

Trade, production sharing and the international transmission of business cycles*

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Abstract

This paper is motivated by two observations on international trade and business cycles: (1) cross-country correlations between core regions (such as US and the E.U.) are generally lower than the cross-country correlations between core and periphery regions (such as US and its NAFTA trading partners), and (2) trade between core and periphery regions involves more production sharing than trade between 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 accounting for these two observations but, quantitatively, the direct effects from trade do not generate large divergence in output correlations across countries. Extending the model to allow for cost reduction spillovers from MNEs in the core country to their affiliates in the periphery increases the impact that product sharing has on output correlations between core and peripheral countries.

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1. Introduction

Continual improvements in communications and transportation technology have made it possible for multinational firms to slice up the production chain into separate parts that can be performed in different locations according to region- or country-specific comparative advantage. Such vertical integration creates close interdependencies between different parts of the firm located across national borders. For example, the five major bridges and one tunnel linking Ontario to Michigan and New York account for 27 percent of all US-Canada trade. When the border crossings were closed following the 9/11 attacks, many of the “big three” automakers stood idle waiting for parts shipments from Canada.¹ Similarly, the outbreak of the SARS virus in Asia led to widespread concern about a possible interruption in the production of power supplies for laptop computers. A quarantine of China would “mean nuclear winter to the semiconductor and electronics industry.”²

In this paper we ask whether vertically integrated production chains affect the global transmission of business cycles. We find it useful to distinguish trade flows that occur between “core” regions (such as the flows between US and Europe) from the trade flows between core regions and their “periphery” (such as US trade with Canada and Mexico). The data suggest that trade between core regions and their periphery involves more production sharing – the division of production processes into separate stages that can be done in different locations – than does trade between core regions. The data also suggest that business cycles are more synchronized between core regions and their periphery. Our goal is to generate asymmetric business cycle transmission depending on the nature of trade.

We extend the basic international business cycle model proposed by Backus, Kehoe and Kydland (1995), henceforth BKK, to a multi-country setting. As in BKK, trade occurs at the level of intermediate goods, and business cycles are driven by shocks to total factor productivity that change relative marginal costs across countries. Trade between the core regions of the US and Europe involve trade in goods that are substitutes. 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 good. As is well known, under risk sharing across countries this results in a negative transmission of the business cycle. In contrast, trade between core regions and periphery countries involves

¹The effects of 9/11 on US-Canada trade is discussed in a 2002 Council of Foreign Relations report, “America still unprepared - America still in danger,” headed by Congressmen Hart and Rudman.

²“Analysis: Asia casts shadow over supply chain,” *EE Times*, April 1, 2003.

production chains that are linked across national borders. In this case, traded intermediate goods are complements in the production of the final good. A decline in the relative marginal cost in the core country will produce an increase in the demand for the intermediate good in the periphery, leading to a positive transmission of the business cycle. Therefore, depending on the nature of a country's dependence on intermediate inputs, we can generate asymmetric bilateral transmission of business cycles like those we see in the data.

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. Productivity shocks are assumed to be uncorrelated across countries so that all of the transmission of business cycles occurs through trade. We then examine the change in cross-country correlations of business cycles that result from changes in trade shares. We find that our benchmark model is qualitatively successful in terms of producing an increase in output correlations between core and periphery countries, relative to output correlations between core countries. However, quantitatively these divergences are significantly smaller to those observed in the data.

The failure of our model to generate large differences in business cycle transmission occurs for two reasons. First, although trade in manufactures has been growing over time, the share in total GDP of value added generated by exports is small for both core and periphery regions. 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. Interestingly, while production sharing makes trade appear to be very important relative to local production, the contribution of local value added - the key to business cycle transmission - remains small because of the dependence on imported intermediate inputs.

The second reason for the quantitatively small impact of trade on business cycles is that 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. To put it another way, the impact of production sharing may loom large in the sector where it occurs, but its importance for the business cycle at the macroeconomic level is offset by other general equilibrium effects at work in the economy.

