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Sources and Propagation of International Output Cycles: Common Shocks or Transmission?

by

Fabio Canova*
Jane Marrinan **

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* Università degli Studi di Modena
Dipartimento di Economia Politica
Viale Berengario, 51
41100 Modena (Italia)
e – mail: canova@unimo.it

** Universitat Pompeu Fabra
Barcelona

Abstract

This paper studies the generation and transmission of international cycles in a multi-country model with production and consumption interdependencies. Two sources of disturbance are considered and three channels of propagation are compared. Technology disturbances, which are mildly correlated across countries, are more successful than government expenditure disturbances in reproducing actual data. The presence of a common component to the shocks and of production interdependencies appear to be crucial in quantitatively matching the properties of the data.

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We share the uncommonness of being different — J.P. Roche

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 Gregory, Head and Raynauld (1995) among others, have documented the existence of commonalities in economic activity across countries using a variety of methods. Economic similarities can be accounted for by the presence of 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 economic activity are primarily attributable to demand or supply disturbances is a long standing question that 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 others) but the answers provided have often been 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 (see e.g. Cantor and Mark (1988) or Canova and Dellas (1993)).

Knowledge of what generates and transmits cycles across countries is important for policy purposes. The issues surrounding the problem of generation are well understood. If, as widely perceived, output fluctuations are undesirable and foreign demand shocks are largely responsible, there may be a role for aggregate Keynesian-type policies cushioning the economy from foreign disturbances. On the other hand, as often emphasized in the real business cycle literature, if cyclical fluctuations in economic activity are the optimal response to unforeseen disturbances of both domestic and foreign origin, rather than mitigating fluctuations per se, a more appropriate role for the government is to reduce economically relevant uncertainties.

Identifying the channels of international propagation is also crucial. For example, in designing 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 or financial markets. In addition free trade agreements, which have generated considerable debate in policy circles in the last few years, will have a different impact on the cyclical properties of output depending on whether and how disturbances are transmitted.

The empirical evidence regarding these issues is somewhat scant. Canova and Dellas (1993) document that trade interdependencies in intermediate goods are important in explaining the transmission of country specific disturbances in post WWII data. They also find that after 1973 the presence of common disturbances plays a role in accounting for international output comovements. Cole and Obstfeld (1991), Backus, Kehoe and Kydland (1992) and Crucini and Baxter (1995) suggest that international risk sharing occurs primarily through the goods markets and that the welfare loss due to incomplete or autarkic financial markets appears to be small.

This paper contributes to the debate by building 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 trade interdependencies in both intermediate and final goods in transmitting shocks across countries. The model employed, which is described in section 2, is general and differs from those of Cantor and Mark (1988), Mendoza (1991a), Backus, Kehoe and Kydland (1992), Baxter and Crucini (1993) or Stockman and Tesar (1994) in at least three 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, foreign capital is used as an intermediate good in the production of domestic final goods. Allowing for production interdependencies introduces an important and previously neglected channel through which country-specific disturbances can be propagated across countries.

One type of disturbance we consider 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 across countries because they modify the flow of consumption services accruing to domestic households. Consequently, governments influence trade of final goods, as consumers substitute foreign to domestic goods in response to the disturbances, affect trade of intermediate goods, as consumers substitute leisure intertemporally and change investment patterns, and alter production levels around the world (see Ashauer (1989) for an empirical documentation of a closed economy version of this effect for the US economy).

A second type of disturbance is modelled as an exogenous technology disturbance. These shocks affect the marginal product of factors of production, influence investment opportunities within each country and alter trade of final goods because of income effects. One crucial difference between the two sources of disturbances is in the way they impact on trade flows: government shocks first alter net exports of consumption goods and later on net exports of investment goods as leisure choices change. For technology shocks the order is reversed.

The stylized properties of the actual data are summarized in section 3 using statistics based on the impulse response function of outputs. In this we follow Cogley and Nason (1995) and we extend their point of view by looking at the international interaction of output persistence. The statistics used measure the location and the size of the peak response, the length of the expansion phase and the total impact multipliers following a (reduced form) output shock.

Section 4 describes how the two types of 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 and no trade in either investment or consumption goods occur - and discusses the properties of the spillover mechanism in each case.

Section 5 asks whether a realistic parameterization of the model is able to reproduce the main features of the actual impulse response function of output. In particular, we are interested in knowing which of the two disturbances generate summary statistics for simulated output responses which are similar to those of the actual data and through what channel they act.

The results indicate that, when the model is parametrized so that the three countries all resemble the US, knowledge of the source of fluctuations is somewhat irrelevant in determining the qualitative features of the propagation of output shocks across countries. Both disturbances generate a delayed peak response in foreign outputss which is similar in location and magnitude to the one observed in the actual data. However, government expenditure disturbances can also generate a delayed peak response in the country experiencing the shock, a feature which is not present when technology shocks drive the cycle. Both models also fail to reproduce the magnitude and the asymmetries of total multipliers and the length of the expansion phase. Quantitatively, a model with government expenditude shocks accounts for Us and German output dynamics better than a model with techonlogy disturbances, while for Japan the ordering is reversed. Also, among the three channels of transmission, it is the presence of a common component to the shocks which best accounts for output dynamics.

The inclusion of cross-country heterogeneities, in particular heterogeneity in the distribution of the exogenous processes, is important in generating asymmetries in simulated total multipliers and improves somewhat the quantitative performance of the model. With a country-specific parameterization, the model with technology disturbances accounts best for the propagation of German and Japan output shocks while for US output shocks the performance of the two versions of the model is similar. Once again the presence of a common component to the shocks is important in quantitatively reproducing actual data but now the importance of production interdependence is substantially increased. Section 6 concludes.

2 The Model

We consider a N country model with N consumption goods, where each country specializes 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)).

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:

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

with $c^*_{hjt} = c_{hjt} + \phi_h g_{ht}$ if $h = j$ and $c^*_{hjt} = c_{hjt}$ if $h \neq j$, 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 agent of its own country (as in e.g. Baxter and King (1993)). When $\phi_h = 0$ government h consumption expenditure does not affect utility, while for $\phi_h = 1$, government and private domestic consumption are perfect substitutes. One way to rationalize our specification, is to think of the government as having a linear technology, $m_t = \phi_h g_{ht}$, through which it produces services for private use. If $\phi_h < 1$, it is costly for the society to have the government provide these consumption services.

Consumption goods are produced according to:

$$Y_{ht} = A_{ht}(\prod_{j=1}^{N} K_{hjt}^{\alpha_{hj}})(X_{ht}N_{ht})^{1-\sum_{j=1}^{N}\alpha_{hj}} \qquad \forall\ h,\ j \tag{2}$$

where $X_{ht} = \gamma_h X_{ht-1}$ with $\gamma_h \geq 1\ \forall h$. X_{ht} represents 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 an intermediate input produced in country j is not used in producing final goods in country h, $\alpha_{hj} = 0$. Intermediate capital goods are accumulated according to:

$$K_{hjt+1} = (1-\delta_j)K_{hjt} + \psi(I_{hjt}/K_{hjt})K_{hjt} \qquad \forall\ h,\ j \tag{3}$$

where $\psi(\frac{I_{hjt}}{K_{hjt}})$ represents the cost in country h of using intermediate capital inputs produced in country j and satisfies $\psi \geq 0,\ \psi' \geq 0,\ \psi'' \leq 0$.

Mendoza (1991a), Backus, Kehoe and Kydland (1992) and Baxter and Crucini (1993) 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 that of Baxter and Crucini (1993) and was chosen because it retains simplicity, while linking transaction costs to Tobin's Q. $[\psi'(\frac{I_{hjt}}{K_{hjt}})]^{-1}$ is in fact Tobin's Q, i.e. the price of existing capital in location h relative to the price of new capital produced in 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 (so that $I_{hj} > 0$), but there may also be a contemporaneous flow in the opposite direction as investments in intermediate goods used by other countries (say, I_{jh}) increase with domestic wealth.

