1993

Intermediate Goods and the Transmission of International Business Cycles

Donna M. Costello

J Praschnik

Follow this and additional works at: https://ir.lib.uwo.ca/economicsresrpt

Part of the Economics Commons

Citation of this paper:
Research Report 9305

Intermediate Goods and the Transmission of International Business Cycles

by

Donna M. Costello and J. Fraschnik

Department of Economics
University of Western Ontario

March 1993

Social Science Centre
University of Western Ontario
London, Ontario, Canada

N6A 5C2
Intermediate Goods and the Transmission 
of International Business Cycles

Donna M. Costello 
University of Florida 
and 
University of Michigan

and

J. Praschnik* 
University of Western Ontario

March 1993

Abstract: An empirically significant component of the international trade conducted by the U.S., Germany, and Japan is the trade in intermediate goods. In this paper, we consider the trade in intermediate goods as a source for transmitting business cycles internationally. We modify a dynamic, two-country, one-good, equilibrium model of the business cycle by introducing an intermediate good sector. Just as final goods, intermediate goods are also produced and traded in this economy. Impulse response functions and simulations of our economy suggest that trade in intermediate goods is an important source of the international transmission of business cycles.

* We thank Andreas Hornstein for helpful discussion. All errors remain our own.
1. Introduction.

It has long been recognized that trade in intermediate goods is an important component of world trade. In 1966, Mckinnon estimated that between 60 and 70 percent of world trade is in intermediate goods. On average since 1970, 54 percent of the trade conducted by the United States, Germany, and Japan has been in intermediate goods, 28 percent of trade in machinery and equipment, and 16 percent in services.\(^1\) The extent to which intermediate goods are internationally traded suggests that one possible source of the transmission of business cycles across economies is through the trade of intermediate goods.

Nevertheless, trade in intermediate goods, which has been theoretically considered in international trade studies since Williams (1929), is noticeably absent from recent open-economy business cycle models.\(^2\) One possible reason for their absence is that it may be thought that including intermediate goods will not significantly alter the general conclusions drawn from these models. However, Batra and Casas (1971) theoretically demonstrate that if intermediate goods are produced solely to serve as inputs in the production of final goods, most of the traditional trade theorems may not hold without additional provisions. In addition, they find that if both intermediate and final goods are traded, the pattern of trade may not be found by appealing to trade theorems and will in general be indeterminate. Thus, admitting trade in intermediate goods in addition to trade in final goods may significantly alter the predictions of open-economy business cycle models.

To facilitate the comparison with other models, in this paper we consider a specification

\(^1\) The percentages sum to 98% because 2% of the goods traded were not categorized. For sources concerning these numbers see section 2.

\(^2\) See Backus, Kehoe, and Kydland (1992c) for a survey of the recent open-economy business cycle literature.
that is similar to the one-good, open-economy business cycle model as recently described in Backus, Kehoe, and Kydland, BKK, (1992b). We modify a two-country, one-good model of the business cycle by introducing intermediate goods as a second traded good. A social planner equally weights and maximizes expected utility of two infinitely lived agents. In both economies, the production technologies of final and intermediate goods are symmetrical across economies and subject to distinct productivity shocks which are imperfectly correlated. The agent in each country can borrow and lend in international markets by running trade surpluses and deficits. Technological innovations are transmitted across economies through the trade in both goods.

One important discrepancy between actual international comovements and those predicted by one-good, open-economy business cycle models, which is pointed out in BKK (1992a), is that output is positively correlated across countries in the data, but unless large technological spillovers across economies are introduced to the model, larger than what is justified by VAR’s using aggregate Solow residuals, outputs will not move together across countries. Given the degree to which trade occurs in intermediate goods, one alternative medium for the spillover of technology is through trade in intermediate goods. In this paper, we demonstrate that by introducing a second traded good to the model and making the distinction between intermediate and final goods, the artificial economy will generate positive comovements of output across economies with reasonable levels of technological spillover.\(^3\)

We precede as follows: In section two, we present some statistics concerning trade in

\(^3\) Stockman and Tesar (1990) and Praschnik and Costello (1992) also find that outputs can be positively correlated across economies with reasonable levels of technological spillover if a second non-traded good is introduced to the one-good model.
intermediate and final goods for the United States, Germany, and Japan and furnish information concerning the behavior of business cycles in these economies. In section three, a model economy is developed which is used to study the role that intermediate goods play in transmitting international business cycles. We discuss the calibration of the artificial economy and present the results from its simulation in section four and offer conclusions in section five.

2. The International behavior of intermediate and final goods.

2.1 Trade in intermediate goods.

We begin by considering the position of intermediate goods in international trade. There exists various schemes of international trade classifications which specify products according to intermediate or final use. Our analysis of merchandise trade data is based on the classification used by the U.N. in their Handbook on Trade and Development. This publication lists sectors by three digit Standard International Trade Classification according to primary, intermediate, or capital goods.\(^4\) For modeling purposes, we focus only on the distinction between intermediate and final goods and not on the distinction between primary and intermediate goods. Therefore, our theoretical treatment of intermediate goods will encompass both intermediate materials and primary products.\(^5\) In our data analysis, primary and intermediate good trade are added together to get a total value of intermediate good trade. Service trade is then added to capital

---

\(^4\) An alternative classification of goods is the United Nations Classification by Broad Economic Categories. This publication lists commodities according to intermediate, consumer or capital goods. This is the classification used by Kol and Rayment (1986). They find that in 1983 sixty percent of goods traded were intermediate goods, 23 percent were consumer goods and 17 percent were capital goods.

\(^5\) This definition is consistent with the National Income and Product Accounts (NIPA) definition of intermediate goods. According to the NIPA, goods are classified as intermediate if they are used up in the production of other goods in the same period in which they were produced.
good trade to get an estimate of final good trade.\textsuperscript{6} The service trade data comes from the calculations provided in the OECD Member Countries' Data on Trade in Services. The data appendix provides more information concerning this data.

The top panel of table 1 presents the composition of trade for the United States, Germany, and Japan. From 1970 to 1985 primary and intermediate goods accounted for between 42 and 45 percent of total exports on average in each country. On the other hand, over the same time period, primary and intermediate goods make up the majority of all imports in these countries. These goods accounted for 60 percent of total imports in the United States and Germany and over 73 percent of total imports in Japan.

The lower panel of table 1 presents information on the importance of intermediate good trade for the production of goods and services. In the United States, Germany, and Japan, the volume of trade, as defined as aggregate exports plus aggregate imports over aggregate GDP, was between 15 and 30 percent. As a fraction of primary good GDP, primary good exports are between 15 and 53 percent and as a fraction of intermediate good GDP, intermediate good exports are between 5 and 86 percent. Imported primary and intermediate goods were also an important source of total primary and intermediate goods used in the production process in these economies. Primary good imports accounted for between 13 and 45 percent of total primary goods consumed and intermediate good imports accounted for between 5 and 47 percent of total intermediate goods consumed.

Together, the two panels in table 1 highlight two important characteristics of international trade. First, both intermediate and final goods are significantly internationally

\textsuperscript{6} Services are treated as final goods because according to input-output tables for the U.S., Germany and Japan, the majority of services are sold at the end of the production process.
traded by the United states, Germany, and Japan. And secondly, imported intermediate goods are a major component of total intermediate goods used in these countries.

