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Trade, Production Sharing and the International Transmission of Business Cycles

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Abstract

This paper is motivated by three observations about the link between international trade and international business cycle synchronization: (1) a large increase in trade in manufactures over the last 30 years, (2) a larger fraction of trade between core and periphery regions relative to core regions is in the form of production sharing, (3) cross-country output correlations have increased between core and periphery regions relative to core regions. We examine to what extent these observations can be reconciled in a multi-country version of a standard model of international business cycles. Production sharing is captured in a simple way as trade in intermediate inputs that are complements in production. We find that the model is successful qualitatively in account for these observations. Quantitatively, we find that the direct effects from trade do not generate large divergence in output correlations across countries. We extend the model to allow for cost reduction spillovers from MNEs in the core country to their affiliates in the periphery. This mechanism increases the impact that product sharing has on output correlations between core and peripheral countries.

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1. Introduction

Over the last thirty years trade in manufactures relative to output in manufactures has more than doubled. The nature of this trade differs, however, across country pairs. We find it useful to distinguish between trade that occurs between core regions, such as the U.S. and Europe, and trade between core regions and their periphery (the US with its NAFTA trading partners, for example). Trade between core and periphery countries involves more production sharing - the division of production processes into separate parts that can be done in different locations - than does trade between core regions. A natural question is how the increase in trade has affected international business cycle synchronization.[1]

Figures 1 and 2 show ten-year rolling correlations of GDP, investment and consumption between the U.S. and two of its major trading partners, an EU aggregate and Canada. Figure 1 suggests that, at least as measured by this simple metric, business cycles in the EU have become less linked to the U.S. cycle over time.[2] Figure 2 shows the bilateral relationship with Canada, which appears to be quite different. In this case, correlations with the U.S. have been high since the 1970s with no clear decline in the 1990s.[3] Table 1 shows that Mexico's business cycles have also become significantly more correlated with the U.S. since the 1980s. The one-size-fits-all connection between trade and business cycles does not seem to be supported by the data. Our conjecture is that the higher cross-country output correlations between core and periphery regions is partly a consequence of the increase in production sharing.

We study the link between business cycle synchronization and trade flows between different regions using an extended version of the standard model of international business cycles proposed by Backus, Kehoe, and Kydland (1995), henceforth BKK. We assume that trade between the "core" economic regions of the U.S. and Europe takes the form of trade in intermediate goods of different varieties. Firms in each region specialize in the produc-

[1] Papers that study this question include, among many others, Canova and Dellas (1993), Kelemli-Ozcan, Sorensen and Yosha (2002), Baxter and Michael Kouparitsas (2002), and Kose and Yi (2001, 2002).

[2] A large empirical literature has developed around the issue of business cycle synchronization. Among the many papers that examine this question are Bordo and Helbling (2003), Doyle and Faust (2002), Imbs (1999, 2003), Kose, Otrok and Whiteman (2003a, 2003b), Kose and Yi (2002), Heatchote and Perri (2002, 2003), and Stock and Watson (2003).

[3] Doyle and Faust (2002) test explicitly for breaks in the correlation of output growth for G7 countries corresponding to the 1960s, 1970s, 1980s and 1990s. They find no statistical evidence supporting an increase in correlation coefficients corresponding to those splits by decade, even for the US and Canada where trade integration has increased substantially.

tion of a particular variety, and consumers and firms have demands over a range of varieties produced in both locations. An aggregate shock that lowers the relative marginal cost of production in one country, will induce firms and households in both countries to substitute toward the lower price variety. This results in a negative transmission of the business cycle. In contrast, trade between core regions and "periphery" countries involves production chains that are linked across national borders. In this case, there is trade in intermediate goods but imported inputs are now complementary to domestic factors of production. So, an aggregate shock that lowers the cost of production in the core country will increase the demand of this country for intermediate products produced in the periphery countries that are required to produce the final good. This results in a positive transmission of the business cycle. We develop a multi-country model that has the potential of simultaneously producing a relatively higher output comovement between some country pairs, and a relatively lower comovement between other country pairs.

We take a calibrated version of our model and consider a change in parameters that results in an increase in trade shares as a fraction of GDP. We then examine the change in cross-country correlations of business cycles that result from this expermient. Our benchmark model is successful in producing an increase in output correlations between core and periphery countries, relative to output correlations between core countries. However, it falls short of explaining the magnitude of the divergence observed in the data. This is mainly for two reasons. First, the share of value added generated by exports is small both for the core and the periphery countries. This is true even when exports account for a very large fraction of manufacturing GDP in periphery regions - in those regions, exports are large, but so is the use of imported intermediate inputs. This limits the effects that trade can have on business cycle cross-correlations. Second, we (realistically) assume that periphery countries have both a production-sharing sector as well as a non-production-sharing sector. The business cycle effects stemming from the non-production-sharing sector (where substitution between domestic and foreign inputs is relatively higher) offset the effects coming from complementarity in the production-sharing sector. We also consider an extension of the model where production sharing involves not only inputs that are complements in production, but in addition we assume that technological innovations or cost reductions that occur in the home multinational enterprises (MNE) in the core country are shared with its affiliate in the periphery country. Not surprisingly, this leads to a significant increase in output correlations between the core and periphery, relative to output correlations between the two core regions.

Previous studies have examined the impact of differing degrees of substitutability in traded intermediate inputs on business cycles (see in particular, Ambler, Cardia and Zimmerman (1998), and Heathcote and Perri (2003)). Kose and Yi (2001, 2002) use this type of structure to study the impact of a decline in trading costs on the volume of trade and the transmission of cycles. Our paper differs from these studies in that our goal is to simultaneously produce an increase in output comovements between some country pairs (low elasticity of substitution associated with product sharing), and a decrease in output comovements between other country pairs (higher elasticity of substitution between traded goods). As we will show, the results in a two-country setting are quite different from the multi-country setting because of offsetting effects that result in the full model of trade. Moreover, consistent with their findings, our results indicate that a small share of value added contributed by exports to the local economy in both countries (and not just exports themselves, which include a large fraction of imported inputs) limits the degree to which the production sharing sector (both in the core and in the periphery) can impact local economic conditions.

The structure of our paper is as follows. We first review the observations on international business cycles and trade that we focus on in this paper. We then present our four-country model, and describe how we calibrate it. We then examine the model's implications for the link between trade and international business cycles. We finally discuss two extensions of the model.

2. Trade and business cycle fluctuations.

Observation 1: International correlations differ across trading partners. Core regions tend to have low correlations, while correlations between core and periphery regions are high.

Figures 1 and 2 show that the correlations of detrended GDP between the United States and its trading partners differ across regions and in some cases change over time. To amplify this point, Table 1 provides cross-country correlations for output, consumption and investment over the 1970:1 – 2004:2 period.[4] All data are at a quarterly frequency, seasonally

[4] Bilateral correlations are just one way of measuring the comovement of business cycles across countries. Other methods include the decomposition of time series variation into global, regional and country-specific factors (see the studies by Kose, Otrok and Whiteman (2003a)), dynamic factor analysis (Gregory, Head and Raynauld (1997)), VARs (Clark and Shin (2000)), and identification of common business cycle turning

adjusted and detrended using the HP filter. The top three panels of Table 1 report decade averages of the correlations between the U.S. and its major trading partners for GDP, consumption and investment. The bottom three panels repeat these decadal correlations for Europe[5] and its major trading partners.

Turning first to the output correlations (panels 1a and 2a of Table 1) the data suggest that business cycles in the core regions of U.S., Europe and Japan have become less synchronous from the 1970s to the 1990s. In the case of the U.S. and Europe, the correlation of GDP drops from 0.74 in the 1970s, to 0.53 in the 1980s to 0.06 in the 1990s.[6] There is a dramatic upturn in the 2000:1-2004:2 period reflecting the common recession in both regions. Whether the recent recession marks a change in the correlation structure across countries, or is simply a reflection of a global shock that affected all countries in 2001 is an open question. The U.S. and Japan have also become less correlated over time, with a negative correlation of -0.25 in the 1990s, though this is again followed by a significant increase in the correlation in the last four years. There is also a downward trend in the correlations of output between Europe and Japan, although the magnitude of the change is small.

The last three columns in part 1 of Table 1 show the correlations between the U.S. and its NAFTA trading partners. There is no evidence of a significant decline in business cycle correlations between the U.S. and Canada over the 1970-2004 period. The fourth column shows the correlation with Mexico based on quarterly data, and the last column the correlation based on annual data. In the case of Mexico, quarterly time series is available only from 1980:1. The data suggest that Mexico has become more correlated with the U.S. since the 1980s.

The time series data from Eastern Europe start in 1996. The last column in panel 2 shows the correlation between GDP for the European aggregate and an aggregate of Poland, Hungary, the Czech Republic and Slovakia. The correlation is in the range of 0.41 to 0.43.

Turning to the international correlations for consumption and investment, we see the typical patterns found in international data. On a bilateral basis consumption is almost always less correlated than output. In general, bilateral output, investment and consumption

points (Harding and Pagan (2002)).

[5] The European aggregate includes Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and the UK.

[6] Caution should be exercised in interpreting point estimates of correlations without taking standard errors into account. See Doyle and Faust (2002) for an econometric methodology for estimating breaks in second moments of time series.

correlations tend to rise and fall together.

Observation 2: Most trade flows are either between core regions or between core regions and their corresponding periphery. There is little cross-periphery trade.

Our model of trade will assume that there are two core regions, namely the U.S. and Europe. Each core region trades with a periphery region – the U.S. with Canada and Mexico, and Europe with Eastern Europe. Table 2 reports the decomposition of trade flows between the U.S., Europe, North America and Eastern Europe. Europe accounts for roughly 20 percent of U.S. exports and imports. Trade with its NAFTA partners accounts for 30 percent of U.S. imports and 37 percent of U.S. exports. Our model will abstract from trade with Asia, which accounts for the remainder of U.S. trade.