We consider two extensions of the model. First, we assume that production of the inter-

mediate good in each country requires intermediate inputs from the local economy, thus increasing the spillover effect from trade stemming from the production-sharing sector. Second we assume that technological innovations or cost reductions that occur in the multinational firm headquartered in the core country are shared with its affiliate in the periphery country. The latter of these two experiments has the largest effect and results in an 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 (2002), and Heathcote and Perri (2003)). Kose and Yi (2001, 2005) 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 co-movements between some country pairs (low elasticity of substitution associated with production sharing), and a decrease in output co-movements between other country pairs (higher elasticity of substitution between traded goods) in a multi-country setting that is calibrated to relative country sizes and the importance of trade in each country. 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 affect local economic conditions.

In the next section we document the main facts that characterize the relationship between trade and business cycles that we will attempt to explain with our model. Section 3 describes the benchmark model and the two extensions. Section 4 presents the main results and Section 5 concludes.

2. Trade and business cycle fluctuations.

Fact 1: International correlations differ across trading partners. In the 1990s, the data suggest that correlations are higher between core and periphery regions than bilateral correlations between core regions.

Figures 1 and 2 show that the correlations of detrended GDP between the US and its trading partners differ across regions and in some cases change over time.³ 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 adjusted and detrended using the HP filter. The top three panels of Table 1 report decade averages of the correlations between the US and its major trading partners for GDP, consumption and investment. The bottom three panels repeat these decadal correlations for Europe and its major trading partners.⁵

Turning first to the output correlations (panels 1a and 2a of Table 1) the data suggest that business cycles in the core regions of US, Europe and Japan have become less synchronous from the 1970s to the 1990s. In the case of the US 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 US 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 unlikely to be statistically significant.

The last three columns in part 1 of Table 1 show the correlations between the US and its NAFTA trading partners. There is no evidence of a significant decline in business cycle correlations between the US 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 US since the

³A large empirical literature has developed around the issue of business cycle synchronization. Among the many papers that examine this question are Bordo and Helbling (2004), Doyle and Faust (2005), Imbs (1999, 2004), Kose, Otrok and Whiteman (2003), Kose and Yi (2002) and Stock and Watson (2005).

⁴Bilateral 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 (2003)), dynamic factor analysis (Gregory, Head and Raynauld (1997)), VARs (Clark and Shin (1998)), and identification of common business cycle turning points (Harding and Pagan (2005)).

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

⁶Caution should be exercised in interpreting point estimates of correlations without taking standard errors into account. See Doyle and Faust (2005) for an econometric methodology for estimating breaks in second moments of time series.

1980s.

We complement this evidence with industrial production data. Figure 3 shows growth rates over the previous year in monthly industrial production in Mexico and the US. Splitting the sample at end of 1995, the correlation increases from 0.19 in the 1980-95 period to 0.83 in the 1996-2004 period.⁷

The national accounts time series data for 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 roughly 0.4.

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 correlations tend to rise and fall together.

These data suggest that bilateral correlations are sensitive to the time interval over which they are calculated as well as to the country pairing. The goal of our paper is to see whether different patterns of trade can generate a wedge between the correlations of core-core pairs relative to core-periphery pairs similar to those observed in the 1990s.

Fact 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 US and Europe. Each core region trades with a periphery region – the US with Canada and Mexico and Europe with Eastern Europe. Table 2 reports the decomposition of trade flows between the US, Europe, North America and Eastern Europe. Europe accounts for roughly 20 percent of US exports and imports. Trade with its NAFTA partners accounts for 30 percent of imports and 37 percent of exports. Our model will abstract from trade (and production sharing) with Asia, which accounts for the balance of US trade.

Part B of Table 2 shows a similar decomposition for Europe. Trade with the US 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

⁷Gordon 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 US manufacturing.” *New York Times*, “A Boom Along the Border” August 26, 2004.

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.

Fact 3: Trade in manufactured goods as a share of manufacturing production has risen dramatically since the 1970s. Total trade relative to GDP has also increased but at a slower rate.

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 US, Europe, Japan, Canada and Mexico. Note that European trade is the external trade of the European aggregate with countries outside of Western Europe. The US 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 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 value added of the manufacturing sector. In the US, Europe, and Japan, this ratio exceeds 1, and in Canada and Mexico the ratio is over 2.5. This reflects the shift toward greater 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 (see Yi (2003) for a detailed description). 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 value 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 trade is a relatively small 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 cycle

correlations in standard models of international business cycles, a finding that is underscored in Kose and Yi (2005). We will show below that production sharing helps to amplify the trade link, but its overall impact depends on the spillover from the production sharing sector to the local economy.