2.2 Properties of the aggregate economy and intermediate and final goods sectors over the business cycle.

In theory, disaggregating total output into intermediate and final output is straightforward: goods and services are classified as intermediate if they are used up in the production of other goods during the same period in which they were produced and final goods and services are those goods that are the end product of the productive process. However, in reality, disaggregation of economic data into these two categories is not as straightforward.

To our knowledge, there is no available data set which categorizes economic activity by intermediate and final good production. For this reason, we use data disaggregated by two digit International Standard Industrial Classification sectors and approximate intermediate and final good production by selecting sectors to represent each type of production. Sectors are selected by considering the type of production that primarily occurs in the sector as reported in input-output tables for the U.S., Germany, and Japan. In some sectors, such as agriculture and mining, the decision was clear cut. The most controversial categorization occurs when considering the food, beverage and tobacco sectors. However, most of what is produced in these sectors, even if final in nature, is first sold to retailers before being purveyed to the consumer. The intermediate goods sectors are: agriculture, mining, wood, paper, chemicals, nonmetallic metals, basic metals, food, beverage and tobacco, and textiles. The final good sectors include: machinery and equipment, transportation, finance and insurance, construction, retail and wholesale trade, and other services. Again, there is some quantity of output produced by the transportation and finance and insurance sectors that is an intermediate good in the
production of other final goods. However, the majority (over 50%) of the goods produced in these sectors are sold directly to consumers. Also, wholesale trade is obviously not a final good, but wholesale trade could not be separated from retail trade and retail trade's value added was the major contributor to this category.\(^7\) The aggregate economy is defined as the sum of the intermediate and final good sectors. The data are described in greater detail in the data appendix.

Table 2 presents the properties of business cycles in the U.S., Germany, and Japan for the period 1970-1985. The data are sampled at an annual frequency and all of the series are real, per-capita variables that are transformed by the natural logarithm and detrended using the Hodrick-Prescott (1980) filter.\(^8\) Many of the properties of the aggregate data presented below are also documented in other studies (see Backus, Kehoe and Kydland (1992a, 1992b) and Stockman and Tesar (1990)).

We find that aggregate output is more variable than consumption and aggregate employment but less variable than aggregate investment in all countries. Also, in all economies, aggregate consumption, investment, employment and productivity are procyclical. Savings, which we define in both the data and the model as output minus consumption, is always positively correlated with investment.\(^9\) In addition, the trade balance, which we define as the ratio of net exports to aggregate output, is countercyclical in all three economies. At the

\(^7\) Retail trade, as defined in the data, also includes the value added by restaurants and hotels.

\(^8\) This filter emphasizes the medium and high frequency movements in the data. See King and Rebelo (1989) for discussion of the properties of this filter.

\(^9\) The much discussed positive savings-investment relationship has been well documented beginning with Feldstein and Horioka (1980). Tesar (1991) finds that there is less regularity in the positive savings-investment relationship at the business cycle frequency. See Tesar for a recent survey.
sectoral level, output is always more variable than employment and less variable than investment and all variables, with the exception of investment, are more variable in the intermediate good sector than in the final good sector in all economies. Furthermore, outputs are positively correlated across sectors in all countries.

With regard to international comovements, we find that aggregate and sectoral output are positively correlated across countries. Interestingly, the cross-country correlation of final outputs is about the same as the cross-country correlation of intermediate outputs and in all but one case aggregate outputs are more strongly correlated. Also, the cross-country correlations of consumption are positive, but less than the cross-country correlations of aggregate output.

3. The Model Economy.

In this section we extend a one-good, two-country model of business cycles by including a second intermediate good that is both produced and traded across economies.

Consider a world economy with two countries (i=1,2). The representative household in country i maximizes their expected lifetime utility, as given by

\[ E_0(U_e) = E_0 \sum_0 \beta^t u(c_{i,t}l_{i,t}) \]  

(1)

where \( E_0 \) is the expectation at time 0, \( c_{i,t} \) is consumption of the final good, \( l_{i,t} \) is leisure at time t, and

\[ u(c_{i,t}l_{i,t}) = \log c_{i,t} + \psi \log l_{i,t} \]  

(2)

where \( \psi \) is the weight placed on leisure in deriving utility.

Each country produces an intermediate good and a final good using the same constant
returns to scale technology. Firms are assumed to produce the intermediate good in country $i$ using Cobb-Douglas technology:

$$X_{it} = w_{it}G(H_{it},E_{it}) = w_{it}H_{it}^{(1-\sigma)}E_{it}^\sigma$$

(3)

where $H_{it}$ is the capital stock utilized in the intermediate good sector in country $i$, and $E_{it}$ is the labor employed in the intermediate good sector. $w_{it}$ represents a technology shock in the intermediate good sector of country $i$.

Production of the final good, $Y_{it}$, takes place in each country using CES technology:

$$Y_{it} = z_{it}F(K_{it},N_{it},V_{it}) = z_{it}[aK_{it}^{-\alpha} + (1-a)V_{it}^{-\gamma}]^{-\alpha\gamma}N_{it}^\theta$$

(4)

where $K_{it}$ denotes the capital stock in the final good sector, $V_{it}$ denotes the intermediate good utilized by the final good sector, $N_{it}$ denotes the labor input employed in the final good sector, and $z_{it}$ denotes the technology shock in the final good sector.

The parameter $\theta$ is labor's distributive share and $\gamma$ is equal to $(1-s)/s$, where $s$ is equal to $\sigma_k - \sigma_k, \theta + \theta$ and $\sigma_k$ is the Allen elasticity of substitution between capital and the intermediate goods. We assume that the final good sector has CES technology so that we may consider values of the elasticity of substitution between intermediate goods and capital other than that implied by Cobb-Douglas technology.

The productivity shocks, $w_{it}$ and $z_{it}$, are assumed to follow a stationary, first-order, Markov process. Letting a circumflex over a variable denote a percentage deviation, i.e., $\hat{w} = \Delta w/w$ and $\hat{z} = \Delta z/z$, the evolution of the technological process is given by:
\[
\begin{bmatrix}
\hat{z}_{1,t+1} \\
\hat{z}_{2,t+1} \\
\hat{w}_{1,t+1} \\
\hat{w}_{2,t+1}
\end{bmatrix}
= 
\begin{bmatrix}
\rho_{s,s} & \rho_{s,v} & \rho_{s,w} \\
\rho_{v,s} & \rho_{v,v} & \rho_{v,w} \\
\rho_{w,s} & \rho_{w,v} & \rho_{w,w}
\end{bmatrix}
\begin{bmatrix}
\hat{z}_{1,t} \\
\hat{z}_{2,t} \\
\hat{w}_{1,t}
\end{bmatrix}
+ 
\begin{bmatrix}
\hat{\varepsilon}_{s,t+1} \\
\hat{\varepsilon}_{v,t+1} \\
\hat{\varepsilon}_{w,t+1}
\end{bmatrix}
\] (5)

where

\[
\begin{bmatrix}
\hat{\varepsilon}_{s,t} \\
\hat{\varepsilon}_{v,t} \\
\hat{\varepsilon}_{w,t}
\end{bmatrix}
= 
\begin{bmatrix}
0 \\
0 \\
0
\end{bmatrix}
\begin{bmatrix}
\sigma_{s}^{2} & \sigma_{s,v} & \sigma_{s,w} \\
\sigma_{s,v} & \sigma_{v}^{2} & \sigma_{v,w} \\
\sigma_{s,w} & \sigma_{v,w} & \sigma_{w}^{2}
\end{bmatrix}
\] (6)