Leisure choices are constrained by:

$$0 \leq l_{ht} + N_{ht} \leq 1 \qquad \forall\ h \tag{4}$$

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

To ensure a balanced growth path with a stationary distribution of wealth, we assume that $\beta = \beta_h \mu_h$ and $\gamma_h \mu_h = \gamma \ \forall h$ 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 recent literature (see e.g. Dotsey (1990)) models tax rates as stochastic, we adopt a parametric representation in order to isolate the contribution of government expenditure disturbances to the international transmission of business cycles. The government budget constraint is given by:

$$g_{ht} = TR_{ht} + \tau_h Y_{ht} \qquad \forall \ h \tag{5}$$

where τ_h is the tax rate and TR_h transfers in country h. The resource constraints are:

$$Y_{ht} - g_{ht} - \sum_j c_{jht} - \sum_j k_{jht+1} \geq - \sum_j (1 - \delta_h) k_{jht} \ \ \forall \ h \tag{6}$$

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

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

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

To find a solution we first detrend those variables drifting over time, then 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 (as in Baxter and Crucini (1993)). The weights ω_h in the planner problem are chosen to be proportional to the initial population in 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).

Reynolds (1992) has used a model with some of the same features to study 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 equations.

3 Some Empirical Evidence

One way to address the questions we have posed in the introduction is to identify at least one source of domestic and international supply shock and one source of domestic and international demand shock in the actual data using restrictions derived from the model and then examine their international propagation. The restrictions could take the form of short-run (see Canova (1991)), long-run (see Amhed, et al. (1993)) or shape constraints. However, as is clear from the description of the model, the imposition of constraints of this type will not provide a definitive answer to the questions we care about since different versions of the model are consistent with the same set of restrictions on domestic and international variables.

To fully exploit the general equilibrium nature of our model and its rich set of constraints we take an alternative approach. We identify semi-structural shocks from the actual data using arbitrary restrictions and compare the resulting impulse response function with the one obtained from data simulated from different specifications of the model where shocks are identified using the same arbitrary restrictions. In other words, we use the impulse response function as a "window" to measure the quality of the model approximation to the data.

We chose to report impulse responses, as opposed to simple correlations, to link the analysis with the large body of statistical literature which characterizes business cycles using durations and turning point classifications (see e.g., Diebold and Rudebush (1992)). In addition, we narrowly focus attention on the interdependences of the cyclical components of national outputs for two reasons. First, multicountry VAR models containing many variables are imprecisely estimated with short samples and therefore difficult to interpret (see Gregory, Head and Raynauld (1995) for such an attempt). Second, since there is a tradition in the literature studying the properties of domestic output persistence (see, e.g., Cogley and Nason (1995)), it seems worthwhile to focus attention on the international interactions of output persistence.

Since we are interested in studying the performance of the model for major world trading blocks, we examine the transmission features of output shocks in the US, Germany and Japan. To characterize the cyclical transmission of output shocks it is necessary to detrend the series and questions arise as to how to best extract the long-run component of the data. Canova (1994) indicates that alternative detrending methods impose different assumptions on the underlying structure of the time series, 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, we use here an economic-based decomposition. Since in the model all variables in country h, except hours, grow deterministically at the rate of labor-augmenting technological change γ_h, we extract a country-specific deterministic trend from the log of raw output data. While this choice is arbitrary, in the sense that an alternative (say, a unit root) assumption on the properties of exogenous technological progress may be as sensible, it provides useful restrictions on the cyclical properties of actual data and imposes discipline in simulation exercises.

Quarterly real GDP data for the three countries is taken from OECD tapes, covers the sample 1960,1-1994,4 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. We estimate a VAR with 9 lags and a constant on the log of detrended outputs and report responses when the contemporaneous correlation matrix of the shocks is triangularized in the order US, Germany and Japan outputs.

Two potential problems should be mentioned before the evidence can be interpreted: the impulse response function may not be stable over the sample and the properties of the transmission may not be robust to the ordering of the triangularization. Evidence (available on request) shows that (i) apart from Japanese output in 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 impulse responses are approximately stable across subsamples and (iii) the properties of the transmission are independent of the ordering of the triangularization.

Figure 1 plots the mean estimate of the impulse response function together with the upper and lower limits of a 95% Monte Carlo band. Table 1 reports statistics summarizing the main features of transmission: the size and the location of the peak response of the three variables, the length of the expansion phase and the magnitude of the cumulative multipliers. Several interesting features emerge. First, US output shocks have significantly large and positive international impacts while this is not the case for Japanese and German output shocks. Second, it takes time for a shock to be transmitted across countries and the return to the trend line is very slow in all cases. For example, the peak response of German output lags a US output shock by three quarters and the peak response of Japanese output lags by eighteen quarters. Third, the durations of the cycles differ depending on the origin of the shocks. For example, US output shocks generate fluctuations lasting 4-6 years while Japanese output shocks produce very short and irregular cycles. Finally, point estimates of the cumulative multipliers are very asymmetric. A 1% surprise increase in the log of detrended US output generates a 10.91% cumulative response in US output after 24 periods, a 9.72% cumulative response in German output and a large 19.33% cumulative response in Japanese output, while 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 this evidence. First, there exists an international transmission of disturbances but, except for 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, leading credence to 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 run, while Japanese output shocks have modest international impacts. Second, the cross-country propagation of output shocks takes time, with the lag in the peak response varying from 2 to 18 quarters, and cycle durations differ depending on the national origin of the shocks.

4 The Properties of the Model

Since the model we consider has not yet been studied in the literature and since its transmission properties are more complex than the ones obtained in one-good economies (see e.g. Backus, Kehoe and Kydland (1992) or Baxter and Crucini (1993)) and in multigood economies where only domestic capital is used in production (see e.g. Schlagenhauf (1989)), we start by first summarizing the qualitative properties of the transmission of shocks in existing models and then describe how different propagation channels amplify and transmit disturbances in our model.

In a one-good world an idiosyncratic positive persistent domestic technological disturbance raises the productivity of domestic factors of production, along with domestic investment, hours and output and, to a lesser extent, domestic consumption because of permanent income considerations. Because of the one-good assumption, capital will flow to the most productive location (the magnitude of the 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. Also, when capital markets are perfect and the utility function is separable in consumption and leisure, risk sharing implies that consumption profiles will be perfectly correlated across countries and that, once the initial inflow of capital goods is exhausted, the current account of the country experiencing the shocks will show a surplus. Hence, one-good models generate cross country output responses of opposite signs and transmission occurs because of substitution and income effects that occur in the market for investment goods.

An idiosyncratic positive persistent government shock, which yields no utility for domestic consumers and leaves the 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 (1995)). Note that because of risk sharing foreign consumption will also be crowded out. In this case, output responses will be positively correlated across countries, will reach their peak a few periods after the shock and transmission occurs because of the consumption risk sharing scheme which is in place.

These features of the domestic and international transmission appear to be robust to several modifications of the basic framework. For example, Mendoza (1991b), Backus, Kehoe and

Kydland (1992), Baxter and Crucini (1995) show that dispensing with complete capital markets slightly reduces cross-country consumption correlations without affecting 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 costs of moving capital, introducing time to ship or changing the size of the countries changes the magnitude of foreign responses but not their qualitative features. Finally, Costello (1991) shows that the same international propagation obtains in a two-sector model where each country produces both consumption and investment goods but only investment goods are traded.

In Schlagenhauf's (1989) model investment dynamics do not drive the cycle because the investment good is nontraded (see also Stockman and Tesar (1994)). Instead, idiosyncratic shocks are propagated to the world economy because of consumption interdependencies. When a positive and persistent disturbance increases domestic output, consumption of both domestic and foreign goods by domestic residents increases. The increase in demand and the risk sharing arrangement imply that consumption of foreign goods will go up in all countries, depressing foreign investments and future foreign output. Hence, although cross-country output correlations are negative 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 operates in a small open economy faced with exogenous productivity disturbances.

In the model considered here there are three reasons why domestic disturbances may result in a temporary displacement of foreign outputs from their trend: shocks may be correlated across countries, independent shocks may be transmitted through production interdependencies or consumption interdependencies. Figure 2 displays how the transmission mechanism works in each of these situations when the three countries are symmetric: the first three panels show output responses when technology disturbances are present and the last three panels output responses when government disturbances which yield no utility for agents are present (table 2 gives the exact parametrization in each of the three cases). In all cases time series of length T=6000 were generated from the model, a VAR with 9 lags was fit to detrended outputs and empirical impulse responses following an output shock in country 1 were computed triangularizing the system in the order country 1, 2 and 3 The sample size is chosen to be very large to eliminate sampling variability in the impulse response estimates and empirical responses (as opposed to "population" responses (see e.g. King, Plosser and Rebelo (1988))) are used in order to maintain comparability with the responses of figure 1.

