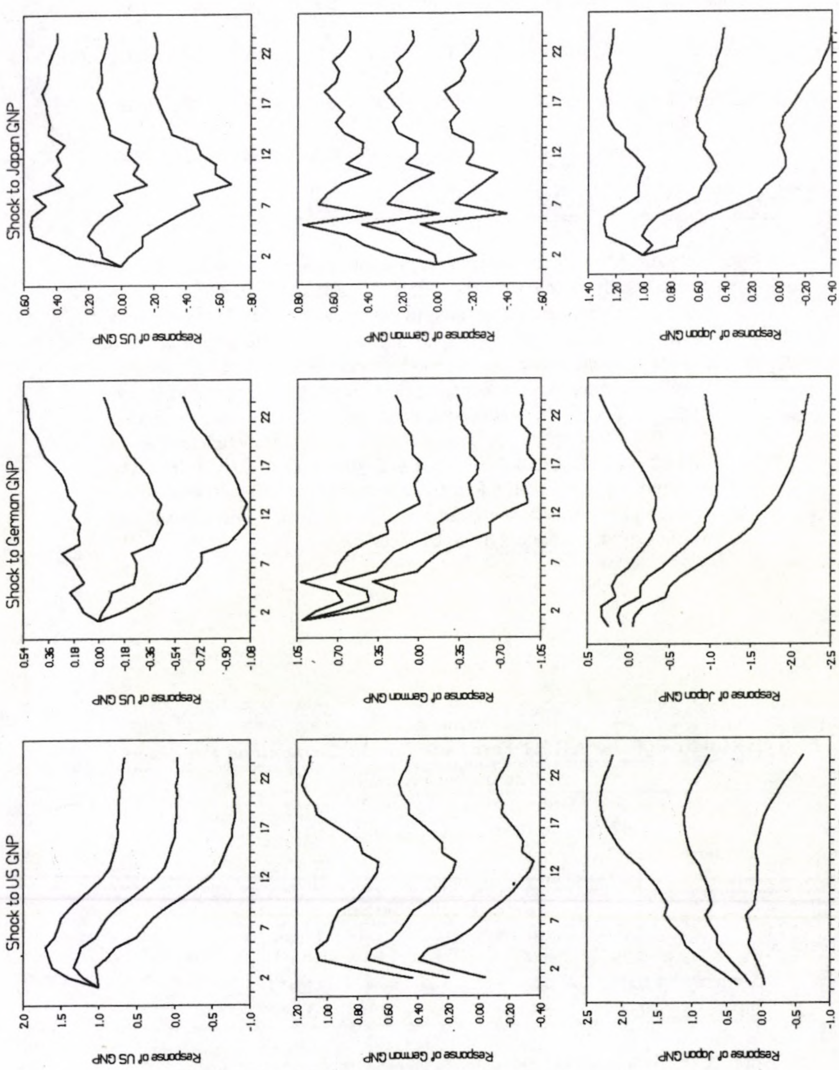
Note: Actual refers to consumption correlation obtained from actual data after linearly detrending the series. Baseline 1 refers to the consumption correlations generated in experiment 5 with heterogeneous countries (differences in exogenous processes, technologies, growth patterns, fiscal variables and preferences) and technology shocks. Baseline 2 refers to the consumption correlations generated in experiment 5 with heterogeneous countries and government shocks. $\phi = 0.5$ refers to an experiment where the parameters are as in table 2, except that $\phi_h = 0.5\ \forall h$ and government shocks drive the economy. $\eta_{i,j} = -0.1$ refers to an experiment where the parameters are as in table 2, there are high costs to install new capital and technology disturbances drive the economy.