The capital stocks in the intermediate and final good sectors accumulate over time according to

\[
H_{i,t+1} = (1-\delta)H_{i,t} + \Phi \left( I_{H,t} / H_{i,t} \right) H_{i,t}
\] (7)

\[
K_{i,t+1} = (1-\delta)K_{i,t} + \Phi \left( I_{K,t} / K_{i,t} \right) K_{i,t}
\] (8)

where \(\delta\) is the annual depreciation rate of capital which is assumed to be the same in both sectors and both countries. \(\Phi\) is the adjustment cost function and \((1/\Phi')\) is Tobin's "Q" which represents the number of units of output that must be foregone to increase the capital stock in a particular sector by one unit. \(\Phi\) and \(\Phi'\) are assumed to be greater than zero and \(\Phi''\) is assumed to be less than zero. The adjustment cost formulation is the same as the one used in Uzawa.
(1969) and Lucas and Prescott (1971). This formulation captures the observation that it is costly to both install and to move already existing capital from one country to another or from one sector to another.

In each country the sum of work effort and leisure cannot exceed the endowment of time, which is normalized to one, and is given by:

\[ 1 - I_{i,t} - N_{i,t} - E_{i,t} \geq 0 \]  

The world resource constraints for the intermediate and final goods are given by:

\[ X_{1,t} + X_{2,t} - V_{1,t} - V_{2,t} \geq 0 \]  

\[ Y_{1,t} + Y_{2,t} - C_{1,t} - C_{2,t} - I_{K,t} - I_{K,t} - I_{M,t} - I_{M,t} \geq 0 \]  

The equilibrium allocations of consumption, work effort, capital, and intermediate goods are found by considering the problem facing the social planner who maximizes equally weighted expected utility functions of two agents subject to world resource constraints.

4. The Model's Solution and Its Calibration.

The model's solution and approximate dynamics are computed using the method described in King, Plosser, and Rebelo (1988). That paper gives the details of the procedure so we chose to not replicate it here. We compute a linear approximation of the world economy around the model's steady state which is the same both with and without adjustment costs. The periodicity of the model is one year.

We use information from national accounts and micro studies concerning secular movements in the U.S. to restrict the model's preference and production technologies.
parameters. The parameter values are given in table 3a.

The steady-state interest rate is set equal to 1.4 percent per annum, which is the average real rate of return for U.S. Treasury bills between the years 1970 to 1985, and implies that $\beta$, the discount parameter, is equal to 0.986. The steady-state fraction of time worked is set equal to .22, which is the average fraction of hours spent working per week in the U.S. over the sample period. The steady-state values of the time devoted to work in the final and intermediate good sectors is .18 and .04 respectively.\(^{10}\)

The specification and parameters for the production technologies were chosen based on several considerations. The Allen elasticity of substitution between capital and labor in the intermediate goods sector and between capital and intermediate goods and labor in the final good sector is always equal to -1. This choice reflects the estimate of this elasticity given by Berndt and Wood (1975) using gross aggregate U.S. data. The labor share in the intermediate good sector is set to .58, which is the average value for this parameter in the U.S. economy between the years 1970 and 1985. In the final goods sector, Berndt and Wood estimate the shares distributed to labor and intermediate goods to be .29 and .66 respectively. Because labor is employed as an input in the production of intermediate goods, intermediate goods embody labor. Thus, for the model's aggregate labor share to be equivalent to the value of this parameter documented for the U.S. in other studies, we set the labor share in the final good sector to be .22. This values implies that the aggregate labor share is .64. The Allen elasticity of substitution between capital and intermediate goods in the final goods sector is set to .49,

\(^{10}\) If total employment is defined as employment in both the intermediate and final good sectors then the total amount of time devoted to any one sector is the average fraction of employment in that sector multiplied by the average amount of time devoted to working over the sample period.
which is the value estimated by Berndt and Wood for the U.S. economy between the years 1947 and 1971, and implies that capital and intermediate goods are more complementary than what is assumed under a Cobb-Douglas specification. An elasticity of .49 results in a value of v equal to .66.

The parameter value, \( a \), was chosen so that the steady-state values of the capital-to-output ratios matched the data as closely as possible given the values chosen for the shares distributed to capital and intermediate goods. In the model economy, the steady-state capital-to-output ratios in the intermediate and final good sectors are 4.51 and 1.72 respectively. Finally, the parameter \( \delta \) is set to .10 which implies a 10 percent annual depreciation rate for capital in both sectors.

Our near steady-state analysis does not require that we specify a functional form for the adjustment cost parameter, \( \Phi \). We only need to specify the parameters which describe the behavior of \( \Phi \) near the steady state. The necessary parameters include: (i) the steady state value of Tobin's "Q", (ii) the steady-state ratios of investment in the intermediate good and final good sectors to final good output, and (iii) the elasticity of the marginal adjustment cost function. (i) and (ii) amount to setting the steady state values of \( \Phi(I_g/Y) \), \( \Phi(I_y/Y) \), \( \Phi'(I_g/Y) \), and \( \Phi'(I_y/Y) \). These parameters are set so that the model with adjustment costs has the same steady-state as the model without adjustment costs. Hence, the steady-state values of Tobin's "Q" in both sectors is one and the steady-state adjustment cost in both sectors is equal to \( \delta \). Because there are two sectors, there are two parameters describing the elasticity of the marginal adjustment cost function with respect to changes in \( I_g/Y \) and \( I_y/Y \). Our analysis simplifies the parameter choices by setting them equal in both sectors. However, we experiment with
different values of the parameter by setting it to -.05 and -.10.\textsuperscript{11,12}

The technological processes are measured using Solow's (1957) method. We calculate Solow residuals in each sector for the U.S., Germany, and Japan using annual data from 1970-1985. Given these technology series, we consider two settings for the parameters of the technological processes in our simulations.

For the benchmark case, we describe the Solow residuals of each country and sector by univariate AR(1) processes, estimate them, and take an average over each sector. The corresponding autocorrelation matrix contains no off-diagonal terms and for each sector the same persistence. The variance-covariance matrix of the innovations to these processes is computed by taking an average of the covariances between the the residuals from the estimated univariate processes and is assumed to be symmetrical.

For the alternative case, we describe the Solow residuals between each country pair as a vector autoregressive process (VAR) with one lag and one equation describing each of the four sectors. Given the three country pairs, an average value is taken for each parameter in the autocorrelation matrix and the matrix is assumed to be symmetrical. The variance-covariance matrix describing the innovations to the VAR, is computed in a similar fashion to the computation of the autocorrelation matrix. It too is symmetrical.

The autocorrelation matrices and variance-covariance matrices for both the benchmark

\textsuperscript{11} The elasticity of the marginal adjustment cost function, $\xi$, is equal to the inverse of the elasticity of the investment response to changes in Tobin's "$Q". A smaller absolute value of $\xi$ corresponds to a more elastic adjustment.