Part B of Table 2 shows a similar decomposition for Europe. Trade with the U.S. accounts for roughly 20 percent of European imports and 24 percent of European exports. About 10 percent of European trade is now with Eastern Europe. Note that there is very little trade between Europe and Canada and Mexico. In the model developed in Section 3 we will make the extreme assumption that there is no trade between Europe and the periphery countries in North America. Panels C, D and E show trade patterns for Canada, Mexico and Eastern Europe. The data support the view that the bulk of trade for these countries is regional trade, either within North America or within Europe.

Observation 3: Trade as a share of manufacturing has risen, but the importance of trade in total GDP remains small.

Table 3 shows the importance of trade in production. Panel A reports the share of trade measured as exports plus imports over aggregate GDP in the U.S., Europe, Japan, Canada and Mexico. Note that European trade is the external trade of the European aggregate with countries outside of western Europe. The U.S. trade share has increased from roughly 12 percent of GDP in the 1970s to about 18 percent at the end of our sample. The share of trade in GDP has declined slightly in Japan. External European trade has risen to account for nearly 40 percent of GDP. However, the most dramatic increase in trade is in Canada, growing from about 40 percent of GDP to nearly three-quarters of GDP. In Mexico the trade share now exceeds 50 percent.

While trade in total GDP has risen modestly in most regions, there has been a much more dramatic increase in trade in manufactures. Panel B reports trade in manufactures as a share of GDP of the manufacturing sector. In the U.S., Europe, and Japan, this ratio exceeds 1, and in Canada and Mexico the ratio is over 2.5. This provides a glimpse of the importance of production sharing within the NAFTA zone, where intermediate inputs are shipped across international borders and value is added at intermediate stages of production. As transportation costs and other trading barriers are reduced, goods may cross international boundaries several times along the production chain, resulting in a measure of trade that is larger than the value of local production (for a more detailed description, see Yi (2000)). This is consistent with the high trade shares in manufacturing observed for Canada and Mexico and will be a key feature of our model of trade between core and periphery regions.

The third panel of Table 3 shows that the share of manufacturing in total GDP is roughly 15 to 20 percent. This ratio has either declined or stayed constant in most countries. The fact that manufacturing is a small share of GDP, and that value added generated by exports is not a large share of total GDP, poses a challenge to models that attempt to link trade and business cycles. The increase in trade alone is insufficient to deliver significant changes in business cycles correlations in standard models of trade, a finding that is underscored in Kose and Yi (2002). We will show below that production sharing helps to amplify the role of trade in the business cycle, but its overall impact depends on the strength of the ties between the production sharing sector and the local economy.

Observation 4: Production sharing tends to occur between core and periphery regions.

A central feature of our argument is that the type of trade that occurs between countries will affect the way that business cycles are transmitted. Trade between core countries, we argue, is largely trade in varieties of goods that can be readily substituted for each other. Trade between the core and periphery, however, reflects the slicing up of the production chain, where inputs are shipped across borders to capitalize on location-specific advantages and each stage of production depends on the particular inputs from the previous stage.[7] According to Hummels, Ishii and Yi (2003), vertical specialization (the production of goods in multiple stages of production in multiple countries) accounted for one-third of export growth between 1970 and 1990.[8]

[7] Many terms are used to describe this phenomenon: vertical specialization, fragmentation of production, production sharing, rationalization of production, vertical production networks, outward processing and outsourcing, and there are likely more. We will follow the US International Trade Commission and use the term production sharing to mean the manufacture of a good that takes place in more than one country.

[8] A number of factors are credited for the expansion of production sharing: reduction in trading barriers

Re-importation of domestic content

Anecdotal evidence of production sharing and vertical integration are plentiful. Two often-cited examples are the production of Barbie dolls and automobiles. An article in the *Los Angeles Times* documented the global travels of Barbie, who required plastic and hair from Taiwan and Japan, assembly in Indonesia, Malaysia and China, dress cloth from China, and multiple trips through Hong Kong (Tempest (1996) and Feenstra (1998)). Another well-known example is the temporary shut down of automobile assembly plants in Detroit following the border closures on 9/11 due to the delay of delivery of automobile parts and inventory from Canada (Council on Foreign Relations Report, 2002).

Concrete evidence on the magnitude of this phenomenon is harder to come by.[9] One measure of the extent of production sharing by U.S. corporations is captured by the fraction of U.S. content in U.S. imports, shown in Figure 3. Under Harmonized Tariff Schedule 9802, companies are granted an exemption from U.S. customs duties and user fees for the value of U.S.-made components that are contained in goods that are assembled overseas and re-imported into the U.S.[10] While this data would appear to be the ideal source for information about the extent of U.S. production sharing, there is an important problem. Companies have an incentive to report U.S. content in imported goods only when faced with significant tariff barriers. After the signing of the Canda-U.S. free trade agreement in 1991 and the creation of NAFTA in 1994, firms in Canada and Mexico no longer had as great an incentive to apply for exemption under 9802. This is reflected in the dramatic decline in Canadian imports coming in under 9802 between 1990 and 1991, to just a trickle thereafter (see Figure 3). Similarly for Mexico, the share of imports coming in under 9802 begins to decline in 1995, though it remains fairly high even in the years after the formation of NAFTA.[11]

The low numbers for U.S. content in imports from Europe also contain some information. While tariff barriers remain for firms engaged in production sharing in Europe, note that virtually none of the manufacturing imports from Europe contain U.S. content, suggesting that little production sharing is taking place by U.S. firms operating in Europe. The second conclusion is that a conservative estimate of the U.S. content of goods imported from Mexico

and physical trading costs, improvement in information technology, and other technological advances that make it possible to split production processes.

[9] See, for example, Yeats (1999).

[10] See "Production Sharing: Use of U.S. Components and Materials in Foreign Assembly Operations" various issues for detailed discussion of the data on US production sharing and trade.

[11] Companies still enjoyed some benefits under 9802 even after NAFTA was enacted. For details, see various issues of the USITC reports on production sharing.

under the production sharing provision ranges from 30 to 35 percent of US manufacturing imports. Studies by the OECD and the European Union suggest that a similar process of production sharing is taking place between countries in Western Europe and Central Europe. (see Topolansky 1998).

Trade between U.S. multinationals and their foreign affiliates

Trade between U.S. multinationals and their affiliates provide an alternative source of information about the extent of production sharing.[12] This obviously abstracts from production sharing through arms-length transactions. Panel A of table 4 shows the ratio of sales of U.S. affiliates in Canada, Mexico, Europe and Japan to total affiliate sales. A significant fraction (35 to 45 percent) of the sales of affiliates in the NAFTA region are sales back to the United States, suggesting that affiliates are part of a vertically- integrated production chain and the goods are ultimately shipped back to the U.S. In contrast, only a small fraction of the sales of European and Japanese affiliates are sales to the U.S. (3 and 6 percent, respectively), evidence that the activity of those affiliates is quite different.[13]

Panel B shows the ratio of exports of U.S. parents to their affiliates as a fraction of the total sales of affiliates. This measure provides an estimate of the importance in production of imported intermediate inputs from the parent company. Again, there is an apparent difference between the activities of affiliates in Canada and Mexico relative to Europe and Japan. Exports to affiliates account for roughly 40 percent of the sales volume of affiliates in the NAFTA region, but only 5 to 10 percent of the sales volume in Europe and Asia. This suggests that much more of the production by European and Asian affiliates is done where the affiliate is located, and there is less dependence on intermediate inputs from the parent in the United States.

Finally, Panel C provides an index of the importance of production sharing in terms of local value added in manufacturing. This will be a critical parameter in the calibration of our model, because it measures the extent to which production sharing matters for the local economy. The value of exports includes a large fraction of imported intermediate inputs[14], but what is important to determine the extent of synchronization of business cycles is the *local value added* generated by exports. The numerator of the index is sales of affiliates to the

[12] See, for example, Hanson, Mataloni, and Slaughter (2004), and Chen and Yi (2003).

[13] This fact is also document by Ekholm et.al (2003). They designate affiliate sales to the home or third countries as "export-platform FDI" as opposed to FDI motivated by vertical integration.

[14] See Yi (2003).

U.S. less U.S. exports to affiliates scaled by the share of U.S. sales in total sales. The scaling adjusts for the fact that not all exports to affiliates return to the U.S., and the difference picks up the net transfer of resources from the affiliate back to the parent. The data in Panel C suggest that production sharing is a trivial fraction of manufacturing value added in Europe and Japan, while it accounts for some 35 to 42 percent of manufacturing value added in Mexico and Canada. The data also suggest that the importance of production sharing in local value added has increased over time in Mexico and Canada.

Mexican Maquiladoras

Data on the manufacturing and trade of the maquiladora plants in Mexico provides direct evidence on the extent of production sharing with Mexico. The Maquiladora Program was established in 1964 to help relieve high unemployment in the northern region of Mexico. Firms were granted the right to set up production in the region and to import materials and equipment duty-free under the proviso that, after assembling the inputs into final goods, the goods would be re-exported. They are most active in the electronics, auto parts, and apparel industries. Many maquiladoras are not foreign-owned, and deal with MNE's through arms-length transactions. As shown in Figure 4[15], maquiladora exports account for about 50 percent of all non-oil exports from Mexico.[16] The figure also shows the ratio of imports to the maquiladora sector as a fraction of exports from the maquiladora sector. The ratio is roughly 0.75, suggesting that for every 75 cents of intermediate inputs exported from the U.S. to Mexico, a dollar is sent back, or that 25 cents of Mexican value is added to the product. This ratio will also play a key feature in our model, as it reflects the extent to which local factors of production are drawn into the production sharing process.