Consider first a situation where there are three completely separate economies which move together because of correlated disturbances (panels 1 and 4 of figure 2). In this case, the domestic dynamics are the same as in a closed economy (see e.g. King, Plosser and Rebelo (1988) and Aiyagari, Eichenbaum and Christiano (1992)). Two features of the cross-country output responses need to be noted. First, the model generates the same type of short-run output responses regardless of the source of structural disturbances. In particular, in both cases a positive output shock in country one is associated with positive output responses in other countries and a slow return to the steady state position; a peak response lagging the initial shock 3-6 quarters in all countries and an expansion phase which is approximately the same length in the two cases. Second, it is possible to distinguish between the two sources of structural disturbances by examining the sign of long-run output responses (negative with technology disturbances and positive with government disturbances) the magnitude of total multipliers (larger for government shocks).

Next, consider the case of idiosyncratic shocks which are propagated to the world economy because of production interdependencies. The experiment, which mimics a situation where domestic residents consume only domestic goods and countries are connected via trade in intermediate goods, is similar to the one examined by Backus, Kehoe and Kydland (1993) except that here production requires domestic and foreign *capital* goods while Backus, Kehoe and Kydland do not distinguish between consumption and capital goods in their model.

A positive and persistent disturbance displacing output in country one from its trend increases consumption, hours and investments in capital goods used for domestic production (both of domestic and foreign origin), in the country experiencing the shock. However, contrary to the one-good case, the features of the international transmission depend on the relative size of capital inflows (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 domestically produced intermediate 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 produced intermediate inputs are more intensively used, the wealth effect prevails generating positive, although lagged, foreign output responses.

The second and fifth panels of figure 2 present an intermediate case where domestic and foreign intermediate inputs have equal intensity in each of the three production functions. Two features of the responses need to be noted. First, while initially a positive output shock in country 1 induces a negative response in the output of other countries, as foreign production for capital goods used in country 1 increases (and foreign investment in capital goods used in foreign countries decline), in the medium run the spillover effect dominates and net exports of investment goods from country one becomes positive. Second, the shape of the output responses does not depend on the structural sources of disturbances. These results agree with those of Backus, Kehoe and Kydland (1993) who show that both government and technological disturbances induce contemporaneously negative output comovements and a negative current account balance in the country experiencing the shock. Notice also that the peak response of output in countries 2 and 3 lag the shock by about 6 quarters, that responses have a cyclical behavior which resemble the one in the data and that total multipliers have the right sign but smaller magnitude than those of the actual data.

Finally, consider the case of uncorrelated disturbances which are transmitted to the world economy because of consumption interdependencies (in this case we assume that domestic production requires only domestic inputs). Depending on the parameters of the utility function, we may have no transmission if the utility function weighs domestic goods heavily, or a substantial one if domestic consumers prefer foreign goods. The third and sixth panels of figure 2 present impulse responses for the case where all goods have the same weight in the utility function. Consistent with the dynamics described in Stockman and Tesar (1994), this channel of transmission generates small positive output responses coupled with a lot of short run variability when technology disturbances drive the cycle. In general, none of the cyclical features of the actual data we have emphasized can be reproduced with this model specification. When government disturbances drive the cycle the dynamics are more interesting. A negative government disturbance increases current output available for private use and current consumption of all goods. Because the level of foreign output is given when the shock occurs, the increased domestic demand for foreign goods is accommodated via a reduction of foreign investments. Since foreign hours increase at impact, foreign output increases temporarily and then falls as the decline in foreign investment reduces the capital stock. Also, because part of the increase in private consumption falls on foreign goods, domestic investments increase more than in the closed economy case boosting domestic production and leading to the lagged domestic peak 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 negative effects on foreign outputs as resources are moved from future to current consumption. In the medium-run the wealth effect dominates and positive cross country spillovers ensue. The features of the resulting output cycles are very similar to those obtained with goverment disturbances and production interdependencies. Peak responses lag 3-6 quarters in countries 1 and 2, the length of the expansion phase is 3-4 years while total multipliers are too small, especially for country 3.

Three main conclusions can be derived from studying the dynamics of the model. First, output responses look very similar in two out of the three cases making it difficult to distinguish which source of disturbance buffets the system. Second, while contemporaneously correlated shocks induce short-run positive, cross country output responses which die out in the medium-run, contemporaneously uncorrelated shocks transmitted via trade in goods induce an immediate negative response in foreign outputs and a positive spillover in the medium-run. Third, the lagged peak response of output observed in the data can be generated by contemporaneous spillovers or lagged spillovers, but it is when contemporaneous spillovers are allowed that the shape of the responses is similar to those in the data.

5 Can the Model Reproduce Actual Impulse Responses?

The next question we ask is whether the model can, with a realistic parameterization, quantitatively reproduce the stylized features of output responses contained in table 1. To start with we consider a situation where the world is composed of three identical countries. This step is useful for two reasons: to clarify which of the three channels we have discussed is dominant in transmitting the two types of disturbances across the world and to make the analysis comparable with previous work by e.g. Cantor and Mark (1988), Backus, Kehoe and Kydland (1992) or

Stockman and Tesar (1994) who primarily consider the case of identical countries.

5.1 The Parameterization of the Model

The parameters of the model are $\sigma_h, \theta_{hj}, \beta, \gamma_h, \alpha_{hj}, \tau_h, A_h(L), \phi_h, \delta_h, \Sigma$, η_{hj}, the social planner weights ω_h, the elasticity of the investment-capital ratio to changes in Tobin's Q, the steady state values of Tobin's Q plus steady state ratios (c/y; g/y; i/y). The selected values are in table 3.

As in all real business cycle models, we desire that a model trying to explain the cyclical properties of the data also fits long-run observations. This parameter selection procedure is equivalent to the method of moments approach suggested by Christiano and Eichenbaum (1992) when only first moments of the data are used to form orthogonality conditions. Once this is done, parameters which are specific to business cycle frequencies are typically selected on the basis of existing studies or, absent such literature, fixed a-priori and a sensitivity analysis is performed to assess the robustness of the results. According to this logic we 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 long run averages in the data. We directly estimate $A(L)$ and Σ from the data, while $\beta_h, \delta_h, \phi_h, \eta_{hj}, \sigma_h$ 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 *Yearbook of Labor Statistics* provides 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 state 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 1960,1-1994,4 while the 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 (see e.g. Rotemberg and Woodford (1992)). Here we do not follow this approach because military expenditure is only a small fraction of total government expenditure (and of GDP) in Japan and Germany, so that the resulting properties for g_{ht} 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 we 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 and [0.67, 2.23] for Japan. The values used are exactly identified GMM estimates and are from Canova and De Nicolo' (1995).

Many of the values for US parameters presented in table 3 are standard. For the other two countries the values are similar to those previously employed in the literature (see e.g. Cardia (1991), Reynolds (1992), Stockman and Tesar (1994), Parente and Prescott (1994)). Tax rates are slightly lower than those used by e.g. Baxter and Crucini (1993) but this may be due to the presence of measurement errors in tax revenues.

The table contains estimates of the parameters of share of foreign capital in production which have not been previously used. Estimates of the share of foreign consumption in total consumption are partially new. To construct the share of total intermediate foreign goods in total output we 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 we calculate the share of intermediate goods coming from each of the other two 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 large especially for Germany. The share of foreign goods in total consumption is obtained by summing up the value of imports of food, beverages and nondurable 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 previously used value for the share of foreign nondurable goods and services coming from abroad is higher than the one employed here (Schlagenhauf (1989) has e.g. 0.157). However, previous measures are biased upward since they include items like imports of transport equipment which are neither nondurable nor final goods. One should also note that our estimates may be downward biased because no direct measure of the flow of services from foreign produced durable goods is available. This may be important for the US, where consumption of Japanese and German durables is substantial.

As in Christiano and Eichenbaum (1992) and Backus, Kehoe and Kydland (1993), we consider primarily the case of ϕ_h=0 but also examine whether results change when ϕ_h varies from zero to one. Similarly, $\eta_{i,j}$ are chosen so that the investment-capital ratio is sensitive to changes in Tobin's Q but we 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. Because the model contains multiple capital goods and because no disaggregated investment data exist, no fruitful estimation seems possible. Finally, we assume that ω_h's are proportional to the population of the three countries in 1960. Because, Baxter and Crucini (1993) have shown that country size has some effect on the time series properties of saving and investment within countries, we examine whether the properties of transmission are altered when these weights change.