\textsuperscript{12} The values chosen for the $\xi$ are similar to those used in Baxter and Crucini (1993). However, our choices imply that the elasticity of investment responses to changes in Tobin's "$Q" are much lower than those estimated by Abel (1978). We experimented with the values estimated by Abel, but using these values caused the model's predicted volatilities to be much lower than found in the data.
and alternative cases are given in table 3b. Eigenvalues for both autocorrelation matrices indicate that both systems are stationary. For the benchmark case, the correlations between the innovations to the Solow residuals across sectors within a country are on average .66 and are larger than the correlations across countries within a sector, .49 and .50 respectively. The same holds true for the alternative case. These correlations are consistent with the finding in Costello (1993) that technology is more highly correlated across sectors within a country than across countries within a sector.

4.1. Simulation Results.

We now consider the statistics computed from the simulations of our theoretical world economy and compare them to statistics computed from the actual data. All sample moments are computed from 100 simulations of the artificial economy, each of 16 periods. The number 16 corresponds to the sample length of the actual data, 1970-1985. As for the data used in section 2, the artificial data is Hodrick-Prescott filtered. We begin by presenting results from the economy with the benchmark technological processes discussed above. We then consider alternative specifications of the technological process, the adjustment cost parameter, and the elasticity of substitution between capital and intermediate goods.

Table 4 reports the model’s predictions when the economy is driven by the benchmark specification for the technological processes and $\xi = -.05$. At the aggregate level, the predictions for standard deviations of output, employment, productivity, and net exports are all larger than in the data and the standard deviation of consumption is much smaller than found in the data. However, the relative volatilities predicted by the model economy are much more in line with what is found in the data. As in the data, aggregate investment is more variable than aggregate output and aggregate consumption and employment are less variable than aggregate output.
Although, the relative volatility of investment to output is between 2 and 3 in the data but only 1.5 in the model economy. Also similar to the actual data, the model economy predicts savings and investment to be highly positively correlated. With respect to international comovements, the model captures the fact that aggregate output is positively correlated across countries.

At the sectoral level, the model economy correctly predicts investment to be more variable than output, and labor and labor productivity to be less variable than output in both sectors. The model also captures the fact that with the exception of labor, all variables are more volatile in the intermediate good sector than the final good sector. Similarly, the model correctly predicts the procyclical behavior of output, investment, and labor as well as the positive correlation of output across sectors and across countries.

There are also some discrepancies between the predictions of the model economy and the data. One significant discrepancy is that the model economy predicts a positive relationship between net exports and aggregate output while in the data the correlation is negative. The model economy also predicts productivity in the final good sector to be countercyclical while in the data it is procyclical. However, this result is consistent with labor being procyclical and more volatile than output in the final goods sector and stems from the share distributed to labor in the final goods sector being relatively small as compared to the aggregate economy or intermediate goods sector. An important international regularity that the model is unable to capture is the cross-country correlation of consumption. The model predicts this correlation to be one while in the data consumption is positively correlated across countries but less than one.13

13 The model predicts a correlation of one because there is only one consumption good and preferences are logarithmic. However, logarithmic preferences were chosen so that the origin of our results could be traced to
To get some intuition for the dynamic behavior of the model economy we examine impulse response functions. Figures 1a through 4b illustrate the response of the benchmark economy to an innovation in the home country’s final or intermediate goods sector technological process, $e_{j,t}$, which is equal to its standard deviation, $\sigma_{j,t}$. In all of the figures, employment and labor productivity are measured as a percent of their steady-state values, and the remaining variables are measured as a percent of steady-state output in their respective sectors or aggregate steady-state output if the variables are aggregate variables.

Figure 1a through 2b give the responses of an innovation to the final goods sector. The industry level responses in 1a and 1b show that initially output, investment, and employment rise in the final goods sector at home and output, investment, and employment fall in the final goods sector in the foreign country. Given the opportunities which now exist in the home country’s final goods sector, resources are shifted out of the foreign final goods sector and into the home final goods sector. However, in order to produce more of the final good, the home country requires more of the intermediate good. The foreign country has a comparative advantage in producing the intermediate good. Thus, output, investment and employment in the intermediate good sector fall in the home country and rise in the foreign country. Given relative prices, these responses are consistent with the positive aggregate output correlations reported in table 4.

Figures 2a and 2b show the response of the aggregate variables to a shock to the home country’s final good sector. Output, investment, and employment increase in the home country.

---

the production side of the economy. If we had assumed that preferences were CES, then under some choices for the relative degree of risk aversion we could get consumptions across countries being correlated at less than one, but the model would still miss on the important international regularity that consumptions are less correlated across countries than output.
due to the higher total factor productivity. But labor productivity falls because employment
responds more than aggregate output. Aggregate output rises by more than consumption plus
investment which results in positive net exports. Correspondingly, in the foreign country,
aggregate output rises less than consumption plus investment which causes the foreign country’s
net exports to fall.

Figures 1a through 2b also illustrate that the addition of the intermediate goods sector
rather than a second final goods sector alters the responses of the aggregate economy to a shock
to the final goods sector. If both goods were final, then a shock to one of the sectors in the
home country, say sector 1, would result in output of sector 1 in the home country to rise and
output of sector 1 in the foreign country to fall. Substitution effects would cause output of
sector 2 to fall in the home country and to rise in the foreign country. Wealth effects would
cause the consumption of both goods in both countries to rise. But relative price changes, now
good 1 being relatively less expensive, would result in the world production of good 1 rising
more than world production of good 2. Hence, if there is a positive shock to the home country
production function in sector 1, aggregate output will rise in the home country and fall in the
foreign country. However, if the second sector produces an intermediate good and the economy
is vertically integrated in both economies, as in our model economy, we find that aggregate
output will increase in both the home and foreign countries.\textsuperscript{14}

Figures 3a through 4b give the responses to an innovation to the intermediate goods
sector. In figures 3a and 3b, industry level responses are given. In the intermediate goods
sector, output and employment rise in the home country but fall in the foreign country.

\textsuperscript{14} For this result we are assuming that utility is logarithmic. If instead the two sectors produced final goods
that are strong complements, then output could rise in both countries even with two final goods sectors.
However, in the final goods sector both at home and in the foreign country, output and employment rise. This is most likely due to increases in wealth and intermediate goods not being consumable. The intuition behind the increases in investment in all sectors is not immediately clear. For the same reason that agents increase current consumption they also increase future consumption. Hence, investment in the final goods sector rises in both countries. Wealth effects also raise leisure in both countries. Thus, for output to rise in the final goods sector, given less employment, inputs of intermediate goods must also rise. Increases in future production of intermediate goods requires investment in the intermediate goods sector both at home and in the foreign country.

Turning to figures 4a and 4b we see that aggregate employment, investment, productivity and output all increase in the home country, but consumption plus investment rise by less than output so there is a trade balance surplus. In the foreign country, investment, consumption, and employment rise but output, labor productivity, and net exports fall. As in a one-good, two-country business cycle model, output increases at home and falls abroad with shocks to the intermediate goods sector.

4.2. The Economy with Alternative Technological Processes, Adjustment Costs, and Elasticities of Substitution.

In this section we investigate whether our results are sensitive to modest changes in our parameters. Our first experiment is to allow for spillovers across countries and sectors (the off-diagonal elements of \( A \)). We estimate three, four variable VARs for the technology processes: one using data for the U.S. and Germany, another using data for the U.S and Japan, and a third using data from Germany and Japan. We then take averages of the three estimates. These estimates along with the eigenvalues are presented in table 3. The results from this experiment
are reported in the right hand side of table 4. Introducing cross-country and cross-industry technology spillovers does introduce some differences from the benchmark economy. The largest differences involve the cross-country correlation of intermediate good output and investment. The cross-country correlation of intermediate output declines from .17 to .05. However, the cross country correlation of aggregate output remains positive. The volatility of investment and the relative volatility of investment to output are both much larger than found in the benchmark economy. Additionally, and the correlation between investment and output declines by between .20 and .24.