Finally, we can use the maquiladora data to obtain an alternative value of our production sharing index. The sum of value added of maquiladoras plus domestic intermediate inputs, as a fraction of manufacturing GDP in Mexico increased from 7% in 1990 to 17% in 2002.[17] Note that this does not include operations by affiliates of U.S. multinationals in Mexico. According to Hanson, Mataloni and Yorgason (2002), the share of value added by nonbank

[15] The source of information on maquiladoras is INEGI, Mexico's official statistical agency. The data on gross output, intermediate inputs (domestic and imported), and value added can be found in this website: http://dgcnesyp.inegi.gob.mx/cgi-win/bdieintsi.exe/NIVJ150008001000100010 0020#ARBOL

[16] The distinction between oil and non-oil exports was important in the 1980s but now has very little effect on the ratio. In 2002, the ratio of maquilidora exports in total exports was 49 percent compared to maquilidora exports in total exports excluding oil of 55 percent.

[17] The source of information on manufacturing GDP is Banco de Mexico.

affiliates as a fraction of Mexican manufacturing gross domestic product increased from 12% in 1989 to 19% in 1999.

The presence of US corporations operating in Mexico through the Maquiladora program has created a close correspondence between fluctuations in industrial production in Mexico and the US.[18] Figure 5 shows growth rates over the previous year in monthly industrial production in Mexico and the US. Splitting the sample at end-1995, the correlation between industrial production in the two countries increases from 0.19 in the 1980-95 period to 0.83 in the 1996-04:9 period.

To summarize, the goal of our paper is to replicate four features of the data on international business cycles and trade. First, there has been a tendency for cross country output correlations between core regions to increase relative to cross-correlations between core and periphery regions. Second, most trade flows are either intra-core trade or trade between a core and its corresponding periphery. There is very little trade between periphery regions. Third, value added generated by exports has increased, but still constitutes a relatively small share of total GDP. And fourth, trade between core and periphery regions involves more production sharing than trade between core regions.

3. Benchmark model

Our model of international trade and business cycles includes four countries, two "core countries" denoted 1 and 2, and two "periphery countries" denoted 3 and 4. To help fix ideas, it may help to think of countries 1 and 2 as the U.S. and Western Europe, country 3 as the United States's NAFTA partners, Canada and Mexico, and country 4 as Eastern Europe. Consistent with the bilateral trade data in Table 2, we assume that the core countries engage in trade with each other, and each core country trades with its own periphery country (1 with 3 and 2 with 4). There is no trade between the periphery regions, or between a core country and the other periphery (i.e. the U.S. trades with Europe and its NAFTA partners but not with Eastern Europe, and Europe trades with the U.S. and Eastern Europe but not with Canada and Mexico).

We measure time in discrete periods and index each period by $t = 1, 2, 3, ...\infty$. Countries

[18] Gordon Hanson provided the following characterization of business cycle fluctuations in Mexico: 'The business cycle in the maquila sector is a highly exaggerated version of the U.S. business cycle...Growth in the maquila sector is a couple of times what it is in U.S. manufacturing." New York Times, "A Boom Along the Border"August 26, 2004.

are indexed by $i = 1, 2...., 4$. Each country i has a population of L^i individuals. Countries 1 and 2 are symmetric, as well as countries 3 and 4.Preferences of the representative agent in country i are characterized by an expected utility function of the form:

$$U_i = \max E_0 \sum_{t=0}^{\infty} \beta^t u\left(c_{it}, 1 - n_{it}\right) \ ,$$

where c_i and n_i are per capita consumption and employment in country i, and $u\left(c, 1-n\right) = 1/\left(1-\sigma\right)\left[c^{\mu}\left(1-n\right)^{1-\mu}\right]^{1-\sigma}$.

Each country specializes in the production of one intermediate good. Per capita output of the intermediate good z_i requires inputs of domestic labor n_i and capital k_i, and is affected by country specific aggregate productivity A_i which changes stochastically over time. The production function has constant returns to scale, and is given by:

$$z_{it} = A_{it}\left(n_{it}\right)^{\alpha}\left(k_{it}\right)^{1-\alpha} .$$

The vector of aggregate productivity shocks $A_t = \left(A_{1t}, A_{2t}, A_{3t}, A_{4t}\right)$ follows the process $A_{t+1} = PA_t + \varepsilon_{t+1}$, where ε_t is distributed log-normally and independently over time with mean $\bar{A} = \left(\bar{A}_1, \bar{A}_2, \bar{A}_3, \bar{A}_4\right)$ and variance Σ.

We assume that all trade occurs at the level of intermediate goods. Local and imported intermediate goods are combined in each country to create two types of goods, x and v. The asymmetric impact of trade on business cycles is due to an assumption about the technology used to create these two goods. We assume that good x is not produced in a vertically integrated production chain, and that firms can readily substitute between local and foreign inputs in response to changes in technology and relative prices. Specifically, production of good x_i combines local and imported intermediate goods according to the following Armington aggregator:

$$x_{1t} = \left[\theta_1^{1-\rho}\left(x_{11t}\right)^{\rho} + \left(1-\theta_1\right)^{1-\rho}\left(x_{12t}\right)^{\rho}\right]^{\frac{1}{\rho}}$$

$$x_{2t} = \left[\theta_1^{1-\rho}\left(x_{22t}\right)^{\rho} + \left(1-\theta_1\right)^{1-\rho}\left(x_{21t}\right)^{\rho}\right]^{\frac{1}{\rho}}$$

$$x_{3t} = \left[\theta_3^{1-\rho}\left(x_{33t}\right)^{\rho} + \left(1-\theta_3\right)^{1-\rho}\left(x_{31t}\right)^{\rho}\right]^{\frac{1}{\rho}}$$

$$x_{4t} = \left[\theta_3^{1-\rho}\left(x_{44t}\right)^{\rho} + \left(1-\theta_3\right)^{1-\rho}\left(x_{42t}\right)^{\rho}\right]^{\frac{1}{\rho}}$$

The first subscript denotes the location of production, and the second subscript the input's country of origin. (x_{12} is the intermediate input from country 2 used in country 1's production.) We assume that the elasticity of substitution, $1/\left(1-\rho\right)$, between inputs in this sector is relatively high. The parameter $1-\theta_i$ reflects the importance of imported intermediate goods in production of good x_i.

The second good, v, is produced in a vertical production chain that involves a production sharing arrangement between firms in a core country and its periphery. Production of good v_1 in country 1 combines the local intermediate good with the intermediate good from country 3 according to:

$$v_{1t} = \left[\lambda^{1-\zeta} (v_{11t})^{\zeta} + (1-\lambda)^{1-\zeta} (v_{13t})^{\zeta}\right]^{\frac{1}{\zeta}}.$$

The parameter $1-\lambda$ measures the importance of imported intermediate goods provided by the periphery regions. We can think of good v_1 as the product of a multinational enterprise (MNE) in conjunction with its foreign affiliate in the periphery region. We can also think of v_{13} as the inputs provided by Maquiladoras, which are not necessarily under the control of a firm in the U.S. To capture the flavor of production sharing in a simplified way, we assume that inputs into the production of good v are complements relative to the production of the good x. So, the elasticity of substitution in the production sharing sector, $1/(1-\zeta)$, is assumed to be small relative to $1/(1-\rho)$. Our model is intended to characterize the decision of firms at business cycle frequencies, where plant and equipment in the periphery country is already established and the firm's decision is the optimal combination of factor inputs and the amount to produce given relative prices. We abstract from interesting longer run issues such as the location of the vertical production chain and the possibility that firms could move between periphery locations.[19]

Two alternative assumptions can be made about the international flow of intermediate goods to produce good v_1. Under the first assumption, v_{11} is initially shipped to country 3, v_{13} is added to produce good v_1, and then v_1 is shipped back to country 1. Under the second assumption, v_{13} is shipped from country 3 to country 1, and combined with v_{11} in country 1 to produce the good v_1. Even though the gross volume of trade is larger under the first assumption, the trade balance is identical as are equilibrium allocations.

Symmetrically, production of good v_2 in country 2 is given by:

$$v_{2t} = \left[\lambda^{1-\zeta} (v_{22t})^{\zeta} + (1-\lambda)^{1-\zeta} (v_{24t})^{\zeta}\right]^{\frac{1}{\zeta}}.$$

Each country produces a non-tradeable final good y_i, which can be either consumed or invested. In countries 1 and 2, the final good y_i is a composite of goods x_i and v, combined

[19] Ruhl (2004) studies a model where the presence of fixed costs associated with trade imply that the elasticity of substitution is lower for small and temporary shocks than for large and permanent shocks.

according to:

$$y_{it} = (x_{it})^{\omega} (v_{it})^{1-\omega} \quad i = 1, 2$$

We assume that periphery countries do not engage in outsourcing to other countries, so in countries 3 and 4 the final good y_i only uses good x_i:

$$y_{it} = x_{it} \ , \ i = 3, 4$$

The resource constraints for intermediate inputs in the core countries are:

$$L_1 z_{1t} = L_1 x_{11,t} + L_2 x_{21t} + L_3 x_{31t} + L_1 v_{11t}$$

$$L_2 z_{2t} = L_2 x_{22,t} + L_1 x_{12t} + L_4 x_{42t} + L_2 v_{22t}$$

Intermediate goods from the core are either used by home firms in the x and v and sectors, exported to the other core country, or exported to the periphery. Intermediate goods in the periphery regions are used either for local production or in the vertical production chain:

$$L_3 z_{3t} = L_3 x_{33,t} + L_1 v_{13t}$$

$$L_4 z_{4t} = L_4 x_{44t} + L_2 v_{24t}$$

The final good resource constraint in each country is given by:

$$y_{it} = c_{it} + i_{it} \text{ for } i = 1, ..., 4$$

where

$$i_{it} = k_{it+1} - (1 - \delta) k_{it}$$

As our baseline model, we consider a competitive equilibrium for this economy with complete contingent claims markets. Agents can use contingent claims markets to diversify country-specific risk across states of natures. We will exploit the fact that the equilibrium allocations are Pareto optimal by solving the following planner's optimal problem:

$$\max \ L_1 U_1 + L_2 U_2 + L_3 U_3 + L_4 U_4 \ ,$$

subject to the technology and resource constraints described above. By choosing a suitable set of initial wealth levels, the competitive equilibrium allocations are identical to the ones that are obtained by solving this planner's problem. Furthermore, prices can be computed from marginal rates of substitution across goods. The numeraire is the price of the good produced by country 1 (i.e. $P^z_{1t} = 1$). We will also consider a version of the model with incomplete contingent claims markets. In particular, we go to the opposite extreme of ruling out contingent claims markets, so that there is no intertemporal trade. Under this scenario of financial autarky (see Heathcote and Perri 2002), the trade balance of each country has to be 0 in every state of nature.