5.2 Some Simulation Results

Figure 3 presents output responses following a one standard error output shock in country 1 when the underlying economy is driven by technology disturbances (panel 1) or by government disturbances (panel 2) for the case of three countries with identical preferences, technologies and shocks. The lower panel of table 1 reports summary statistics. The figure presents point estimates of the responses where, 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, the same 95% confidence bands presented in figure 1 when US GDP is shocked are superimposed in each panel. US parameters are selected for this baseline case and $\omega_h = \frac{1}{3}$. For technology disturbances the standard error is 0.0102, the serial correlation 0.95 and the cross country contemporaneous correlation 0.25. For government expenditure disturbances the standard error is 0.0156, the serial correlation 0.98 and the cross country contemporaneous correlation 0.20.

When the economy is driven by technology disturbances output responses are all positive in the short run suggesting that the effect due to the contemporaneous correlation of shocks is strong. However, the persistent lagged response of outputs in countries 2 and 3 and their magnitude are the results of production interdependencies which create a virtuous circle in the medium-run. Similarly, when government expenditure disturbances make economies fluctuate, the presence of a common component in the disturbances is responsible for the initial positive output dynamics but transmission via trade is dominant in the medium-run.

For both types of disturbances we observe a delayed peak response in country 2 and sizable cyclical responses in countries 2 and 3, as is the case with the actual data. The magnitude of the peak responses is broadly consistent with those in the data and, for most horizons, simulated responses are inside the 95% band of the actual ones. In addition, the model driven by government disturbances generates a lagged peak response in country one, a feature which appears to be important for actual US output shocks. One remarkable feature of figure 3 is that the two specifications generate output responses which are qualitatively very similar. For example, the model can qualitatively reproduce the "US locomotive" in both cases: positive output shocks in country 1 are associated with instantaneous positive foreign responses, a lagged peak response in country 2 and significant multiplier effects in two of the three countries.

Both specifications fail in other dimensions. For example, the model is unable to reproduce the lengths of the expansion phase under both specifications: cycles in simulated data are somewhat too short and the timing of turning points is off by a few quarters. Also, the model does not reproduce the large and positive Japanese output responses following US output shocks present in the data and it underestimates the magnitude of total multipliers in all three cases.

To quantify the importance of the two disturbances and of the three channels of transmission we compute the cumulative square difference between the mean estimates of the actual impulse responses and the simulated responses where in the latter case we shut down two of the three channels of propagation as we did in section 4. We present results to whether different shocks or different transmission mechanisms are more important at different horizons. The results obtained for two different horizons (4 and 24 quarters), which appear in table 5, suggest that government disturbances do better in reproducing US and German output responses following a US output shocks while technology disturbances do better for Japan output responses. Also, common shocks appear to outperform the other two transmission channels at both horizons regardless of the source of disturbance. Production interdependencies, on the other hand, do better than consumption interdependencies in the long-run when technology disturbances drive the cycle. When government disturbances drive the cycle, consumption interdependencies outperform production interdependencies both in the short and in the long-run.

5.3 Sensitivity Analysis

Before moving to more complicated versions of the model, we run 8 experiments to know whether the features of the impulse responses we have just described are robust to modifications of those parameters which are chosen a-priori or measured with substantial error.

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. $\beta = 0.96$. In experiment 4 no distortionary taxes are levied on output, i.e. $\tau_h = 0.0\ \forall h$. Experiment 5 considers an economy with serially uncorrelated disturbances, i.e. $\rho_g = \rho_a = 0.0$. Experiment 6 presents a case where 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 the cost of using domestically produced capital goods is lower than the cost of using capital produced in another location, i.e. $\eta(h,j)^{-1} = -0.01, \eta(h,h)^{-1} = -0.0001$. Finally, in experiment 8 we study a situation where two of the three countries trade their own capital goods more easily, 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. Summary statistics for the first experiment are in table 1 and for the other 7 experiments are in table 3.

When government expenditure is a better substitute for private consumption, shocks are less persistent and output responses display smaller swings, but the qualitative features of the international transmission are unaltered. Intuitively, an increase in government expenditure has two effects on consumption in this case. The first one is through the resource constraint, as when $\phi = 0.0$. The second occurs because an increase in government expenditure increases current utility of domestic agents, reduces the incentive to substitute leisure intertemporally and, therefore, the magnitude of future output increases. Hence, ceteris paribus, output shocks generate fluctuations of reduced magnitude and have smaller international repercussions. The magnitude of the change in agents' leisure profile depends on the persistence of government disturbances: for highly persistent disturbances and values of ϕ up to 0.7, the importance of this second channel is rather small.

Increasing σ_h or decreasing β has similar effects on the transmission of shocks. When σ_h is high, positive technology or negative government disturbances lower total investment, result in less persistent domestic responses and a weaker and less persistent cross country spillover because agents are less willing to substitute intertemporally. Similarly, with a lower β agents wish to consume more today relative to the future. Consequently, with positive technology disturbances more impatient agents will invest less and, with negative government shocks they will intertemporally substitute more current for future leisure, reducing the profile of future output growth. In both instances, higher current consumption desires induce weaker persistence, shorter cycles, smaller own multiplier and a reduced international transmission of disturbances. Also in this case, the magnitude of the changes is small.

Variations in tax rates from 0 to 50% have no significant effects on either the shape or the magnitude of output responses when the economy is driven by technology disturbances. When government spending disturbances drive the cycle and there are no distorting taxes, agents enjoy more good times on domestic goods so that the spillover effect is reduced. Also in this case the differences in the shape and magnitude of the shocks are small.

When disturbances are serially uncorrelated, output responses die out quickly, cycles are short, spillovers are small apart from the initial contemporaneous effect, multiplier effects are insignificant and the location and magnitude of turning points change. When $g_{ht} = 0, \ \forall t$, $\delta = 1.0$, $\alpha_{hj} = \theta_{hj} = 0 \ \forall j \neq h$ 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 setup. They assert that with iid technology shocks, the model can generate output comovements across sectors or countries. This experiment demonstrates that even when output disturbances are uncorrelated over time, comovements in the cyclical component of output do exist (the contemporaneous correlation of outputs is around 0.70). But this is a high frequency not a business cycle phenomenon.

Variations in η change the propagation features of output shocks. 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, and this reduces the magnitude and the international persistence of output responses. 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 the deadweight loss. This result is independent of the exact value of η: for values up to the one used by Baxter and Crucini, $\eta^{-1} = -0.075$, output dynamics are similar.

When higher costs must be paid to install new foreign capital domestically, the transmission features are altered when technology shocks drive the cycle since output swings in country 1 are magnified in the medium run. When government disturbances drive the cycle, only minor differences with the baseline case emerge.

Finally, when two of the countries (say, countries 1 and 2) enjoy some proximity which allows them to incur lower costs in importing each other's capital goods, we observe a substantial asymmetry in output responses when technology disturbances drive the cycle. The responses of country 3 are fairly close to zero at all horizons. This is to be expected since investment dynamics are responsible for the international cycle when technology disturbances drive the cycle. With government expenditure disturbances, responses do not change much since in this case the gross flow of capital across borders is of a smaller order of magnitude.

In sum, the properties of the domestic and international transmission of the two types of disturbances change when we reduce the serial correlation of the disturbances and when the sensitivity of the investment-capital ratio to changes in Tobin's Q is low or asymmetric. In all the other cases both the shape of the responses and their quantitative features are fairly robust to changes of parameters within a reasonable range.

5.4 Heterogeneous Countries

Since the model with three identical countries does not account for all features of output responses, we next examine its performance when country-specific heterogeneity is included. We first consider a case where countries differ in the serial and contemporaneous correlation properties of the disturbances. Then we proceed to six additional experiments, which maintain country-specific distributions in the disturbances and add differences in country size (experiment 2), in preferences - both in terms of θ_{hj} and σ_h - (experiment 3), in fiscal policies (experiment 4) and in technologies and growth patterns (experiment 5). Finally, to maintain comparability with other studies, we study a case where exogenous disturbances display asymmetric, one-period cross country feedbacks (experiment 6). Plots of the point estimate of the impulse responses obtained with data generated in experiment 5 are in figure 4 for the case of technology disturbances and in figure 5 for the case of government expenditure disturbances. Once again, to facilitate the comparison, actual 95% confidence bands are superimposed and, to downplay the importance of sampling variability, the length of the simulated time series is set to T=6000. Summary statistics for these experiments are in an appendix available upon request.