We continue our sensitivity analysis by considering a modification to the adjustment cost parameter. The motivation for introducing a cost to adjusting capital was to recognize that it is costly to adjust the physical number of units of capital. To determine whether our results were sensitive to the choice of the adjustment cost parameter, we considered the benchmark economy with VAR shocks but introduced a larger cost of adjusting capital. The first two columns of table 5 report the results for an adjustment cost parameter of $\xi = -.10$. In general, higher adjustment costs lower the predicted volatility of all variables. The intuition is simple. A higher cost of adjusting capital makes it more costly to alter production when there is a change in technology. This leads to a lower variability in investment and output. The higher adjustment cost, however, does not have a large effect on the predicted correlations.

Our last two experiments concerned the effects on the benchmark economy from changing the elasticity of substitution between capital and intermediate goods. Columns 3 through 6 of table 5 present the results from these experiments. Columns 3 and 4 report the model results when there is more complementarily between capital and intermediate goods than in the benchmark economy. Columns 5 and 6 report the results when capital and intermediate
goods are less substitutable than in the benchmark economy. Changing the elasticity of substitution between capital and intermediate goods has relatively little effect on the standard deviations nor correlations in the model economy, with the exception of the correlation of sectoral output across countries. When capital and intermediate goods are assumed to be more complementary than in the benchmark economy the cross country correlation of intermediate good output falls and when the inputs are more substitutable than assumed in the benchmark economy the cross-country correlation of intermediate goods increases.

5. Conclusions.

As noted in the introduction, trade in intermediate goods is an empirically significant feature of the international trade conducted by the U.S., Germany, and Japan. In this paper we modified a dynamic, two-country, one-good, equilibrium model of the business cycle by introducing a second traded intermediate good. We distinguished between intermediate and final goods so that we could study the contribution of intermediate goods to the international transmission of business cycles.

Our results from conducting simulations and studying impulse response functions suggest that trade in intermediate goods is an important source of the international transmission of business cycles. Conducting simulations of the theoretical economy we discovered that the model captures many important business cycle phenomena. Among our findings are that output is positively correlated at both the sectoral and aggregate level and the volatility of aggregate employment, investment, consumption and productivity relative to the volatility of aggregate output is similar to what is found in the data. In addition, as in the data, we find that the correlation of output across sectors is positive and savings and investment are positively
correlated. The results from impulse response functions illustrate the different effects productivity shocks will have on an economy depending on whether they occur in the final good sector or in the intermediate good sector. In particular, we show that if the home country has a productivity shock in its final good sector then outputs will move together across countries but if instead the change in productivity occurs in the intermediate good sector then outputs will move in opposite directions.

There are also some discrepancies between the predictions of the model economy and the data. One noteworthy difference is that the model economy predicts a positive relationship between the trade balance and output while in the data this relationship is negative.

We examined how sensitive our results were to particular parameter values. We found that although higher adjustment costs lower the predicted volatility of all variables, it did not have a large effect on the predicted correlations. Our model is also robust to changes in the Allen elasticity of substitution between capital and intermediate goods. A range of this parameter between .09 and .89 had relatively no effect on the correlations of aggregate outputs across countries.
References


Data Appendix

The information for the data used in table 1 come from the following sources:

The export and import information for primary, intermediate and capital goods is from table 4.1 in the 1987 supplement to the Handbook on trade and development published by the United Nations. The definitions for primary intermediate and final goods is the one used by GATT. The information for trade in services is from OECD Member Countries Data on Trade in Services, OECD, Paris, 1987. The measure used for exports of services was total exports (1) - Investment export income(3) - export of government services(4). The measure used for imports of services was total imports (1) - Investment import income(3) - import of government services(4). All data is the average of 1970, 1975, 1980, 1985.

The following table provides information on the composition of output by industry in the U.S., Germany, and Japan. These numbers were used to construct panel two in table 1.

<table>
<thead>
<tr>
<th></th>
<th>U.S.</th>
<th>Germany</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary GDP/Total GDP</td>
<td>10.51</td>
<td>9.54</td>
<td>7.56</td>
</tr>
<tr>
<td>Intermediate GDP/Total GDP</td>
<td>11.04</td>
<td>14.21</td>
<td>13.31</td>
</tr>
<tr>
<td>Capital GDP/Total GDP</td>
<td>9.47</td>
<td>14.34</td>
<td>11.59</td>
</tr>
<tr>
<td>Service GDP/Total GDP</td>
<td>57.31</td>
<td>44.61</td>
<td>58.81</td>
</tr>
<tr>
<td>Construction</td>
<td>5.18</td>
<td>6.71</td>
<td>9.37</td>
</tr>
<tr>
<td>Retail &amp; Wholesale</td>
<td>16.93</td>
<td>10.74</td>
<td>15.32</td>
</tr>
<tr>
<td>Transportation</td>
<td>6.45</td>
<td>5.79</td>
<td>6.16</td>
</tr>
<tr>
<td>Finance and Insurance</td>
<td>20.40</td>
<td>10.34</td>
<td>16.28</td>
</tr>
<tr>
<td>Other Services</td>
<td>8.35</td>
<td>11.03</td>
<td>11.68</td>
</tr>
</tbody>
</table>


The data in table 2 and the data used for the calibration exercises come from the following sources:

The data are annual observations from 1970 to 1986. The countries included are Japan, Germany and the U.S.. The CPI, consumption, exports, imports and population are taken from the 1988 International Financial Statistics Yearbook. All Sectoral Data are from the OECD International Sectoral Data Base (ISDB). The sectors of each economy were characterized as
either intermediate or final based on whether the average good in the sector was sold as an 
intermediate good which required further processing or as a final good sold to either a business 
or consumer that was ready for use. The intermediate goods sectors are: agriculture, mining, 
wood, paper, chemicals, nonmetallic metals, basic metals, food, beverage and tobacco, and 
textiles. The final good sectors include: machinery and equipment, transportation, finance and 
insurance, construction, retail and wholesale trade, and other services. The aggregate is the sum 
of the intermediate and final sectors.

CAPITAL STOCK

The aggregate capital stock is the sum of the capital stock for intermediate and final good 
sectors. Source: OECD sectoral data bank.

EMPLOYMENT- number of employees, ISDB

OUTPUT- GDP value, 1980 prices

INVESTMENT-- 1980 value ISDB

The labor share is defined as compensation over GDP less net indirect taxes. The total time 
spent working in each sector is defined as average hours per week as a fraction of total hours 
per week weighted by the fraction of employment in each sector. Hours are from the 
International Labor Office Yearbook.