Fact 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 can impact international business cycle transmission. Trade between core countries, we argue, is largely trade in varieties of intermediate 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.⁸ According to Hummels, Ishii and Yi (2001), vertical specialization (the production of goods in multiple stages of production in multiple countries) accounted for more than one-third of world export growth between 1970 and 1995.⁹

Re-importation of domestic content

While anecdotal evidence of production sharing and vertical integration are plentiful, concrete evidence on the magnitude of this phenomenon is harder to come by. One measure of the extent of production sharing by US corporations is captured by the fraction of US content in US imports, shown in Figure 4. Under Harmonized Tariff Schedule 9802, companies are granted an exemption from US customs duties and user fees for the value of US-made components that are contained in goods that are assembled overseas and re-imported into the US¹⁰ While this data would appear to be the ideal source for information about the extent of US production sharing, there is a significant problem. Companies have an incentive to report US content in imported goods only when faced with significant tariff barriers. After the signing of the Canada-US free trade agreement in 1991 and the creation of NAFTA in

⁸Many 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.

⁹A number of factors are credited for the expansion of production sharing: reduction in trading barriers and physical trading costs, improvement in information technology, and other technological advances that make it possible to split production processes.

¹⁰See “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.

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 4). 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 US 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 US content, suggesting that little production sharing is taking place by US firms operating in Europe. The second conclusion is that a conservative estimate of the US content of goods imported from Mexico and Canada under the production sharing provision ranges from 40 to 55 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. Similar to provision 9802, the EU has established an exemption for “outward processing trade” (OPT) that allows for the duty-free re-importation of goods that contain EU content. Data on the extent of production sharing in Europe are limited, but according to the ITC, Hungary accounted for 10 percent of EU OPT imports from Central Europe during the 1993-96 period, Poland 40 percent, and the Czech Republic 19 percent. Similar to the issue with Mexican and Canadian data, the extent of OPT is thought to be understated in official statistics (Topolansky 1998).

Trade between US multinationals and their foreign affiliates

Trade between US multinationals and their affiliates provide an alternative source of information about the extent of production sharing.¹² Panel A of Table 4 shows the ratio of sales of US 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 US, suggesting that affiliates are part of a vertically-integrated production chain and the goods are ultimately shipped back to the US. In contrast, only a small fraction of the sales of European and Japanese affiliates are sales to the US (3 and 6 percent, respectively),

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

¹²See, for example, Hanson, Mataloni, and Slaughter (2005), and Chen and Yi (2003).

evidence that the activity of those affiliates is quite different.¹³

Panel B shows the ratio of exports of US parents to their affiliates as a fraction of the total sales of affiliates. 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 US.

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, but what is important for our model is the local value added generated by exports. The numerator of the index is sales of affiliates to the US less US exports to affiliates scaled by the share of US in total sales. The scaling adjusts for the fact that not all exports to affiliates return to the US, 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. Note that operations of multinational with its affiliates underestimates the importance of production sharing because it excludes outsourcing via arms length trade.

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 1965 to help relieve high unemployment in the northern region of Mexico. Foreign-owned firms were granted the right to set up production in the region and to import materials and equipment duty-free under the proviso that the goods would be re-exported. Not all maquiladoras are controlled by US corporations, so this data complements the previous analysis using US multinational data (it would be useful to have a number here). As

¹³This fact is also documented 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.

shown in Figure 5, maquiladora exports account for about 50 percent of all non-oil exports from Mexico.¹⁴ 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 US 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. Note that this does not include operations by affiliates of US multinationals in Mexico, discussed in the previous subsection.

To summarize, the goal of our paper is to develop a model of international business cycles and trade that is consistent with four key features of the data. First, the bilateral correlations between core regions have generally fallen over time and are lower than the bilateral 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, trade in manufactures has increased but it 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 US and Western Europe, country 3 as the US’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

¹⁴The 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 maquiladora exports in total exports was 49 percent compared to maquiladora exports in total exports excluding oil of 55 percent.

the other periphery (i.e. the US trades with Europe and its NAFTA partners but not with Eastern Europe, and Europe trades with the US and Eastern Europe but not with Canada and Mexico).