When technology disturbances drive the cycle, the presence of asymmetries in the distribution of disturbances does not dramatically affect the transmission properties of output shocks. In particular, we see that German output responses to German output shocks die out quickly while there are significant swings in US and Japan output responses. Japan output shocks die out slowly domestically, induce a lagged peak response in the US and small total multipliers in all countries.

When government disturbances drive the cycle, we note important asymmetries in output responses and total multipliers. Positive US output shocks are somewhat persistent domestically, induce long swings in German output and larger but less persistent output responses in Japan. German output shocks have a strong contemporaneous impact, generate output swings of wide amplitude in Japan and strong negative and persistent US output responses. Finally, Japan output shocks generate short but recurrent swings in its own responses and a negative displacement of US and German outputs for about 15-16 quarters.

The qualitative similarities in the impulse responses we noted previously when the two sources of disturbances drive the cycle disappear in this case. One major difference is in US and

German output responses following a Japan output shock: both output responses are strongly negative and German output responses are much more cyclical with government disturbances.

Changing the planner weights has very little influence on the cross-country propagation of output shocks. The major difference is in the magnitude of US output responses to foreign output shocks, which display fluctuations of reduced amplitude. The addition of country-specific preferences, technologies and fiscal policies has only a minor impact on total multipliers, length of the cycle and the location of the turning points when technology disturbances drive the cycle. With government disturbances, differences in fiscal policies and technology are important in determining the magnitude of the peaks and troughs of the cycle, but no major change appears in the transmission properties. These results should not come as a surprise: cross-country heterogeneities in preferences and technologies are too small to substantially change the transmission properties of the model. Fiscal variables do differ across countries both in terms of steady-state percentage of output accounted for by government consumption and average tax rates. However, impulse responses are insensitive to differences of these parameters within the cross-country range presented in table 3.

Finally, when exogenous disturbances display one-period, cross-country feedbacks which are allowed to be asymmetric, the distinction between sources and propagation becomes unclear. However, it is useful to consider this case to maintain comparability with current literature which allows disturbances to have a lagged impact across countries (as in Backus, Kehoe and Kydland (1995)). Estimates of the one-period, cross-country feedbacks appear in an appendix available on request. The inclusion of these feedbacks in the model affects the magnitude and, in some cases, the sign of total multipliers, the location and the magnitude of turning points and the length of the induced cycle. In general, the presence of cross-country feedbacks does not improve the ability of the model to reproduce the data and creates additional discrepancies in some dimensions where it was previously adequate. It is therefore possible that the need to include these feedbacks in previous models was due to the lack of production interdependencies which endogenously generate international repercussions.

In sum, the addition of various forms of heterogeneities does not substantially improve the fit of the model and, in some cases, worsens its performance. Heterogeneities in the distribution of the exogenous disturbances create some asymmetries in the impulse response function but they are either insufficient to rationalize the wide variety of total multiplier effects present in the actual data or go in the opposite direction of what one would like. For example, none of the modifications can generate the large domestic output response, coupled with the modest international transmission effects, observed after Japan output shocks.

To quantitatively examine which of the two sources of shocks and which transmission mechanism account better for the actual impulse responses we compute also in this case the cumulative square difference between actual and simulated reponses at 4 and 24 quarter horizons. The results are in table 6. With a country-specific parameterization, it is a model with technology disturbances which accounts best for features of the propagation of German and Japan output shocks. Note also that now this specification performs very much like to the model with government shocks for the US. Once again the presence of a common component to the shocks is most important in quantitatively reproducing actual data. However, production interdependencies may also play a role in the cross country transmission of output disturbances.

6 Conclusions

This paper investigates the generation and the transmission of international business cycles using a multi-country general equilibrium model with production and consumption interdependencies. The model features two sources of fluctuations and three types of propagation mechanisms which may transmit disturbances across countries. We show how each of the three channels of transmission works for both types of disturbances and describe the induced cross-country output dynamics. The paper then asks whether the model can account for the transmission of actual output shocks with a realistic parameterization. We show that when countries are symmetric both government and technology disturbances which are moderately correlated across countries can reproduce aspects of the "locomotive" role played by the US economy but that they are unable to account for other important features of the actual impulse responses. Quantitatively, the model driven by government disturbances outperforms the one with technology disturbances. Sensitivity analysis demonstrates that the qualitative characteristics of cross-country propagation are largely independent of the parameterization used. Cross-country heterogeneities help to induce some of the asymmetries we see in the data. Also when heterogeneities are present, technology disturbances are more successful than government disturbances in accounting for the data. In general, however, the three countries are too similar to hope that the performance of a symmetric model will be crucially improved by the presence of heterogeneities.

There are at least three modifications which may improve the fit of the model. The first is the inclusion of monetary factors. At least in the case of Germany, monetary policy is used to alter the transmission features of domestic output shocks. The introduction of country-specific monetary factors may therefore improve our understanding of how international cycles are generated and propagated. Second, if countries respond differently to changes in the terms of trade because their size in the world economy differs, an explicit modelling of terms of trade disturbances may give an additional characterization of the sources of international cycles. Third, in the real world labor market practices differ substantially across countries while in the model competitive labor markets are assumed. The inclusion of heterogeneities in labor markets across countries may be important in generating an asymmetric transmission of shocks.

Because the paper has concentrated attention primarily on output dynamics, it has neglected a wealth of empirical information regarding terms of trade, real interest rates, net exports and hours, which may sharpen our understanding of what is responsible for international business cycles. We plan to examine these implications in future work (see also Canova and De Nicolo' (1995) for a study of the asset price implications of the model).

Finally, the model provides some answers to the policy questions posed in the introduction. First, because cross country output dynamics in the short run are almost entirely dominated by the strong common component of the disturbances, the removal of trade barriers across US, Japan and Germany is unlikely to change the way outputs comove and how recessions and expansions spread across countries. Clearly, this does not imply that the changes in trade practices will have no effect on the growth pattern 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, fiscal coordination does not seem responsible for the increased symmetry in world business cycles observed in the 1980's since such a coordination would only affect contemporaneous output comovements and would not change the propagation features of output shocks.

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Table 1: **Transmission of International Cycles**

Actual Data: Sample 1960,1-1994,4							
		US Output Shocks		German Output Shocks		Japan Output Shocks	
		Location	Size	Location	Size	Location	Size
Cycle	US		15		24		9
length	Germany		24		8		2
(in quarters)	Japan		24		3		24
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

Simulated data: Symmetric countries							
		Technology Shocks		Government Shocks ($\phi = 0.0$)		Government Shocks ($\phi = 0.5$)	
		Location	Size	Location	Size	Location	Size
Baseline Case							
Cycle	Country 1		6		20		22
length	Country 2		2		6		5
(in quarters)	Country 3		3		3		4
Peak	Country 1	1	1.00	3	1.54	3	1.41
Response	Country 2	19	0.40	5	0.45	3	0.62
	Country 3	1	0.27	1	0.31	1	0.36
Total	Country 1		2.30		11.75		9.65
Multiplier	Country 2		7.08		6.90		3.12
(24 quarters)	Country 3		-1.50		-6.63		-4.51

Note: The statistics refer to mean responses obtained using 1000 replications.

Table 2: **Parameters of the Model**

	Common Shocks	Production Interdependencies	Consumption Interdependencies
	Utility Parameters		
$\theta_{i,j}$	0.30 if i =j	0.30 if i =j	0.10 i,j=1,2,3
$\theta_{i,j}$	0.00 otherwise	0.00 otherwise	
$\theta_{j,4}$	0.70	0.70	0.70
σ	2.00	2.00	2.00
β	0.99	0.99	0.99
ϕ	1.00	1.00	1.00
	Production Parameters		
$\alpha_{i,j}$	0.36 if i =j	0.12 i,j=1,2,3	0.36 if i=j
$\alpha_{i,j}$	0.00 otherwise		0.00 otherwise
$\alpha_{.,4}$	0.64	0.64	0.64
γ	1.008	1.008	1.008
δ	0.025	0.025	0.025
	Government Parameters		
τ	0.00	0.00	0.00
s_g	0.20	0.20	0.20
	Social Planner Weights		
ω	0.33	0.33	0.33
	Adjustment Cost Parameters		
$\eta_{i,j}^{-1}$	-0.00001	-0.00001	-0.00001
	Parameters of the Shocks		
ρ_a	0.95	0.95	0.94
ρ_g	0.97	0.81	0.88
$\nu_{a_{1,2}}$	0.30	0.00	0.00
$\nu_{a_{2,3}}$	0.30	0.00	0.00
$\nu_{a_{1,3}}$	0.30	0.00	0.00
$\nu_{g_{1,2}}$	0.30	0.00	0.00
$\nu_{g_{2,3}}$	0.30	0.00	0.00
$\nu_{g_{1,3}}$	0.30	0.00	0.00
σ_a	0.0102	0.0102	0.0102
σ_g	0.0156	0.0156	0.0156

Note: The table reports paremeters used to run the experiments contained in figure 2.