Prior to any analyses of the data, the variables were transformed by the natural logarithm 
function and H-P filtered with the penalty parameter, λ, set to 400.
<table>
<thead>
<tr>
<th></th>
<th>U.S.</th>
<th>Germany</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary good exports / total exports</td>
<td>26.45</td>
<td>16.25</td>
<td>15.50</td>
</tr>
<tr>
<td>Intermediate good exports / total exports</td>
<td>18.21</td>
<td>28.64</td>
<td>26.19</td>
</tr>
<tr>
<td>Primary + Intermediate / total exports</td>
<td>44.67</td>
<td>44.89</td>
<td>41.69</td>
</tr>
<tr>
<td>Capital good exports / total exports</td>
<td>36.29</td>
<td>39.69</td>
<td>45.38</td>
</tr>
<tr>
<td>Service exports / total exports</td>
<td>16.00</td>
<td>13.96</td>
<td>11.98</td>
</tr>
<tr>
<td>Capital + Services / total exports</td>
<td>52.29</td>
<td>53.65</td>
<td>57.36</td>
</tr>
<tr>
<td>Primary good imports / total imports</td>
<td>37.88</td>
<td>37.74</td>
<td>63.10</td>
</tr>
<tr>
<td>Intermediate good imports / total imports</td>
<td>21.67</td>
<td>23.18</td>
<td>10.00</td>
</tr>
<tr>
<td>Primary + Intermediate / total imports</td>
<td>59.55</td>
<td>60.12</td>
<td>73.13</td>
</tr>
<tr>
<td>Capital good imports / total imports</td>
<td>25.12</td>
<td>15.12</td>
<td>6.60</td>
</tr>
<tr>
<td>Service imports / total imports</td>
<td>13.20</td>
<td>21.89</td>
<td>20.18</td>
</tr>
<tr>
<td>Capital + Services / total imports</td>
<td>38.32</td>
<td>37.10</td>
<td>26.78</td>
</tr>
</tbody>
</table>

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total exports/total GDP</td>
<td>6.20</td>
<td>30.94</td>
<td>14.81</td>
</tr>
<tr>
<td>Primary exports/primary GDP</td>
<td>15.89</td>
<td>52.53</td>
<td>30.36</td>
</tr>
<tr>
<td>Intermediate exports/intermediate GDP</td>
<td>5.34</td>
<td>85.92</td>
<td>29.14</td>
</tr>
<tr>
<td>Capital exports/capital GDP</td>
<td>24.30</td>
<td>62.40</td>
<td>57.99</td>
</tr>
<tr>
<td>Service exports/service GDP</td>
<td>1.76</td>
<td>9.50</td>
<td>3.02</td>
</tr>
<tr>
<td>Total imports/total GDP</td>
<td>8.09</td>
<td>30.55</td>
<td>14.77</td>
</tr>
<tr>
<td>Primary imports/primary GDP</td>
<td>23.00</td>
<td>13.00</td>
<td>45.00</td>
</tr>
<tr>
<td>Intermediate imports/intermediate GDP</td>
<td>7.00</td>
<td>47.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Capital imports/capital GDP</td>
<td>20.00</td>
<td>49.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Service imports/service GDP</td>
<td>2.00</td>
<td>12.00</td>
<td>4.00</td>
</tr>
</tbody>
</table>

The data are averages over the years 1970, 1975, 1980, and 1985. Domestic use is defined as GDP minus exports plus imports. The export and import figures for primary, intermediate, and capital goods come from the Handbook of International Trade and Development (1987). The service trade figures are from the OECD Member Countries Data on Trade in Services. Total exports, imports, and GDP are from the OECD National Accounts Statistics (1987).
Table 2

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>U.S. STD</th>
<th>U.S. RSTD</th>
<th>U.S. CORR</th>
<th>Germany STD</th>
<th>Germany RSTD</th>
<th>Germany CORR</th>
<th>Japan STD</th>
<th>Japan RSTD</th>
<th>Japan CORR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>2.94</td>
<td>1.00</td>
<td>1.00</td>
<td>2.01</td>
<td>1.00</td>
<td>1.00</td>
<td>2.86</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Labor</td>
<td>2.28</td>
<td>0.78</td>
<td>0.85</td>
<td>1.76</td>
<td>0.87</td>
<td>0.66</td>
<td>1.16</td>
<td>0.41</td>
<td>0.63</td>
</tr>
<tr>
<td>Investment</td>
<td>6.93</td>
<td>2.36</td>
<td>0.86</td>
<td>6.80</td>
<td>3.37</td>
<td>0.69</td>
<td>5.82</td>
<td>2.03</td>
<td>0.46</td>
</tr>
<tr>
<td>Consumption</td>
<td>1.93</td>
<td>0.66</td>
<td>0.93</td>
<td>2.09</td>
<td>1.03</td>
<td>0.74</td>
<td>1.67</td>
<td>0.58</td>
<td>0.72</td>
</tr>
<tr>
<td>Productivity</td>
<td>1.54</td>
<td>0.52</td>
<td>0.64</td>
<td>1.58</td>
<td>0.78</td>
<td>0.54</td>
<td>2.32</td>
<td>0.81</td>
<td>0.92</td>
</tr>
<tr>
<td>Net Exports</td>
<td>0.74</td>
<td>0.25</td>
<td>-0.52</td>
<td>1.40</td>
<td>0.69</td>
<td>-0.39</td>
<td>1.37</td>
<td>0.48</td>
<td>-0.24</td>
</tr>
</tbody>
</table>

Intermediate goods sector

| Output        | 3.07 | 1.00 | 1.00 | 2.36 | 1.00 | 1.00 | 3.74 | 1.00 | 1.00 |
| Labor         | 2.80 | 0.91 | 0.71 | 1.98 | 0.84 | 0.53 | 2.11 | 0.56 | 0.65 |
| Investment    | 10.48| 3.41 | 0.40 | 6.77 | 2.87 | 0.35 | 3.88 | 1.04 | -0.38 |
| Productivity  | 2.25 | 0.73 | 0.26 | 2.13 | 0.90 | 0.61 | 3.51 | 0.94 | 0.83 |

Final goods sector

| Output        | 3.06 | 1.00 | 1.00 | 1.99 | 1.00 | 1.00 | 2.84 | 1.00 | 1.00 |
| Labor         | 2.27 | 0.74 | 0.85 | 1.73 | 0.87 | 0.68 | 1.11 | 0.39 | 0.67 |
| Investment    | 9.40 | 3.07 | 0.75 | 7.24 | 3.64 | 0.71 | 8.17 | 2.88 | 0.64 |
| Productivity  | 1.65 | 0.54 | 0.68 | 1.52 | 0.76 | 0.54 | 2.25 | 0.79 | 0.93 |

Other Correlations

<table>
<thead>
<tr>
<th>Final and Intermediate Output</th>
<th>U.S.</th>
<th>Germany</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.75</td>
<td>.86</td>
<td>.67</td>
</tr>
<tr>
<td>Savings and Investment</td>
<td>.96</td>
<td>.91</td>
<td>.86</td>
</tr>
</tbody>
</table>

International Correlations

<table>
<thead>
<tr>
<th>Domestic and Foreign Aggregate Output</th>
<th>US-Germany</th>
<th>US-Japan</th>
<th>Japan-Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.82</td>
<td>.52</td>
<td>.44</td>
</tr>
<tr>
<td>Domestic and Foreign Final Output</td>
<td>.77</td>
<td>.35</td>
<td>.41</td>
</tr>
<tr>
<td>Domestic and Foreign Intermediate Output</td>
<td>.71</td>
<td>.67</td>
<td>.44</td>
</tr>
<tr>
<td>Domestic and Foreign Consumption</td>
<td>.34</td>
<td>.14</td>
<td>.37</td>
</tr>
</tbody>
</table>