Using the resource constraints, gross domestic product in country 1 (in terms of intermediate good z_1) is equal to $L_1 z_{1t}$ and the following national accounts identity holds:

$$L_1 z_{1t} = P^y_{1t} L_1 (c_{1t} + i_{1t}) + TB_{1t} \ ,$$

where P^y_{1t} denotes the price of the final good in country 1, and the trade balance TB_1 is:

$$TB_{1t} = (L_2 x_{21t} + L_3 x_{31t}) - L_1 P^z_{2t} x_{12t} - L_1 P^z_3 v_{13t} \ ,$$

Analogously, in country 3, the national accounts identity is:

$$L_3 P^z_{3t} z_{3t} = L_3 P^y_{3t} (c_{3t} + i_{3t}) + TB_{3t} \ ,$$

where the trade balance TB_3 is:

$$TB_{3t} = L_1 P^z_{3t} v_{13t} - L_3 x_{31t} \ .$$

We will also consider two extensions to the basic model.

Extension 1: Intermediate inputs in intermediate good production

We assume that production of the intermediate good in each country also requires intermediate inputs from the local economy. In the U.S., for example, the share of value added in gross output for the total economy is close to 50%. As we will see below, adding intermediate inputs has the potential effect of increasing the effects of trade on cyclical fluctuations in the periphery countries, as more domestic inputs are required to produce the exportable good. We model the production function in each country in the following way:

$$z_{it} = A_{it} \left(n_{it}\right)^{\alpha\gamma} \left(k_{it}\right)^{(1-\alpha)\gamma} \left(m_{it}\right)^{1-\gamma} \ , \text{ for } i = 1, ..., 4 \ ,$$

where m_{it} denotes the quantity of intermediate inputs used in production of good i, and γ denotes the share of value added in gross output. We assume that intermediate inputs are in units of the final good, so the resource constraint for the final good is given by:

$$y_{it} = c_{it} + i_{it} + m_{it} \ , \text{ for } i = 1, ..., 4$$

Extension 2: Spillover of productivity through production sharing

In the basic model we assume that productivity shocks are uncorrelated and that there is no spillover of technology through trade. An alternative view is that production sharing involves not only inputs that are complements in production, but that technological innovations that occur in the home MNE would be shared with its affiliate. For example, we now assume that a labor-saving innovation that is discovered by the managers of a MNE would also be implemented in that firm's foreign affiliates.[20]

To capture this transmission of technology to affiliates, we assume that the aggregate productivity in country 1 is diffused to those firms in country 3 involved in the production of inputs to v_1. So, firms in country 3 producing the good that is exported to country 1 (f-firms) have a different productivity that firms in country 3 producing the intermediate good that is used to produce the domestic final good (l-firms). Under this assumption, the production functions of the intermediate good in country 3 are now given by:

$$L_1 v_{13t} = L_3 A_{3t} d_{3t} \left(n_{it}^f\right)^{\alpha} \left(k_{it}^f\right)^{1-\alpha}$$

and

$$x_{33t} = A_{3t} \left(n_{it}^l\right)^{\alpha} \left(k_{it}^l\right)^{1-\alpha}$$

where d_{3t} is given by:

$$d_{3t} = 1 + \eta \frac{A_{1t}}{A_{3t}}$$

The parameter η measures the extent of productivity diffusion from country 1 to country 3. The variable d_3 is also the relative price of x_{33} in terms of v_{13}. When $\eta = 0$, we are back to the benchmark model.

It is straightforward to show this model can be mapped to the one-production-sector model as the benchmark economy, where the resource constraint in country 3 is now given by:

$$L_3 z_{3t} = L_3 x_{33,t} + \frac{L_1 v_{13t}}{d_{3t}}.$$

In this modified model, gross domestic product in country 3 at constant prices (i.e.: real GDP) is equal to $L_3 A_{3t} \left(k_{it}/n_{it}\right)^{1-\alpha} \left(n_{it}^l + d_{3t} n_{it}^f\right)$, with $n_{it} = n_{it}^l + n_{it}^f$.

[20] Desai and Foley (2004) find evidence that the investment decisions of MNEs and their affiliates are highly correlated. Ex post returns of MNEs and their publicly listed affiliates are also highly correlated. Both facts are consistent with common productivity shocks to the parent and the affiliate.

4. Choice of parameters

We follow BKK in choosing the values of β, μ , σ , δ , and α. The period length is one quarter. We choose $\beta = 0.99$ so that the quarterly real interest is 1%, $\sigma = 2$ so that the risk aversion coefficient is 0.5, $\alpha = 1/3$, and $\delta = 0.025$. We set the elasticity of substitution between home and foreign intermediate inputs in the production of good x, $[1/(1-\rho)]$, equal to 2. We also assume that ζ is very low in the sector with vertically integrated production, so the elasticity of substitution of the home and foreign intermediate input to produce the interregional good is close to 0. We use data on Mexico's maquiladoras to choose the value of λ. The share of imported intermediate inputs in the maquiladora's gross output in 2001 (see figure 4) is 75%. So, consistent with this observation, we set $\lambda = 0.25$. We also normalize $L_3 = 1$.

We are interested in examining changes in international business cycle synchronization stemming from an increase in trade shares. To isolate these effects, we abstract from international spillovers or contemporaneous cross-correlation of shocks to aggregate productivity. We follow BKK and set the persistence of the shocks equal to 0.91.

As a starting point for examining the impact of trade on business cycles, we set the initial trade shares to 0, so that the international cross-correlation of output, consumption, labor, and investment is zero. We then select values for the parameters L_1, θ_1 , θ_3 , and ω to match the following four observations about country sizes and trade:[21] (1) GDP in country 1 is roughly 7 times as large as GDP in country 3, (2) the share of exports from country 1 to country 2 as a share of country 1 GDP is 15%, (3) the share of value added generated by exports of country 3 to country 1 is 15% of country 3's GDP, and (4) all countries have a trade balance in steady state.[22] Observation (1) is consistent with the ratio of the U.S. GDP to the combined GDP of Mexico and Canada. The 15% share of exports' value added in GDP is chosen so that we can compare our compare our results with other studies (BKK, Heathcote-Perri). We recognize that this share is higher than the shares reported in Table 2[23] - in the experiments below we also report the results for cases with lower trade shares.

[21] It is well known that in a symmetric model, international trade costs generates home bias in the use production inputs (see for example Obstfeld and Rogoff (2000)). Along this line, authors like Kose and Yi (2003) get increases in trade shares in their model by reducing the magnitude of international trade costs.

[22] Note that none of these observations depends on the assumption on whether v_{11} is or not shipped to country 3 to produce the good v.

[23] The share of exports in GDP for each country is equal to 15% when v_{11} and v_{33} are not shipped between the core and the periphery. As reported in Table 6, export shares are much higher when all v_{11} and v_{33} are shipped back and forth across the core and the periphery (i.e.: no value added in core when the good returns

The resulting parameter values from this procedure are $L_1 = 3$, $\theta_1 = 0.86$, $\theta_2 = 0.85$, and $\omega = 0.92$.

For each set of parameter values, we solve the model via a standard log-linearization method. We then randomly draw 150 periods of the productivity shock vector A_t, feed them into the model, and compute several moments of interest from the artificially generated data. We repeat this procedure 500 times, and finally average the statistics across simulations to produce the numbers we report in the tables.

5. Results

To gain some basic intuition for how the model works, it is useful to start with a simpler model where trade occurs only between countries 1 and 2 in intermediate goods for x production (see Table 5). We set the parameters $\theta_3 = 1$ and $\omega = 1$, so that core countries do not use inputs from the periphery to produce the final good, and viceversa. The share parameter θ_1 is set so that trade between 1 and 2 accounts for 15 percent of GDP, as in BKK. The table reports moments for countries 1 and 3. Country 3 is effectively a closed economy, so international cross correlations are zero given our joint assumptions that: (1) productivity shocks are uncorrelated across countries, and (2) there is no spillover of productivity shocks over time. Assuming positive cross-country correlation in the shocks would simply scale up all the cross country correlations of the variables we are interested in.

The first column of results shows the impact of trade on business cycles of country 1 when the elasticity of substitution for inputs into x production is set equal to 2. Substitutability of inputs results in a negative transmission of the cycle - as productivity increases in country 1, the relative price of intermediate inputs from country 1 falls and both countries make more intensive use of country 1 inputs. Country 2 reduces production of x_2, resulting in a negative output correlation (-0.05) and a negative investment correlation (-0.31).[24] This is consistent with the tendency to '*make hay where the sun shines*' emphasized by BKK. Consumption risksharing through complete financial markets produces a positive, though somewhat small, correlation in consumption (0.32). The reason that consumption is not perfectly correlated is because the intermediate good from country 1 is used more intensively in the creation of x_1, which is consumed only by country 1 households. So, it is efficient for

from the periphery). Presumably, the truth lies somewhere between these two extreme assumptions.

[24] Cross-correlations become more negative as we increase $1/(1-\rho)$.

country 1 to increase consumption by more than country 2.