Table 3: **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 4: **Transmission of International Cycles: Symmetric Countries**

		Technology Shocks Location	Size	Government Shocks ($\phi = 0.0$) Location	Size
Experiment 1: $\sigma = 10$					
Cycle length (in quarters)	Country 1		6		22
	Country 2		24		7
	Country 3		4		3
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 2: $\beta = 0.96$					
Cycle length (in quarters)	Country 1		6		23
	Country 2		24		6
	Country 3		4		3
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 3: $\tau = 0.0$					
Cycle length (in quarters)	Country 1		6		23
	Country 2		24		6
	Country 3		3		3
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
Experiment 4: $\rho = 0.0$					
Cycle length (in quarters)	Country 1		1		1
	Country 2		1		1
	Country 3		1		1
Peak Response	Country 1	1	1.00	1	1.00
	Country 2	4	0.23	3	0.24
	Country 3	1	0.25	1	0.18
Total Multiplier (24 quarters)	Country 1		0.48		1.22
	Country 2		0.13		0.07
	Country 3		-0.16		-0.35

		Technology Shocks Location	Size	Government Shocks ($\phi = 0.0$) Location	Size
Experiment 5: $\eta_{h,j}^{-1} = -0.05$					
Cycle	Country 1		10		12
length	Country 2		5		8
(in quarters)	Country 3		9		4
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 6: $\eta_{h,h}^{-1} = -0.00001; \eta_{h,j}^{-1} = -0.01$					
Cycle	Country 1		5		11
length	Country 2		2		11
(in quarters)	Country 3		1		2
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 7: $\eta_{h,j}^{-1} = -0.00001$, forh,j = 1,2orh = j = 3$\eta_{h,j}^{-1} = -0.01$ otherwise					
Cycle	Country 1		5		11
length	Country 2		2		11
(in quarters)	Country 3		1		2
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: The statistics refer to mean responses obtained using 1000 replications.

Table 5: **Fit of the Model: Symmetric Countries**

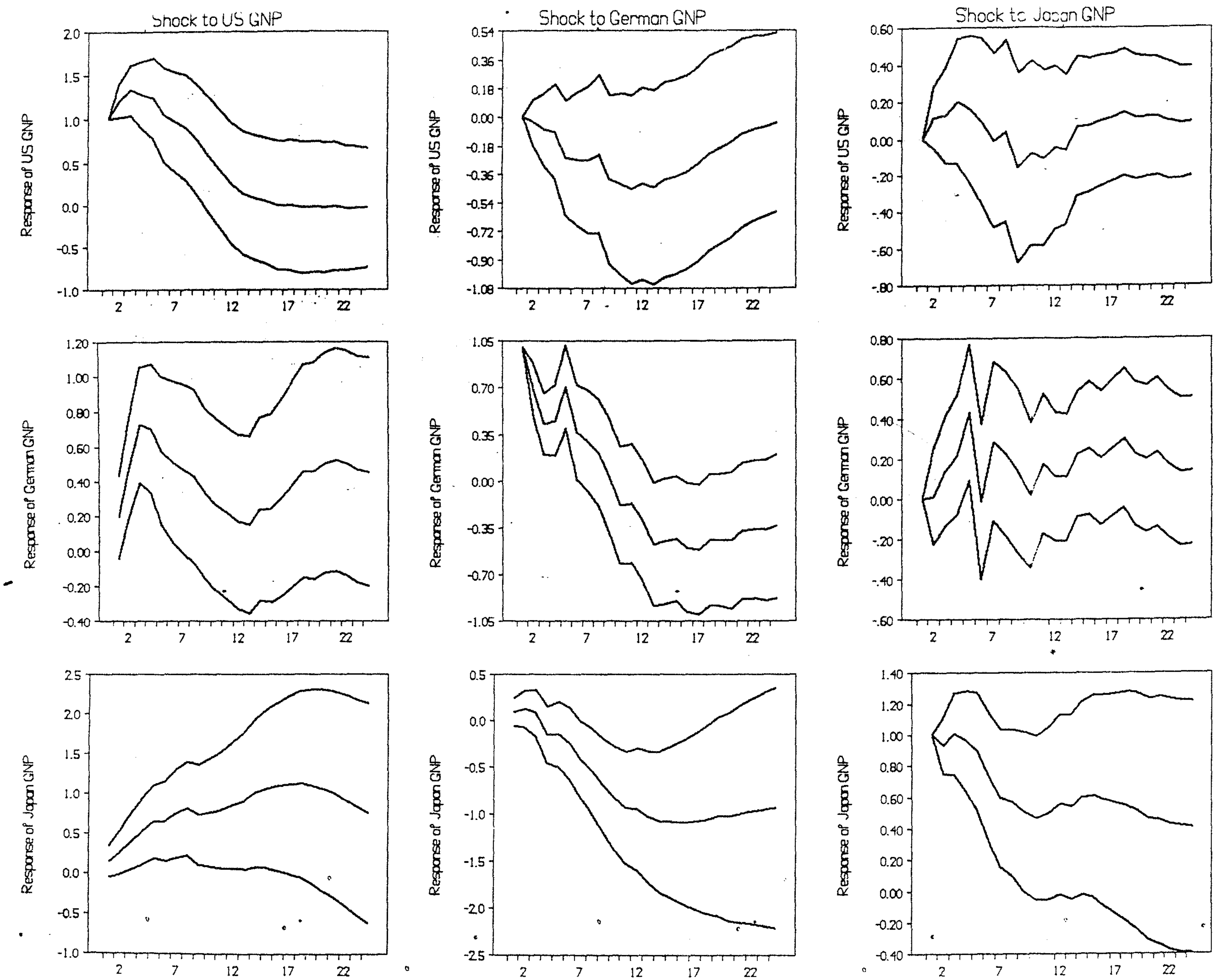
		Technology Shocks			Government Shocks ($\phi = 0.0$)		
Horizon							
4 quarters	Full	1.06	0.72	0.58	0.14	0.28	0.59
	Common	0.67	0.19	0.16	0.37	0.24	0.12
	P.I.	1.17	3.56	0.83	1.01	2.80	2.12
	C.I.	3.66	2.97	0.83	0.09	0.83	1.23
24 quarters	Full	6.31	1.22	21.80	0.45	0.94	32.22
	Common	2.10	2.77	9.32	1.43	3.21	9.07
	P.I.	5.40	6.80	13.91	4.21	5.89	17.21
	C.I.	7.73	3.10	12.36	1.44	2.60	14.83

Note: The table reports cumulative differences between actual and simulated responses. Full indicates an experiment where all channels of transmission are present, Common one where shock are contemporaneously correlated, P.I. one where there are only production interdependencies and C.I. one where there are only consumption interdependencies.