Notes: STD is the standard deviation in percentage. RSTD is the standard deviation relative to output's and Corr is the correlation between the variable and output. Output refers to aggregate output for aggregate variables and sectoral output for sectoral variables.
Table 3a
Parameter Values for the Model Economy and Their Corresponding Actual Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Model</th>
<th>U.S.</th>
<th>Germany</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>subjective discount parameter</td>
<td>.986</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>share of labor in the final good sector</td>
<td>.2172</td>
<td>.289</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>share of intermediate good in the final good sector</td>
<td>.6507</td>
<td>.664</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>share of labor in intermediate good sector</td>
<td>.566</td>
<td>.566</td>
<td>.600</td>
<td>.370</td>
</tr>
<tr>
<td>aggregate labor share</td>
<td>.585</td>
<td>.600</td>
<td>.550</td>
<td>.490</td>
</tr>
<tr>
<td>capital depreciation rate</td>
<td>.100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>elasticity of marginal adjustment cost</td>
<td>-.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>capital/output in final goods sector</td>
<td>1.72</td>
<td>3.67</td>
<td>4.09</td>
<td>2.19</td>
</tr>
<tr>
<td>capital/output in intermediate goods sector</td>
<td>4.51</td>
<td>2.70</td>
<td>2.70</td>
<td>2.95</td>
</tr>
<tr>
<td>average % of time spent working</td>
<td>.216</td>
<td>.216</td>
<td>.250</td>
<td>.247</td>
</tr>
<tr>
<td>% in final goods sector</td>
<td>.178</td>
<td>.178</td>
<td>.182</td>
<td>.207</td>
</tr>
<tr>
<td>% in intermediate goods sector</td>
<td>.038</td>
<td>.038</td>
<td>.068</td>
<td>.048</td>
</tr>
<tr>
<td>Elasticity of substitution between capital and intermediate goods</td>
<td>.49</td>
<td>.49</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>$\nu$</td>
<td>.6645</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha$</td>
<td>.25</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3b
Technology Shocks

\[
A = \begin{bmatrix}
p_{xx} & p_{xw} & p_{w}\nu & p_{w}\nu
\end{bmatrix}
V(e) = \begin{bmatrix}
\sigma_x^2 & \sigma_{xw} & \sigma_{x\nu} & \sigma_{x\nu}\n\sigma_{xw} & \sigma_{ww} & \sigma_{w\nu} & \sigma_{w\nu}\n\sigma_{w\nu} & \sigma_{w\nu} & \sigma_{\nu\nu}
\end{bmatrix}
Corr(e) = \begin{bmatrix}
r_x^2 & r_{xw} & r_{x\nu} & r_{x\nu}
\cdot & r_{ww} & r_{w\nu} & r_{w\nu}
\cdot & \cdot & r_{\nu\nu}
\end{bmatrix}
\]

Benchmark

\[
A = \begin{bmatrix}
.522 & 0 & 0 & 0
0 & .522 & 0 & 0
0 & 0 & .259 & 0
0 & 0 & 0 & .259
\end{bmatrix}
V(e) = \begin{bmatrix}
.000309 & .000291 & .000225
.000309 & .000225 & .000291
.000632 & .000314
.000632
\end{bmatrix}
\]

\[
Corr(e) = \begin{bmatrix}
1.00 & .49 & .66 & .51
.100 & 1.00 & .66
.100 & .50
1.00
\end{bmatrix}
\]

\[\text{Eigenvalues of } A = [0.522, 0.522, 0.259, 0.259]\]

Alternative Technological Shock Structure

\[
A = \begin{bmatrix}
0.954 & 0.247 & -0.486 & -0.215
0.247 & 0.954 & -0.215 & -0.486
0.658 & 0.716 & -0.319 & -0.570
0.716 & 0.658 & -0.570 & -0.319
\end{bmatrix}
V(e) = \begin{bmatrix}
0.000316 & 0.000133 & 0.000205 & 0.000113
.000316 & .000113 & .000205
.000426 & .000125
.000426
\end{bmatrix}
\]

\[
Corr(e) = \begin{bmatrix}
1.00 & .42 & .56 & .31
.100 & 1.00 & .56
.100 & .34
1.00
\end{bmatrix}
\]

\[\text{Eigenvalues of } A = [-0.200, 0.515, 0.739, 0.219]\]
<table>
<thead>
<tr>
<th>Aggregate</th>
<th>Benchmark Shocks</th>
<th>Alternative Shocks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>STD</td>
<td>RSTD</td>
</tr>
<tr>
<td>Output</td>
<td>4.32</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>(0.88)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Labor</td>
<td>3.24</td>
<td>0.78</td>
</tr>
<tr>
<td></td>
<td>(0.71)</td>
<td>(0.07)</td>
</tr>
<tr>
<td>Investment</td>
<td>6.51</td>
<td>1.46</td>
</tr>
<tr>
<td></td>
<td>(1.32)</td>
<td>(0.06)</td>
</tr>
<tr>
<td>Consumption</td>
<td>0.85</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>(0.21)</td>
<td>(0.13)</td>
</tr>
<tr>
<td>Productivity</td>
<td>2.07</td>
<td>0.47</td>
</tr>
<tr>
<td></td>
<td>(0.43)</td>
<td>(0.17)</td>
</tr>
<tr>
<td>Net Exports</td>
<td>1.89</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>(0.10)</td>
<td>(0.24)</td>
</tr>
</tbody>
</table>

**Intermediate goods sector**

| Output            | 3.88 | 1.00 | 1.00  | 4.74 | 1.00 | 1.00  |
|                   | (0.72) | (0.00) | (0.84) | (0.12) | (0.12) |
| Labor             | 3.16 | 0.81 | 0.95  | 4.11 | 0.87 | 0.95  |
|                   | (0.66) | (0.03) | (1.16) | (0.02) | (0.02) |
| Investment        | 7.29 | 1.88 | 0.77  | 15.57 | 3.28 | 0.57  |
|                   | (1.44) | (0.12) | (3.78) | (0.15) | (0.15) |
| Productivity      | 1.31 | 0.34 | 0.66  | 1.53 | 0.32 | 0.54  |
|                   | (0.27) | (0.15) | (0.29) | (0.23) | (0.23) |

**Final goods sector**

| Output            | 2.36 | 1.00 | 1.00  | 2.87 | 1.00 | 1.00  |
|                   | (0.54) | (0.00) | (0.63) | (0.00) | (0.00) |
| Labor             | 3.68 | 1.10 | 0.95  | 4.64 | 1.62 | 0.95  |
|                   | (0.84) | (0.03) | (1.07) | (0.06) | (0.06) |
| Investment        | 8.99 | 2.68 | 0.94  | 16.30 | 5.68 | 0.70  |
|                   | (1.89) | (0.03) | (3.72) | (0.16) | (0.16) |
| Productivity      | 1.61 | 0.48 | -0.69 | 2.10 | 0.73 | -0.72 |
|                   | (0.36) | (0.17) | (0.55) | (0.17) | (0.17) |

**Other Correlations**

<table>
<thead>
<tr>
<th></th>
<th>Benchmark Shocks</th>
<th>Alternative Shocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final and Intermediate Output</td>
<td>.55 (0.20)</td>
<td>.49 (0.28)</td>
</tr>
<tr>
<td>Savings and Investment</td>
<td>.88 (0.07)</td>
<td>.68 (0.18)</td>
</tr>
</tbody>
</table>