The second column of results repeats the experiment with perfect complementarity between the inputs from goods 1 and 2. Holding the trade share constant, this shift in the parameterization of the model yields a large change in the transmission of the business cycle. The cross-country correlation in GDP is now 0.24 - as productivity in country 1 increases, demand for country 2's input also increases. Consumption in countries 1 and 2 is now negatively correlated. This is because the relative price of the good produced by country 2 (and also intensively consumed by country 2) increases by so much that efficient risk sharing dictates that country 2 *reduce* consumption in order to allocate more resources to country 1.[25] These patterns generated by the two-country model as ρ varies are also analyzed by Heathcote and Perri (2002).

While the two-country model helps sharpen intuition, it does not provide the complete picture of the effects of trade on business cycles for two reasons. First, our goal is to develop a model that can simultaneously produce a relatively higher output comovement between some country pairs, and a relatively lower comovement between other country pairs. This requires a multi-country model. Second, the two-country model exaggerates the importance of the elasticity of substitution between inputs because countries produce and consume only one good. When countries participate in both the x and v sectors, the overall effect of trade on output and consumption is a mixture of the effects of the production-sharing (with elasticity of substitution equal to ζ) and non-production-sharing sectors (with elasticity of substitution equal to ρ). Indeed, one of the challenges we face is that while production sharing helps generate positive comovements, the production sharing sector is only small fraction of overall economic activity. To get an accurate picture of the importance of production sharing for aggregate economic activity, we need to embed the production sharing sector in a model that realistically describes the rest of the economy.

Table 6 shows the results for the four-country version of the model. The elasticity parameters are set so that the elasticity of substitution between inputs from 1 and 2 is equal to 2 and between 1 and 3 is close to zero. The first column reports the results when there is zero trade (and therefore zero cross-country correlations). The second column reports the results for the benchmark economy, where ω , θ_1 , and θ_3 are calibrated as discussed in the previous

[25] Under financial autarky (discussed in more detail below), the assumption of a low elasticity of substitution between intermediate goods together with strong home bias implies an *increase* in the relative price of the good produced by country 1. So, output, labor, and consumption are negatively correlated. This pathological example has been studied by Corsetti, Dedola, and Leduc (2003).

section. In terms of business cycle transmission, the basic model successfully generates positively correlated GDP between 1 and 3 and negatively correlated GDP between 1 and 2, but the numbers are not very large in absolute terms. For example, the cross-correlation between GDP in countries 1 and 3 is 0.02. As mentioned above, the drop in the correlation between 1 and 3 relative to the two-country case is because countries now have mixed production structures. An increase in productivity in country 1 increases demand for inputs from country 3 in the production sharing sector, causing output to move together. But inputs from country 1 are also used in country 3's x production. Substitutability in that sector reduces use of x_{33} relative to x_{31}. This offsets the positive correlation arising from production sharing. Furthermore, from the perspective of country 1, the fraction of GDP generated by the production sharing sector is substantially smaller than in the two-country model. This is because good v represents a small share of the final good in country 1 ($\omega = 0.92$). For countries 1 and 2, the four-country model produces bilateral results very similar to the two-country model when the elasticity of substitution is large. Output is negatively correlated (-0.04) because of the substitution between factor inputs over the cycle, investment and labor inputs are negatively correlated.

Assuming a low elasticity of substitution in the production of v relative to the elasticity of substitution between inputs in the production of x is key in generating higher output cross-country correlations between the core and the periphery regions, relative to the two core regions. Column 3 in Table 6 shows that assuming $1/(1-\rho) = 1/(1-\zeta) = 2$ lowers the difference in output cross-correlation from 0.06 under the baseline parametrization to 0.02. Substitutability between inputs in production of good v implies that the output correlation between countries 1 and 3 becomes negative, as is the output correlation between the two core countries.

A large share of value added from country 3 in the production of v, relative to the import content in country 3's production of the x good, increases the extent to which output is correlated between countries 1 and 3. Column 4 in Table 6 reports a modified parametrization of the baseline calibration, where the share of imports in country 3's production of the x good was reduced from 15% to 8%. Complementarity between inputs of countries 1 and 3 associated to production sharing is only partially offset by substitutability in the production of the x good. This implies that the output cross-correlation between these two countries increases from 0.02 to 0.04. If, on top of this, we double the share of value added by the production sharing sector in country 3 from 15% to 30%, the output cross-correlation between countries 1 and 3 increases to 0.12.

Finally, column 5 in Table 6 studies the case where for all four countries the share of value added generated by exports in total GDP is 8%, relative to 15% in the baseline model. As expected given the lower importance of value added associated to trade, the difference in output cross-correlations across the two pairs of regions falls from 0.06 to 0.04.

A property of the baseline model under complete financial markets is that consumption is negatively correlated between countries 1 and 3. The reason this occurs is because as productivity in country 1 rises, demand for country 3's good rises driving up its price. Under complete markets, households in country 3 are willing to substitute consumption intertemporally in order to reallocate its intermediate good to country 1. Column 4 through 6 in Table 7 considers the case of financial autarky. Qualitatively, the patterns in output, investment and labor under financial autarky are similar to those under complete markets. The main difference between the two environments is that consumption in country 1 and country 3 tend to be more highly correlated. In the case of financial autarky, households in country 3 experience a positive wealth effect from the increase in the price of good 3, driving up country 3's consumption. Instead of pushing consumption in opposite directions, the model now tends to push consumption together. This is more consistent with the pattern in the data that cross-country correlations of output, labor, consumption, and investment tend to move together over time.

Two extensions of the benchmark model

Column 2 in Table 7 shows the impact of assuming that value added is only 50% of gross output (i.e.: $\gamma = 0.5$ under extension 1). This increases the wedge in output cross-country correlations across pairs of countries by a small amount relative to the benchmark model (0.06 to 0.08). The use of intermediate inputs acts as a multiplier on the output effect - as more local factors are used in the production sharing sector, for example, the complementarity between inputs now has a bigger effect on the aggregate economy.

Extending the model to include diffusion of technology through MNEs is the most successful in terms of generating a wedge between output cross-country correlations across pairs of countries. We set $\eta = 1$, which assumes that the MNE and affiliate fully share any technological innovations in production. Column 3 in Table 7 reports our findings. The co-movements between 1 and 2 are unaffected by this assumption, because production sharing only occurs between 1 and 3. By effectively increasing the correlation of the shocks to the production sharing sector, the model produces higher correlations between output in countries 1 and 3 (0.35). Consumption is more correlated between 1 and 3 as well, because country 3 no longer has to forego as much home consumption to shift resources to country 1 in response to a given increase in country 1 productivity. It seems clear that significant positive business cycle transmission from 1 to 3 depends on technological diffusion through production sharing.

What does this model teach us about the connection between international business cycles and trade? First, the direction of the transmission of the business cycle (positive vs. negative co-movements) depends on the nature of trade (production sharing with low short run elasticity of substitution between inputs vs. trade in varieties of intermediate goods with relatively higher elasticity of substitution between inputs). Second, the magnitude of business cycle transmission through production sharing depends on the share of value added in the production sharing sector relative to total GDP in both countries, not merely the extent of exports in GDP. This distinction is important because value added may be only a small share of exports when these include a significant portion of imported intermediate inputs. Third, value added shares of trade in the data are low in many countries, so any model of trade will require a significant multiplier to have a measurable impact on the business cycle. Fourth, even with large value added shares, there may be offsetting effects that dampen the overall impact of trade. Thus, it may be difficult to extract the importance of "trade" per se on a country's business cycle, because the effects of trade will have different implications for different sectors of the economy. Finally, the largest effects of trade for business cycle synchronization stem from technological spillovers. This may be an obvious point but what is less obvious - and critically important for understanding the transmission of international business cycles - is whether these spillovers occur at the firm-, industry- or national-level.

6. Conclusions

This paper develops a model to explain international business cycle dynamics and trade flows between different types of countries. The model we study embodies features of production sharing between core and periphery regions as well as trade in intermediate goods between core regions. The model successfully produces diverging output correlations between core and periphery regions, although it falls short of explaining the magnitude of the divergence observed in the data. In order for production sharing to matter significantly for business cycles, it must either draw in a significant amount of value added from the local economy in the core and/or periphery, or lead to significant technological spillovers into the local economy of the periphery.

The model is based on a number of simplifying assumptions that deserve further study. In particular, we abstract from longer run substitutability across countries in the location of production sharing plants. One possible direction for further study is to include fixed costs in the establishment of a production sharing arrangement. This margin will be operative when shocks are large and persistent (i.e.: trade liberalizations, changes in taxation of foreign corporations, etc.). Under this extension, the model has the potential of providing insights into the issue of "footloose" MNEs shifting their production operations across countries at low frequencies, as well as higher frequency business cycle synchronization between core and periphery regions.