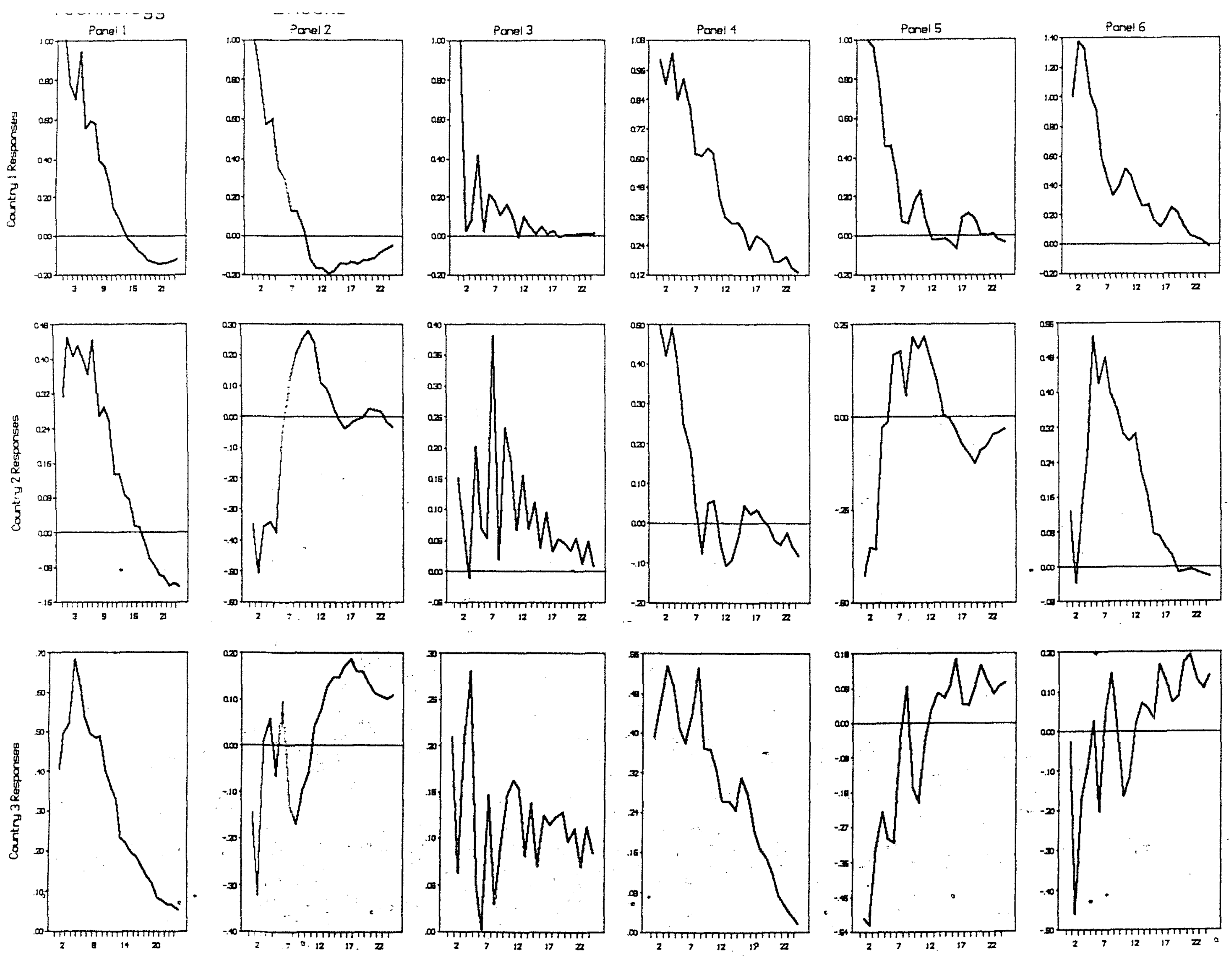
Table 6: **Fit of the Model: Heterogeneous Countries**

	Technology Shocks				Government Shocks ($\varphi = 0.0$)			
	Horizon: 4 quarters							
	Full	Common	P.I.	C.I.	Full	Common	P.I.	C.I.
	0.65	0.74	1.23	3.06	0.63	0.57	1.24	0.31
US	1.03	1.27	4.86	1.92	0.66	0.54	2.66	1.18
Shocks	0.07	0.25	0.88	0.19	0.20	0.38	1.99	1.77
	0.05	0.12	0.13	0.26	0.02	0.04	0.11	0.15
German	0.10	0.17	0.18	0.34	3.86	3.54	5.01	4.66
Shocks	0.27	0.45	0.44	0.62	0.05	0.10	0.14	0.12
	0.08	0.15	0.18	0.36	2.01	3.21	3.68	4.51
Japan	0.04	0.16	0.23	0.52	1.13	1.76	1.98	2.82
Shocks	0.13	0.41	0.55	0.89	0.36	0.86	1.01	0.98
	Horizon: 24 quarters							
	Full	Common	P.I.	C.I.	Full	Common	P.I.	C.I.
	2.31	3.46	6.02	8.17	4.91	4.97	5.12	5.33
US	3.39	3.79	6.95	4.10	8.73	10.12	13.64	12.45
Shocks	14.35	15.43	17.70	18.66	15.25	17.65	18.24	17.94
	2.01	3.06	3.09	4.27	1.28	1.67	1.82	2.95
German	2.19	3.77	4.80	6.92	30.72	28.67	25.86	31.03
Shocks	25.76	32.48	31.98	34.29	17.32	19.23	19.42	26.15
	2.04	2.47	2.94	3.41	6.23	9.02	9.24	10.01
Japan	0.85	0.80	0.88	0.96	29.16	27.48	29.99	31.07
Shocks	1.02	1.44	1.59	2.06	5.67	7.10	8.29	8.27

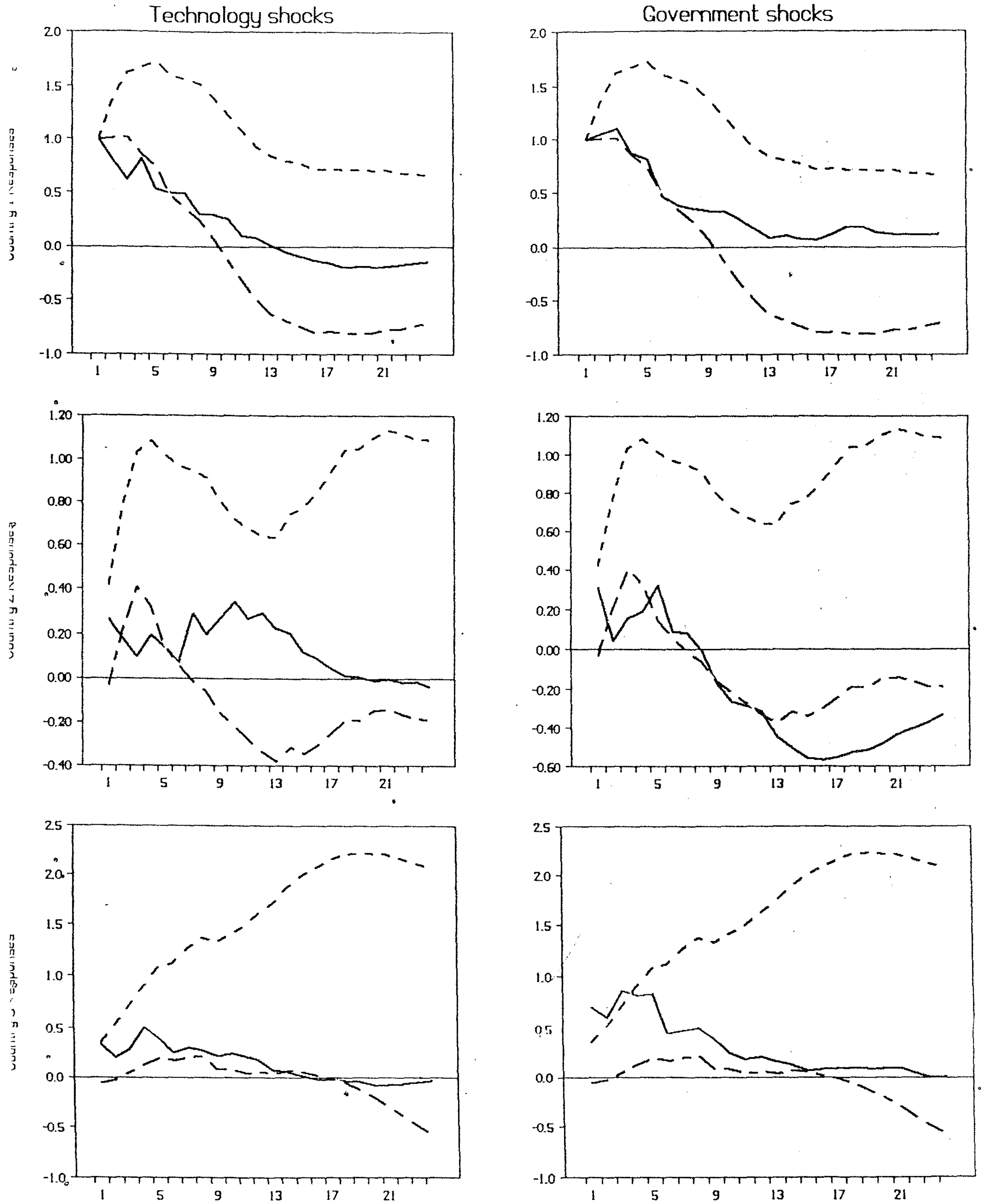
Note: The table reports cumulative differences between actual and simulated responses. Full indicates an experiment where all channels of transmission are present, Common one where shock are contemporaneously correlated, P.I. one where there are only production interdependencies and C.I. one where there are only consumption interdependencies.