We measure time in discrete periods and index each period by $t = 1, 2, 3, \dots, \infty$. Countries are indexed by $i = 1, 2, \dots, 4$. 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:

$$U_i = \max E_0 \sum_{t=0}^{\infty} \beta^t u(c_{it}, 1 - n_{it}) , \quad (3.1)$$

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

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 (its average is A_i) which changes stochastically over time. The production function has constant returns to scale, and is given by:

$$z_{it} = A_i e^{s_{it}} (n_{it})^\alpha (k_{it})^{1-\alpha} . \quad (3.2)$$

The vector of aggregate productivity shocks $s_t = (s_{1t}, s_{2t}, s_{3t}, s_{4t})$ follows the process $s_{t+1} = \rho s_t + \varepsilon_{t+1}$, where ε_t is distributed normally and independently over time, with mean 0 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:

$$x_{1t} = [\theta_1^{1-\rho} (x_{11t})^\rho + (1 - \theta_1)^{1-\rho} (x_{12t})^\rho]^\frac{1}{\rho} \quad (3.3)$$

$$x_{2t} = [\theta_1^{1-\rho} (x_{22t})^\rho + (1 - \theta_1)^{1-\rho} (x_{21t})^\rho]^\frac{1}{\rho} \quad (3.4)$$

$$x_{3t} = [\theta_3^{1-\rho} (x_{33t})^\rho + (1 - \theta_3)^{1-\rho} (x_{31t})^\rho]^\frac{1}{\rho} \quad (3.5)$$

$$x_{4t} = [\theta_3^{1-\rho} (x_{44t})^\rho + (1 - \theta_3)^{1-\rho} (x_{42t})^\rho]^{\frac{1}{\rho}} \quad (3.6)$$

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

$$v_{1t} = [\lambda^{1-\zeta} (v_{11t})^\zeta + (1 - \lambda)^{1-\zeta} (v_{13t})^\zeta]^{\frac{1}{\zeta}}. \quad (3.7)$$

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 US. 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.¹⁵

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 the equilibrium allocations.

¹⁵Ruhl (2004) studies a model where the presence of fixed costs associated with trade imply that the elasticity of exports is lower for small and temporary shocks than for large and permanent shocks.

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

$$v_{2t} = \left[\lambda^{1-\zeta} (v_{22t})^\zeta + (1-\lambda)^{1-\zeta} (v_{24t})^\zeta \right]^{\frac{1}{\zeta}}. \quad (3.8)$$

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 according to:

$$y_{it} = (x_{it})^\omega (v_{it})^{1-\omega} \quad i = 1, 2 \quad (3.9)$$

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 :

$$y_{it} = x_{it}, \quad i = 3, 4 \quad (3.10)$$

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

$$L_1 z_{1t} = L_1 x_{11t} + L_2 x_{21t} + L_3 x_{31t} + L_1 v_{11t} \quad (3.11)$$

$$L_2 z_{2t} = L_2 x_{22t} + L_1 x_{12t} + L_4 x_{42t} + L_2 v_{22t} \quad (3.12)$$

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:

$$L_3 z_{3t} = L_3 x_{33t} + L_1 v_{13t} \quad (3.13)$$

$$L_4 z_{4t} = L_4 x_{44t} + L_2 v_{24t} \quad (3.14)$$

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

$$y_{it} = c_{it} + i_{it} \quad \text{for } i = 1, \dots, 4 \quad (3.15)$$

where

$$i_{it} = k_{it+1} - (1-\delta) k_{it} \quad (3.16)$$

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 nature. We will exploit the fact that the equilibrium allocations are Pareto optimal by solving the following planner's optimal problem:

$$\max L_1 U_1 + L_2 U_2 + L_3 U_3 + L_4 U_4, \quad (3.17)$$

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. $P_{1t}^z = 1$). 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:

$$L_1 z_{1t} = P_{1t}^y L_1 (c_{1t} + i_{1t}) + TB_{1t} , \quad (3.18)$$

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

$$TB_{1t} = (L_2 x_{21t} + L_3 x_{31t}) - L_1 P_{2t}^z x_{12t} - L_1 P_3^z v_{13t} , \quad (3.19)$$