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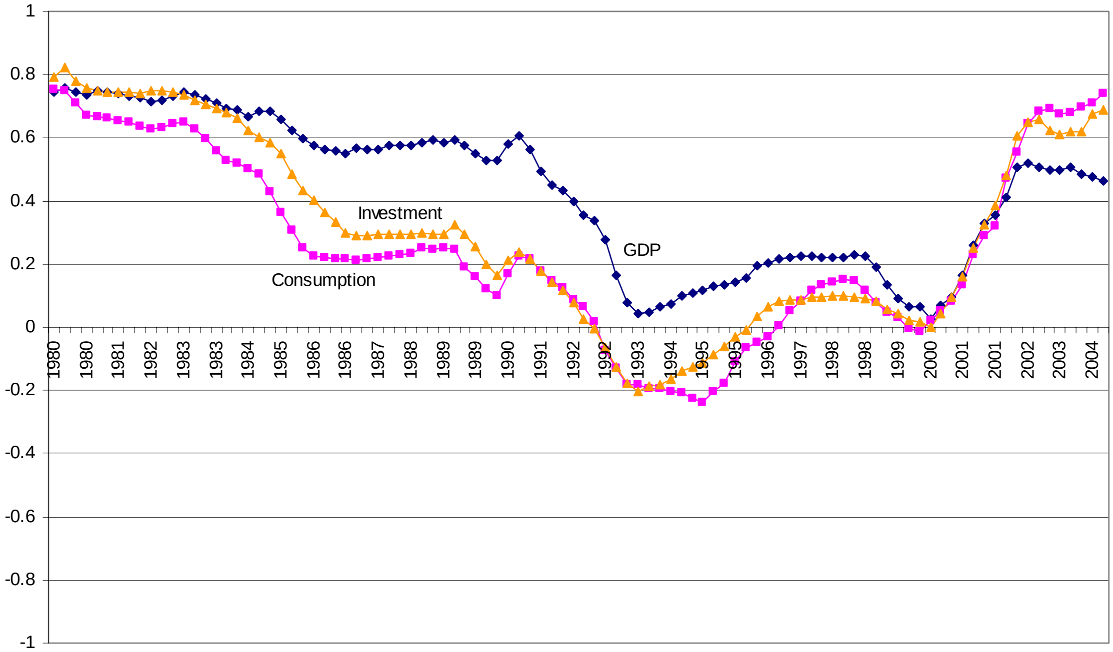
Figure 1: Bilateral Correlations between US and Europe

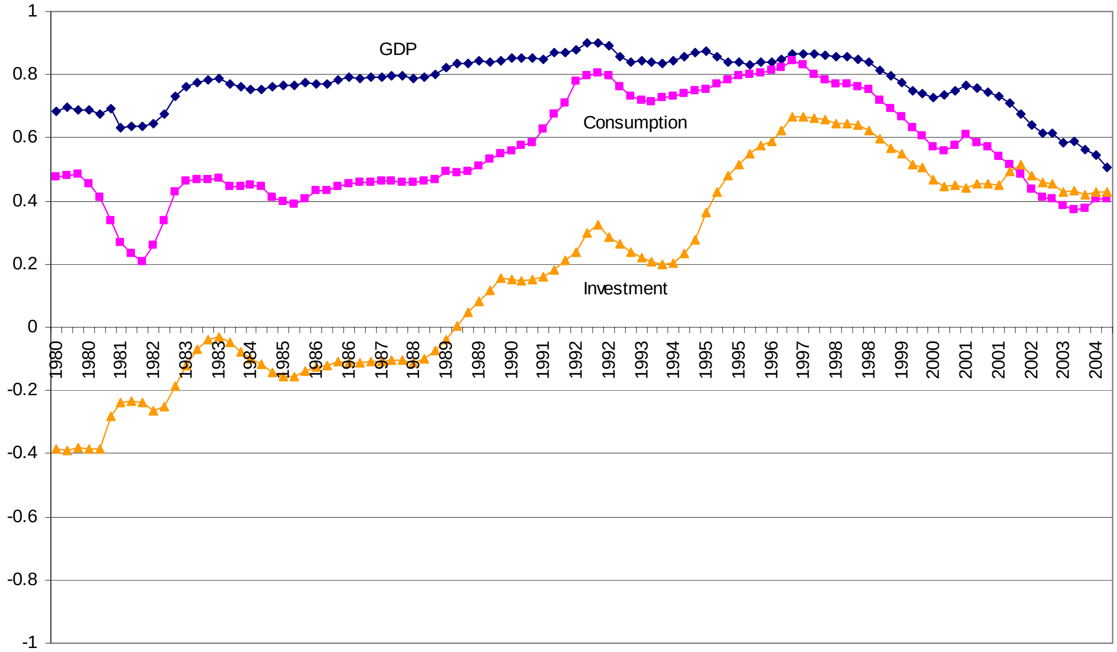
Ten-year rolling correlations of GDP, consumption, investment and employment between the United States and a European aggregate. Data are HP-filtered and deseasonalized.



Source: Quarterly National Accounts, SourceOECD
Values in 2000 Dollars and HP filtered. Europe includes: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and UK.

Figure 2: Bilateral Correlations between US and Canada

Ten-year rolling correlations of GDP, consumption, investment and employment between the United States and Canada Data are HP-filtered and deseasonalized.



Source: Quarterly National Accounts, SourceOECD
Values in 2000 Dollars and HP filtered

Figure 3: US Content of US Manufacturing Imports as a Share of Bilateral Manufacturing Imports