Appendix

Table A.1
Estimates of the AR(1) Feedback for the Exogenous Processes

	US	Germany	Japan
Technology Shocks			
US	0.97	-0.10	0.08
Germany	0.11(*)	0.95	-0.03
Japan	0.12(*)	-0.10	0.94
Government Shocks			
	US	Germany	Japan
US	0.98	0.14(*)	-0.09(*)
Germany	0.03	0.81	0.11(*)
Japan	-0.004	0.15	0.88

Note: A (*) indicates that the value is significant at the 5% level.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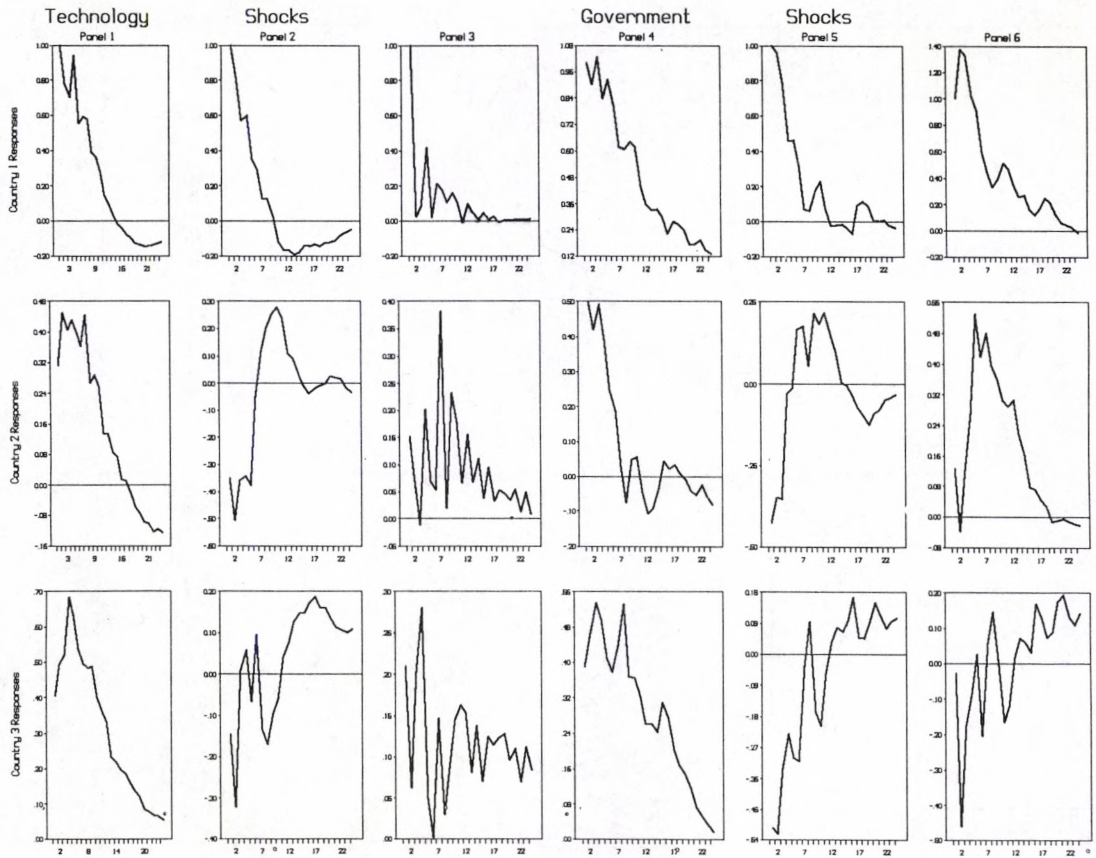
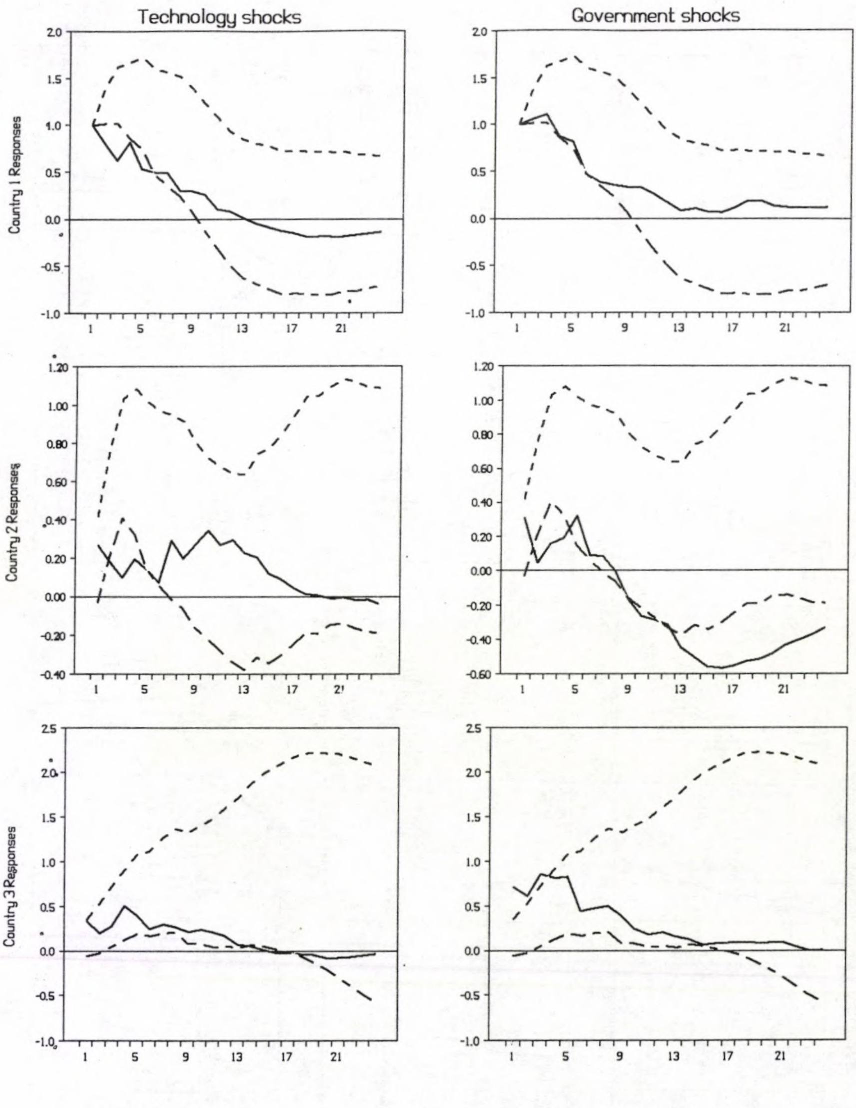
Shock to German GNP
Shock to Japan GNP
Response of US GNP
Response of German GNP
Response of Japan GNP