**International Correlations**

<table>
<thead>
<tr>
<th></th>
<th>Benchmark Shocks</th>
<th>Alternative Shocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic and Foreign Aggregate Output</td>
<td>.46 (0.23)</td>
<td>.43 (0.25)</td>
</tr>
<tr>
<td>Domestic and Foreign Final Output</td>
<td>.29 (0.27)</td>
<td>.24 (0.30)</td>
</tr>
<tr>
<td>Domestic and Foreign Intermediate Output</td>
<td>.17 (0.27)</td>
<td>.05 (0.34)</td>
</tr>
<tr>
<td>Domestic and Foreign Consumption</td>
<td>1.00 (0.00)</td>
<td>1.00 (0.00)</td>
</tr>
</tbody>
</table>

Notes: All entries are averages from 100 simulations each of sample length 16 and their standard deviation is in parentheses. STD is the standard deviation in percentage. RSTD is the standard deviation relative to output's and Corr is the correlation between the variable and output. Output refers to aggregate output for aggregate variables and sectoral output for sectoral variables.
Table 5
Cyclical Properties of the Model Economy
with Benchmark Shocks and Alternative Calibrations

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>$\xi_{-0.10}$</th>
<th>$\sigma_{\kappa_{0.09}}$</th>
<th>$\sigma_{\kappa_{0.89}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>STD</td>
<td>RSTD</td>
<td>CORR</td>
</tr>
<tr>
<td>Output</td>
<td>4.15</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>(0.77)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor</td>
<td>3.06</td>
<td>0.74</td>
<td>0.86</td>
</tr>
<tr>
<td>(0.58)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investment</td>
<td>5.75</td>
<td>1.39</td>
<td>0.89</td>
</tr>
<tr>
<td>(1.11)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumption</td>
<td>1.02</td>
<td>0.25</td>
<td>0.79</td>
</tr>
<tr>
<td>(0.22)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productivity</td>
<td>2.13</td>
<td>0.51</td>
<td>0.69</td>
</tr>
<tr>
<td>(0.45)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net Exports</td>
<td>1.83</td>
<td>0.44</td>
<td>0.52</td>
</tr>
<tr>
<td>(0.39)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Intermediate goods sector

| Output             | 3.72 | 1.00 | 1.00 | 3.46 | 1.00 | 1.00 | 3.87 | 1.00 | 1.00 |
| (0.68)             |     |     |     | (0.68) |     |     | (0.69) |     |     |
| Labor              | 2.95 | 0.79 | 0.93 | 2.68 | 0.77 | 0.88 | 3.37 | 0.87 | 0.94 |
| (0.62)             |     |     |     | (0.54) |     |     | (0.65) |     |     |
| Investment         | 5.88 | 1.58 | 0.78 | 6.83 | 1.97 | 0.68 | 7.79 | 2.01 | 0.76 |
| (1.14)             |     |     |     | (1.38) |     |     | (1.59) |     |     |
| Productivity       | 1.42 | 0.38 | 0.66 | 1.64 | 0.47 | 0.65 | 1.30 | 0.34 | 0.51 |
| (0.28)             |     |     |     | (0.29) |     |     | (0.24) |     |     |

Final goods sector

| Output             | 2.37 | 1.00 | 1.00 | 2.22 | 1.00 | 1.00 | 2.49 | 1.00 | 1.00 |
| (0.47)             |     |     |     | (0.49) |     |     | (0.52) |     |     |
| Labor              | 3.57 | 1.51 | 0.94 | 2.87 | 1.29 | 0.96 | 4.53 | 1.82 | 0.93 |
| (0.68)             |     |     |     | (0.60) |     |     | (0.95) |     |     |
| Investment         | 6.80 | 2.87 | 0.96 | 9.95 | 4.48 | 0.89 | 9.31 | 3.74 | 0.96 |
| (1.30)             |     |     |     | (1.96) |     |     | (1.87) |     |     |
| Productivity       | 1.53 | 0.65 | -0.65 | 0.98 | 0.44 | -0.53 | 2.35 | 0.94 | -0.74 |
| (0.32)             |     |     |     | (0.21) |     |     | (0.51) |     |     |

Other Correlations

<table>
<thead>
<tr>
<th>Final and Intermediate Output</th>
<th>$\xi_{-0.10}$</th>
<th>$\sigma_{\kappa_{0.09}}$</th>
<th>$\sigma_{\kappa_{0.89}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.49 (0.22)</td>
<td>.56 (0.19)</td>
<td>.46 (0.25)</td>
</tr>
<tr>
<td>Savings and Investment</td>
<td>.87 (0.09)</td>
<td>.87 (0.08)</td>
<td>.84 (0.10)</td>
</tr>
</tbody>
</table>

International Correlations

<table>
<thead>
<tr>
<th>Domestic and Foreign Aggregate Output</th>
<th>$\xi_{-0.10}$</th>
<th>$\sigma_{\kappa_{0.09}}$</th>
<th>$\sigma_{\kappa_{0.89}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.44 (0.25)</td>
<td>.38 (0.23)</td>
<td>.46 (0.22)</td>
</tr>
<tr>
<td>Domestic and Foreign Final Output</td>
<td>.21 (0.29)</td>
<td>.37 (0.26)</td>
<td>.14 (0.27)</td>
</tr>
<tr>
<td>Domestic and Foreign Intermediate Output</td>
<td>.12 (0.29)</td>
<td>.06 (0.24)</td>
<td>.20 (0.24)</td>
</tr>
<tr>
<td>Domestic and Foreign Consumption</td>
<td>1.00 (0.00)</td>
<td>1.00 (0.00)</td>
<td>1.00 (0.00)</td>
</tr>
</tbody>
</table>

Notes: All entries are averages from 100 simulations each of sample length 16 and their standard deviation is in parentheses. STD is the standard deviation in percentage. RSTD is the standard deviation relative to output's and Corr is the correlation between the variable and output. Output refers to aggregate output for aggregate variables and sectoral output for sectoral variables.
Figure 1a: In the home country at the sectoral level
Dynamic responses to a productivity shock in the final good sector

Y: Output final
X: Output intermediate
Ik: Investment final
Ih: Investment intermediate
N: Employment final
E: Employment intermediate

Figure 1b: In the foreign country at the sectoral level
Dynamic responses to a productivity shock in the final good sector

Y: Output final
X: Output intermediate
Ik: Investment final
Ih: Investment intermediate
N: Employment final
E: Employment intermediate
Figure 2a: In the home country for the aggregate economy
Dynamic responses to a productivity shock in the final good sector

Figure 2b: In the foreign country for the aggregate economy
Dynamic responses to a productivity shock in the final good sector
Figure 3a: In the home country at the sectoral level
Dynamic responses to a productivity shock in the intermediate good sector

Figure 3b: In the foreign country at the sectoral level
Dynamic responses to a productivity shock in the intermediate good sector
Figure 4a: In the home country for the aggregate economy
Dynamic responses to a productivity shock in the intermediate good sector

Yt: Output
Ct: Consumption
It: Investment
Nt: Employment
Pr: Productivity
NX: Net exports

Figure 4b: In the foreign country for the aggregate economy
Dynamic responses to a productivity shock in the intermediate good sector

Yt: Output
Ct: Consumption
It: Investment
Nt: Employment
Pr: Productivity
NX: Net exports