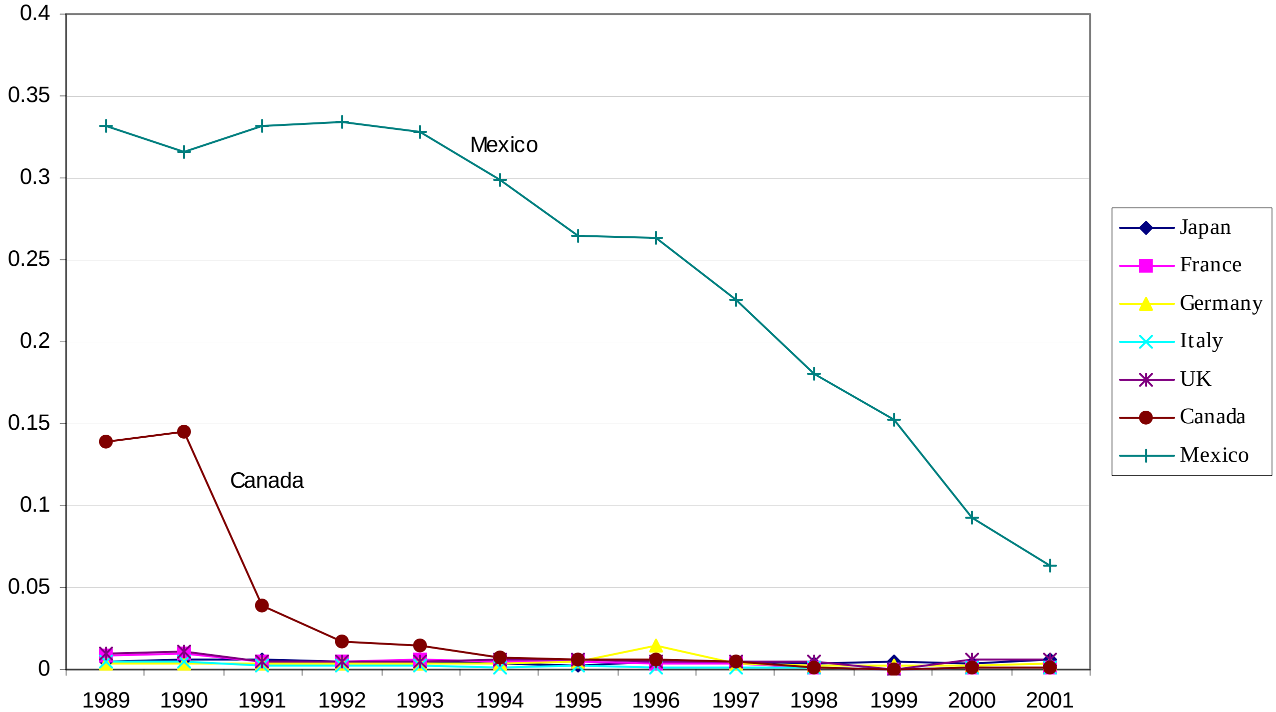


Figure 4: Trade by the Mexican Maquila Sector

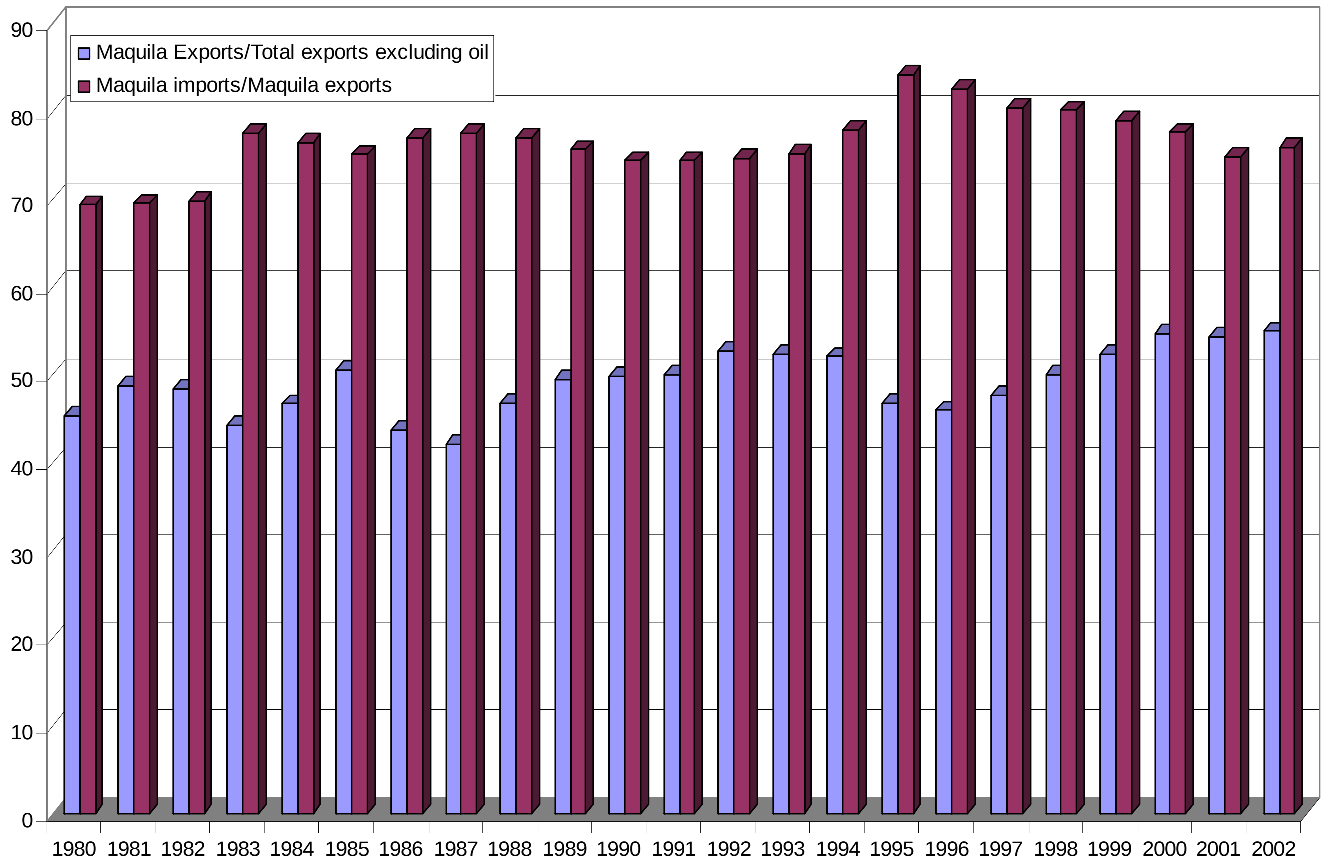
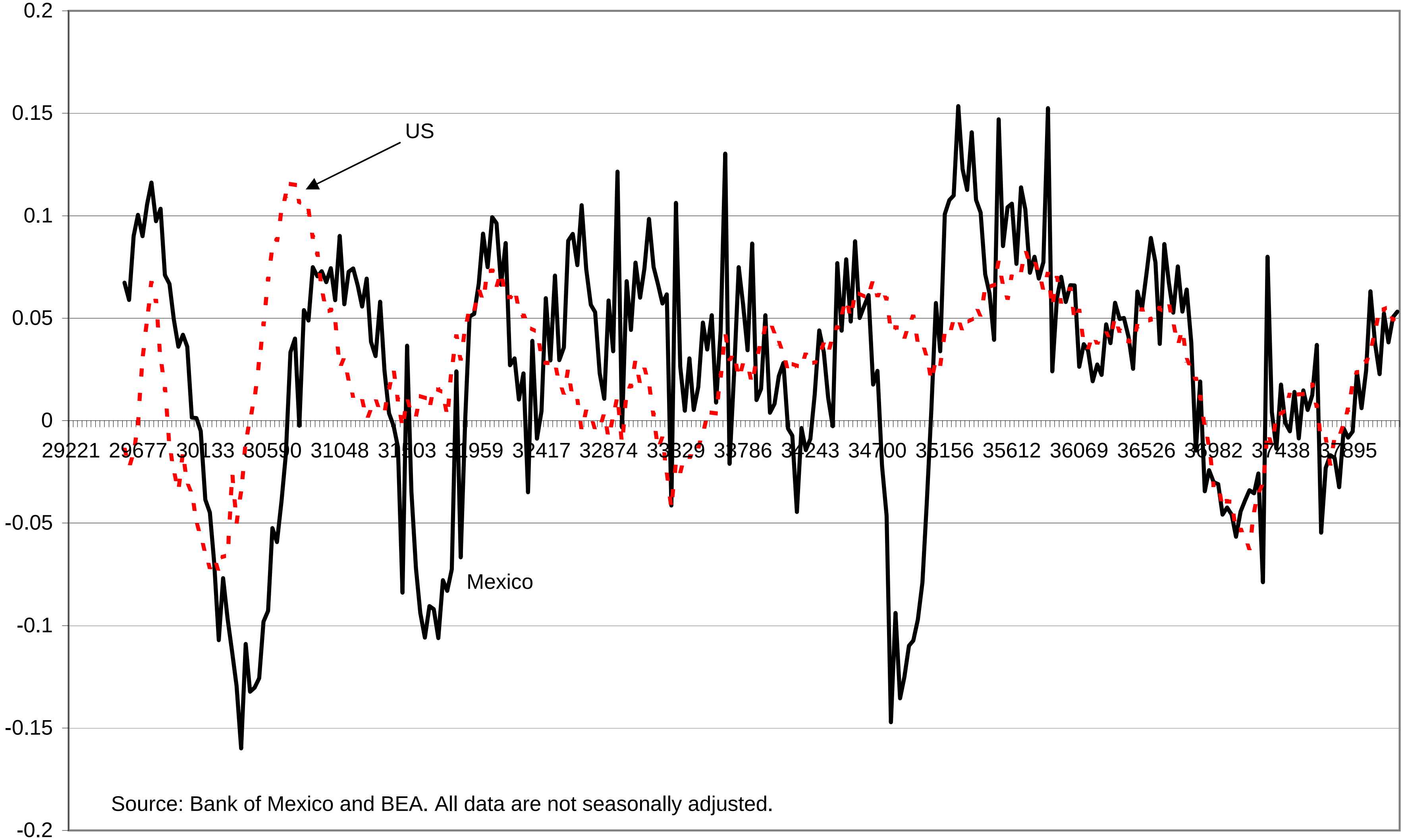


Figure 5: US and Mexican Industrial Production, annual growth rates



Source: Bank of Mexico and BEA. All data are not seasonally adjusted.

Table 1: Co-movements for the United States and Europe with Major Trading Partners

(Quarterly data, all series HP filtered.)

1. Correlations with the United States

a. GDP	US-ROW	US-Eur	US-Jpn	US-Can	US-Mex	US-Mex[a.]
70.1-79.4	0.79	0.74	0.70	0.69		0.54
80.1-89.4	0.49	0.53	0.07	0.84	-0.03	-0.58
90.1-99.4	0.00	0.06	-0.25	0.74	0.19	0.37
00.1-04.2	0.76	0.54	0.71	0.53	0.61	0.51

b. Consumption	US-ROW	US-Eur	US-Jpn	US-Can	US-Mex
70.1-79.4	0.76	0.75	0.69	0.48	
80.1-89.4	0.27	0.12	0.22	0.53	-0.29
90.1-99.4	-0.04	-0.01	-0.23	0.60	0.11
00.1-04.2	0.73	0.77	-0.33	0.77	0.41

c. Investment	US-ROW	US-Eur	US-Jpn	US-Can	US-Mex
70.1-79.4	0.78	0.79	0.70	-0.39	
80.1-89.4	0.11	0.20	-0.06	0.12	0.19
90.1-99.4	-0.07	0.02	-0.26	0.51	0.00
00.1-04.2	0.88	0.75	0.80	0.83	0.78

2. Correlations with Europe [b.]

a. GDP	EU-ROW	EU-US	EUR-Jpn	EUR-EastEur[c.]
70.1-79.4	0.78	0.74	0.67	n.a.
80.1-89.4	0.66	0.53	0.45	n.a.
90.1-99.4	0.37	0.06	0.49	0.43
00.1-04.2	0.52	0.54	0.24	0.41

b. Consumption	EU_ROW	EU-US	EUR-Jpn	EUR-EastEur[c.]
70.1-79.4	0.83	0.75	0.83	n.a.
80.1-89.4	0.12	0.12	0.15	n.a.
90.1-99.4	0.08	-0.01	0.20	0.13
00.1-04.2	0.72	0.77	-0.34	-0.13

c. Investment	EU_ROW	EU_US	EUR-Jpn	EUR-EastEur[c.]
70.1-79.4	0.85	0.79	0.78	n.a.
80.1-89.4	0.51	0.20	0.14	n.a.
90.1-99.4	0.52	0.02	0.54	0.37
00.1-04.2	0.72	0.75	0.53	0.55

Data sources: Source OECD. Quarterly National Accounts

Footnotes:

a. Correlation between GDP in Mexico and the United States using annual data. Historical Mexican GDP from Estadisticas de Contabilidad Nacional, Producto Interno Bruto Serie Historica Desde 1900.

b. European aggregate includes: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and the UK.

c. Eastern European aggregate includes: Poland, Hungary, Czech Republic and Slovakia. The data start in 1996.

Table 2: Bilateral trade flows

	IMPORTS				EXPORTS			
	1970s	**1980s**	**1990s**	**2000-01**	**1970s**	**1980s**	**1990s**	**2000-01**
A. US imports and exports from the following countries as a share of total imports and exports								
EU15	0.22	0.20	0.19	0.19	0.26	0.25	0.22	0.21
Eastern Europe			0.00	0.00			0.00	0.00
North America	0.26	0.23	0.27	0.30	0.25	0.25	0.31	0.37
Canada	0.23	0.18	0.19	0.19	0.21	0.19	0.21	0.23
Mexico	0.03	0.05	0.08	0.11	0.04	0.06	0.10	0.14
Asia	0.29	0.39	0.43	0.40	0.25	0.30	0.32	0.28
B. EU15 imports and exports from the following countries as a share of total imports and exports								
Eastern Europe			0.06	0.08			0.08	0.09
North America	0.23	0.22	0.22	0.22	0.21	0.24	0.22	0.27
US	0.19	0.19	0.19	0.19	0.17	0.20	0.19	0.24
Canada	0.03	0.02	0.02	0.02	0.03	0.02	0.02	0.02
Mexico	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Asia	0.34	0.37	0.38	0.39	0.24	0.30	0.31	0.29
C. Canadian imports and exports from the following countries as a share of total imports and exports								
EU15	0.11	0.11	0.10	0.11	0.13	0.09	0.06	0.05
Eastern Europe			0.00	0.00			0.00	0.00
North America	0.70	0.70	0.69	0.67	0.68	0.73	0.80	0.88
US	0.70	0.69	0.67	0.64	0.68	0.72	0.80	0.87
Mexico	0.00	0.01	0.02	0.03	0.01	0.00	0.00	0.01
Asia	0.10	0.12	0.14	0.15	0.11	0.12	0.10	0.05
D. Mexican imports and exports from the following countries as a share of total imports and exports								
EU15			0.10	0.08			0.05	0.03
Eastern Europe			0.00	0.00			0.00	0.00
North America			0.76	0.80			0.86	0.91
US			0.74	0.78			0.83	0.89
Canada			0.02	0.02			0.02	0.02
Asia			0.09	0.06			0.03	0.01
E. East European imports and exports from the following countries as a share of total imports and exports								
			1997-99	**2000-03**			**1997-99**	**2000-03**
EU15			0.66	0.65			0.74	0.78
North America			0.05	0.04			0.04	0.04
US			0.04	0.04			0.03	0.03
Canada			0.00	0.00			0.00	0.00
Mexico			0.00	0.00			0.00	0.00
Asia			0.19	0.23			0.10	0.08