Technology
Shocks
Government
Shocks
Panel 1
Panel 2
Panel 3
Panel 4
Panel 5
Panel 6
Country 1 Responses
Country 2 Responses
Country 3 Responses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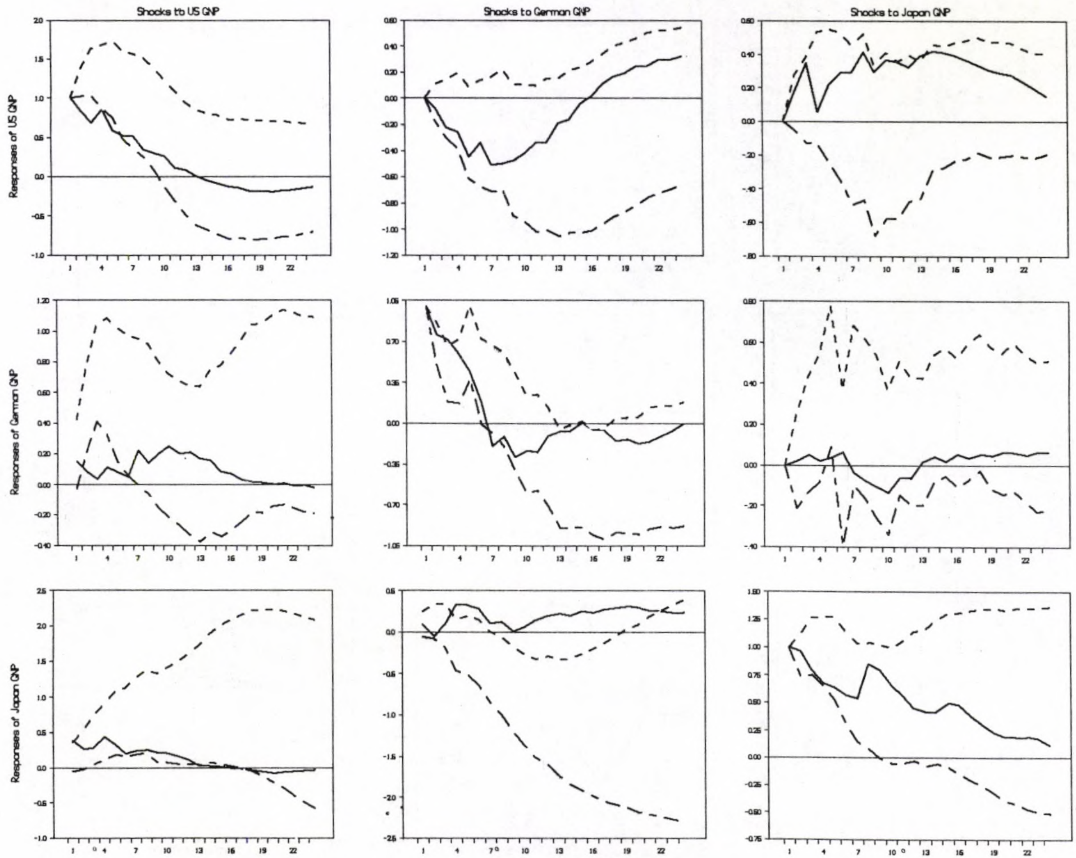
Country 1 Responses
Country 2 Responses
Country 3 Responses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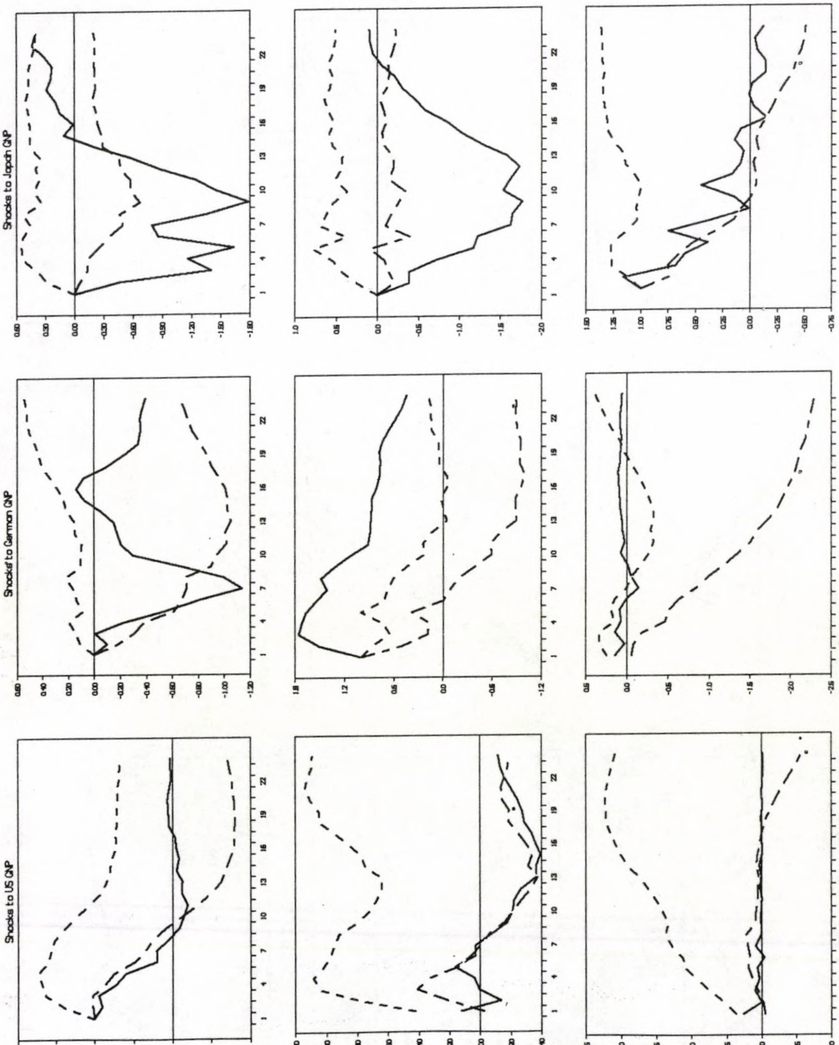
Shocks to German GNP
Shocks to Japan GNP
Responses of US GNP
Responses of German GNP
Responses of Japan GNP


Shocks to US GNP
Shocks to German GNP
Shocks to Japan GNP

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