Shock to US GNP
Shock to German GNP
Shock to Japan GNP
Response of US GNP
Response of German GNP
Response of Japan GNP



Panel 1
Panel 2
Panel 3
Panel 4
Panel 5
Panel 6
Country 1 Responses
Country 2 Responses
Country 3 Responses


Technology shocks
Government shocks
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
1.20
1.00
0.80
0.60
0.40
0.20
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-0.20
-0.40
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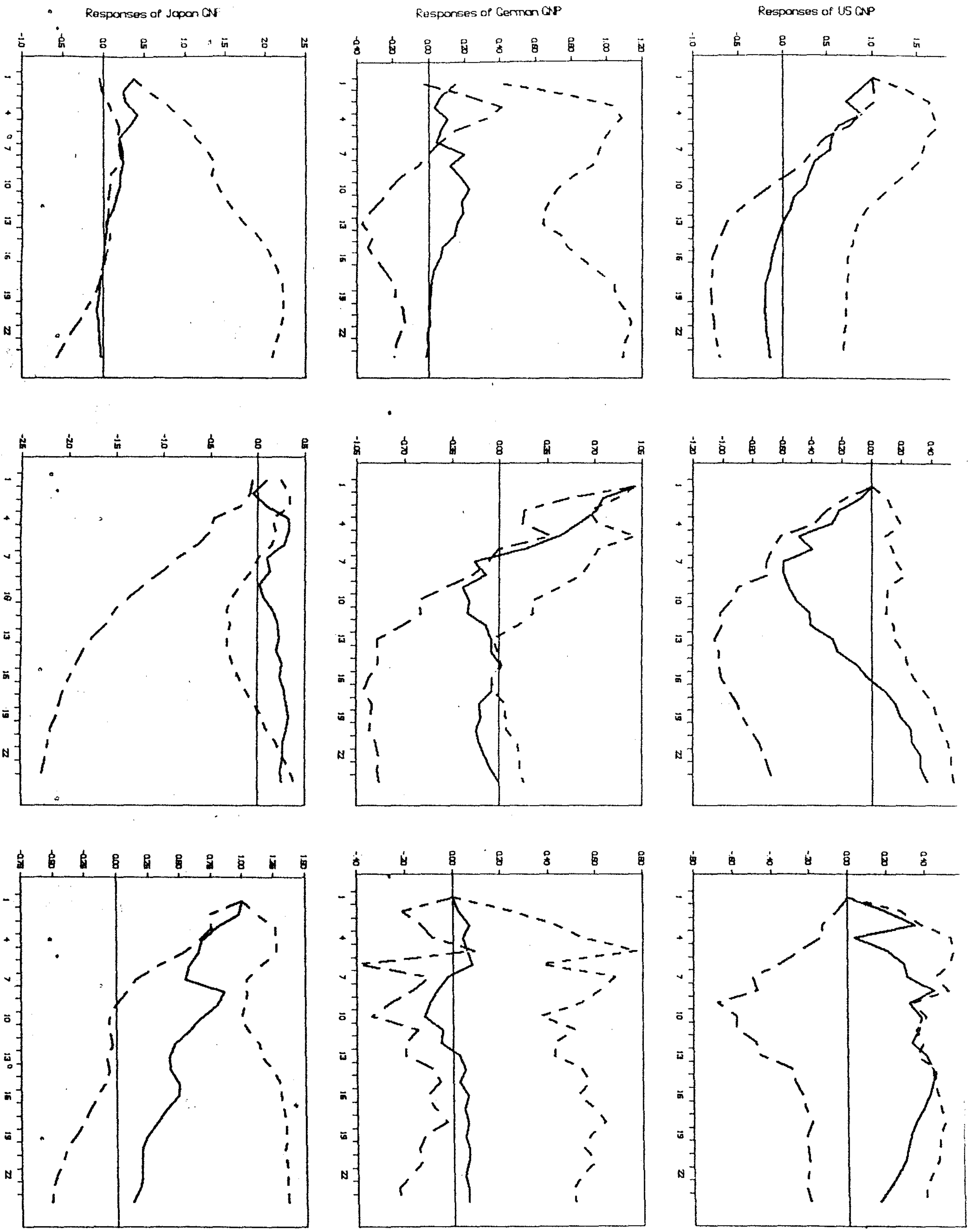
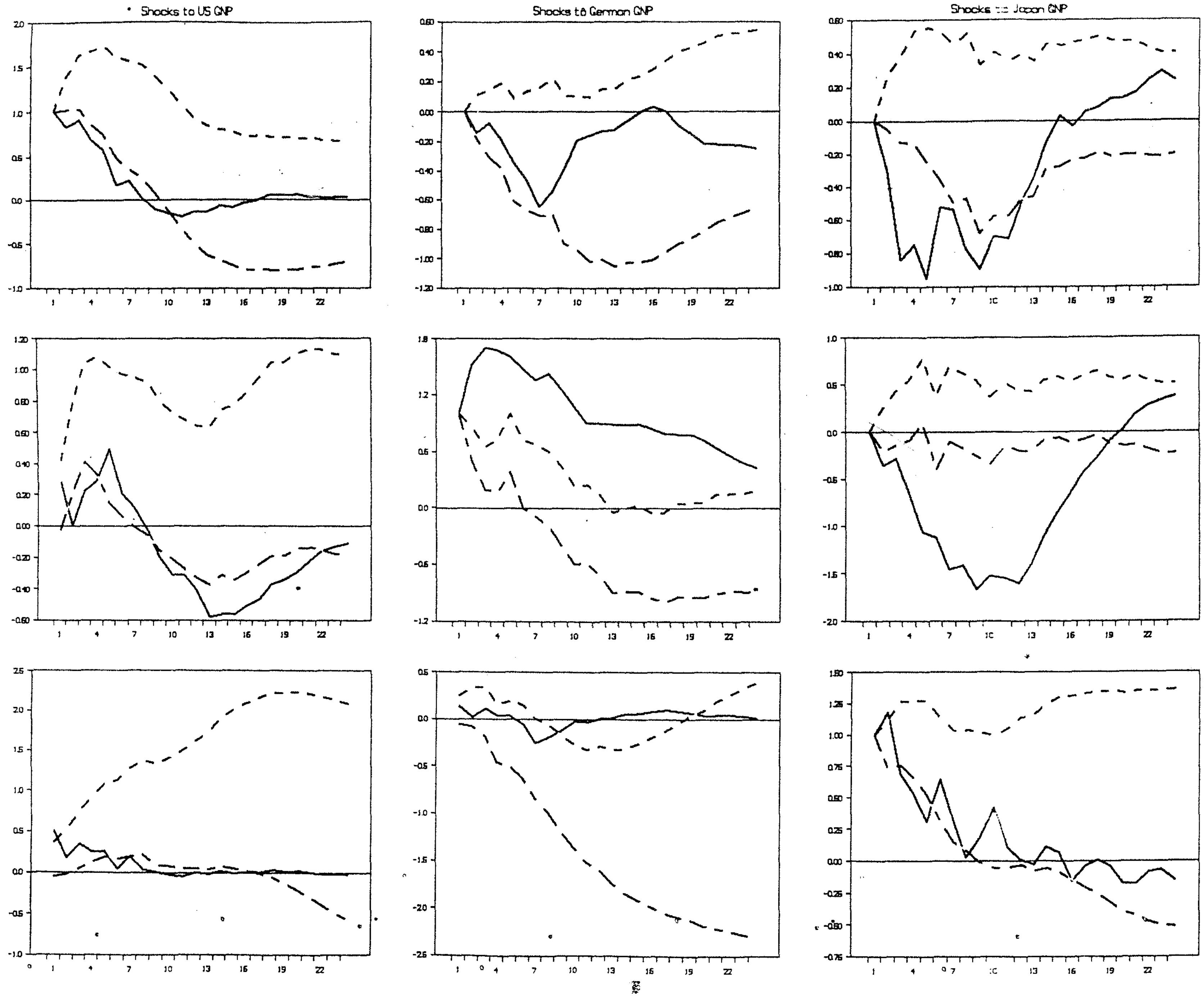
9
13
17
21


Responses of Japan GNP
Responses of German GNP
Responses of US GNP


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

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