Data Sources: Source OECD, International Trade in Commodities

Footnotes:

a. European aggregate includes: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and the UK.

b. Eastern Europe Aggregate is composed of Czech Republic, Hungary, Slovakia, and Poland

c. Eastern European data ends in 2002 for US and 2003 for EU15 and starts in 1995 for both

Table 3: Trade shares in GDP

	1970s	1980s	1990s	2000-01[b.]
A. (Exports + imports)/GDP				
US	0.12	0.14	0.17	0.18
EU15[a.]	0.18	0.19	0.19	0.22
Japan	0.20	0.20	0.15	0.17
Canada	0.41	0.46	0.59	0.74
Mexico			0.47	0.56
Canada+ Mexico			0.54	0.68
B. (Exports + Imports of manufactured goods)/Manufacturing GDP				
US	0.32	0.51	0.79	1.06
EU15[a.]	0.38	0.50	0.70	0.89
Japan	0.66	0.75	0.66	0.88
Canada	1.36	1.79	2.51	2.93
Mexico			1.87	2.57
Canada+ Mexico			2.24	2.75
C. Manufacturing Value Added/GDP				
US	0.23	0.20	0.17	0.14
EU15a.	0.29	0.24	0.21	0.20
Japan	0.30	0.27	0.23	0.20
Canada	0.20	0.18	0.17	0.20
Mexico		0.20	0.20	0.19
Canada+ Mexico		0.19	0.18	0.20

Data sources: Source OECD. International Trade by Commodity Database and STAN Industrial Structural Analysis

Footnotes:

a. European aggregate includes: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and the UK.

b. For Canada and the EU15 GDP and manufacturing value added only available through 1999. Ratios in the last column use trade data through 2001 but divide by 1999 value added.

Table 4: Production sharing by US MNEs

	1977	1982	1989	1994	1999
	(Manufacturing)				
A. Sales by US affiliates to the US, as a share of total sales of affiliates					
Canada	0.26	0.29	0.35	0.43	0.43
Mexico	0.07	0.08	0.29	0.32	0.35
Europe	0.02	0.02	0.06	0.04	0.06
Japan	0.03	0.00	0.09	0.07	0.03
B. US Exports from parents to affiliates/Total sales of affiliates					
	(Manufacturing)				
Canada	0.30	0.31	0.33	0.43	0.38
Mexico	0.15	0.22	0.44	0.43	0.45
Europe	0.06	0.06	0.06	0.06	0.05
Japan	0.09	0.11	0.10	0.10	0.10
C. Importance of Production Sharing in Local Value Added in Manufacturing					
	(Sales of affiliates to US - Exports to affiliates*Share of US in total sales)/Mftg GDP				
Canada	0.23	0.23	0.25	0.30	0.35
Mexico	0.36	0.26	0.37	0.42	0.42
Europe	0.00	0.00	0.01	0.01	0.02
Japan	0.00	0.00	0.00	0.00	0.00

Source: Data on exports to and sales by US affiliates from the Bureau of Economic Analysis. Manurufacturing GDP from Source OECD.

Table 5: Two-country model

	omega= 1, v3= 1 SUBSTITUTES rho= 0.5	omega= 1, v3= 1 COMPLEMENTS rho= -20
Steady state statistics		
GDP3 / GDP1	0.15	0.15
value added of exports1 / GDP1	0.15	0.15
value added of exports3 / GDP3	0.00	0.00
value added of exports from 1 to 2 / GDP1	0.15	0.15
exports 1 (including V11) / GDP1	0.15	0.15
exports 3 (including V11) / GDP3	0.01	0.01
Country 1 moments		
stdev. C1 / stdev. GDP1	0.27	0.41
stdev. I1 / stdev. GDP1	3.66	3.52
correl (TB1 , GDP1)	-0.32	-0.37
Country 3 moments		
stdev. C3 / stdev. GDP3	0.32	0.32
stdev. I3 / stdev. GDP3	3.10	3.10
correl (TB3 , GDP3)	-0.69	-0.49
International cross correlations, country 1 country 2		
GDP	-0.05	0.24
Consumption	0.32	-0.22
Investment	-0.31	-0.03
Labor	-0.09	0.75
International cross correlations, country 1 country 3		
GDP	0.00	0.01
Consumption	0.01	0.01
Investment	0.01	0.01
Labor	0.00	0.01
Difference in cross correl. corr(X1,corrX3) - corr(X1,X2)		
GDP	0.05	-0.24
Consumption	-0.31	0.22
Investment	0.32	0.04
Labor	0.10	-0.75

Table 6: Four country model

		Complete Markets			
	No trade	Benchmark	rho = csi = 0.5	Higher share of V13 in V	Lower trade shares
	1	2	3	4	5
Steady state statistics					
GDP3 / GDP1	0.15	0.14	0.14	0.15	0.14
value added of exports1 / GDP1	0.00	0.15	0.15	0.14	0.08
value added of exports3 / GDP3	0.00	0.15	0.15	0.15	0.08
value added of exports from 1 to 2 / GDP1	0.00	0.13	0.13	0.13	0.07
exports 1 (including V11) / GDP1	0.00	0.21	0.21	0.20	0.11
exports 3 (including V11) / GDP3	0.01	0.60	0.60	0.61	0.32
Country 1 moments					
stdev. C1 / stdev. GDP1	0.32	0.27	0.27	0.28	0.29
stdev. I1 / stdev. GDP1	3.10	3.62	3.63	3.60	3.33
correl (TB1 , GDP1)	-0.01	-0.35	-0.33	-0.32	-0.26
Country 3 moments					
stdev. C3 / stdev. GDP3	0.32	0.30	0.26	0.34	0.31
stdev. I3 / stdev. GDP3	3.10	3.50	3.57	3.26	3.29
correl (TB3 , GDP3)	-0.69	-0.48	-0.25	-0.44	-0.48
International cross correlations, country 1 country 2					
GDP	0.00	-0.04	-0.04	-0.04	-0.03
Consumption	0.00	0.29	0.28	0.30	0.19
Investment	0.00	-0.27	-0.27	-0.27	-0.14
Labor	0.00	-0.09	-0.08	-0.10	-0.07
International cross correlations, country 1 country 3					
GDP	0.00	0.02	-0.02	0.04	0.01
Consumption	0.00	0.07	0.19	-0.06	0.05
Investment	0.00	-0.13	-0.18	-0.12	-0.06
Labor	0.00	0.07	-0.04	0.11	0.03
Difference in cross correl. corr(X1,corrX3) - corr(X1,X2)					
GDP	0.00	0.06	0.02	0.08	0.04
Consumption	0.00	-0.22	-0.09	-0.35	-0.15
Investment	0.00	0.14	0.09	0.15	0.08
Labor	0.00	0.16	0.04	0.21	0.10

Table 7: Extensions to the Four Country model

	Complete Markets			Financial Autarky		
		Intermediate			Intermediate	
	Benchmark	Goods	Diffusion	Benchmark	Goods	Diffusion
	1	2	3	4	5	6
Steady state statistics	0.14	0.14	0.13	0.14	0.14	0.13
GDP3 / GDP1	0.15	0.15	0.15	0.15	0.15	0.15
value added of exports1 / GDP1	0.15	0.15	0.15	0.15	0.15	0.15
value added of exports3 / GDP3	0.13	0.13	0.13	0.13	0.13	0.13
value added of exports from 1 to 2 / GDP1	0.21	0.21	0.27	0.21	0.21	0.27
exports 1 (including V11) / GDP1	0.60	0.60	1.07	0.60	0.60	1.07
exports 3 (including V11) / GDP3						
Country 1 moments	0.27	0.27	0.28	0.30	0.30	0.31
stdev. C1 / stdev. GDP1	3.62	4.16	3.67	2.92	2.95	2.99
stdev. I1 / stdev. GDP1	-0.35	-0.44	-0.33	-0.01	-0.01	0.01
correl (TB1 , GDP1)						
Country 3 moments	0.30	0.30	0.35	0.28	0.29	0.37
stdev. C3 / stdev. GDP3	3.50	4.02	4.05	2.76	2.85	3.65
stdev. I3 / stdev. GDP3	-0.48	-0.47	-0.08	-0.02	-0.02	-0.01
correl (TB3 , GDP3)						
International cross correlations, country 1 country 2	-0.04	0.01	-0.04	0.04	0.15	0.04
GDP	0.29	0.36	0.27	0.15	0.27	0.15
Consumption	-0.27	-0.39	-0.29	0.13	0.24	0.13
Investment	-0.09	-0.05	-0.09	0.13	0.24	0.13
Labor						
International cross correlations, country 1 country 3	0.02	0.09	0.31	0.07	0.25	0.32
GDP	0.07	0.11	0.11	0.26	0.44	0.10
Consumption	-0.13	-0.20	-0.11	0.23	0.40	0.07
Investment	0.07	0.17	-0.02	0.23	0.39	0.07
Labor						
Difference in cross correl. corr(X1,corrX3) - corr(X1,X2)	0.06	0.08	0.35	0.03	0.09	0.28
GDP	-0.22	-0.25	-0.16	0.11	0.17	-0.04
Consumption	0.14	0.20	0.18	0.10	0.16	-0.06
Investment	0.16	0.21	0.07	0.10	0.16	-0.06
Labor						