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

$$L_3 P_{3t}^z z_{3t} = L_3 P_{3t}^y (c_{3t} + i_{3t}) + TB_{3t} , \quad (3.20)$$

where the trade balance TB_3 is:

$$TB_{3t} = L_1 P_{3t}^z v_{13t} - L_3 x_{31t} . \quad (3.21)$$

We 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 US, 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:

$$z_{it} = A_i e^{s_{it}} (n_{it})^{\alpha\gamma} (k_{it})^{(1-\alpha)\gamma} (m_{it})^{1-\gamma} , \text{ for } i = 1, \dots, 4 , \quad (3.22)$$

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:

$$y_{it} = c_{it} + i_{it} + m_{it}, \text{ for } i = 1, \dots, 4 \quad (3.23)$$

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.¹⁶

To capture this transmission of technology to affiliates, we assume that innovations to aggregate productivity in country 1 are 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 than 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 goods in country 3 are given by:

$$L_1 v_{13t} = L_3 A_{3t} e^{s_{3t}} d_{3t} \left(n_{it}^f \right)^\alpha \left(k_{it}^f \right)^{1-\alpha} \quad (3.24)$$

and

$$x_{33t} = A_{3t} e^{s_{3t}} \left(n_{it}^l \right)^\alpha \left(k_{it}^l \right)^{1-\alpha} \quad (3.25)$$

where d_{3t} is given by:

$$d_{3t} = 1 - \eta + \eta \frac{e^{s_{1t}}}{e^{s_{3t}}} \quad (3.26)$$

The parameter η measures the extent of diffusion in productivity shocks from country 1 to country 3. The variable d_3 also denotes 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

¹⁶Desai and Foley (2005) 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.

by:

$$L_3 z_{3t} = L_3 x_{33t} + \frac{L_1 v_{13t}}{d_{3t}}. \quad (3.27)$$

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

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, without loss of generality, $A_1 = P_1^z = L_3 = 1$.

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.¹⁷ 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 A_3 , L_1 , θ_1 , θ_3 , and ω to match the following five observations about steady-state prices, country sizes and trade:¹⁸ (1) $P_3^z = P_4^z = 1$, (2) GDP in country 1 is roughly 7 times as large as GDP in country 3, (3) the share of exports from country 1 to country 2 as a share of country 1 GDP is 15%, (4) the share of value added generated by exports of country 3 to country 1 is 15% of country

¹⁷As discussed by BKK and Heathcote and Perri (2004), productivity shock spillovers over time can produce large negative cross-correlations in output and employment. Income effects in labor supply induce agents to work less in anticipation of future increases in productivity.

¹⁸It 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 (2001)). Along this line, authors like Kose and Yi (2005) get increases in trade shares in their model by reducing the magnitude of international trade costs.

3's GDP, and (5) all countries have a trade balance in steady state.¹⁹ Observation (2) is consistent with the ratio of US 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 results with other studies (BKK, Heathcote-Perri).²⁰ We recognize that this 15% share is higher than those reported in Tables 3 and 4 - in the experiments below we also report the results for cases with lower trade shares. The resulting parameter values from this procedure are $A_3 = 0.51$, $L_1 = 3$, $\theta_1 = 0.86$, $\theta_2 = 0.85$, 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 ε_t , feed them into the model, and compute several moments of interest from the artificially generated data. We repeat this procedure 1500 times, and finally average the statistics across simulations to produce the numbers we report in the tables.

5. Results

Two-country model

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

¹⁹Note that none of these observations depends on the assumption on whether v_{11} is or is not shipped to country 3 to produce the good v .

²⁰The 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 from the periphery). Presumably, the data lies somewhere between these two extreme assumptions.

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). This is consistent with the tendency to ‘*make hay where the sun shines*’ emphasized by BKK. Consumption risk-sharing through complete financial markets produces a positive, though somewhat small, correlation in consumption (0.32). The main 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 country 1 to increase consumption by more than country 2.

The second column in Table 5 repeats the experiment with perfect complementarity between the two inputs of production, holding the trade share constant. This parameter change leads to a different international transmission of productivity shocks. 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 1.²¹ These patterns generated by the two-country model as ρ varies are also analyzed by Heathcote and Perri (2004).

While the two-country model produces quantitatively significant differences in output cross-country correlations as we change the degree of substitution between traded intermediate goods, 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

²¹Under 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).

the challenges we face is that while production sharing helps generate positive comovements, the production sharing sector is only a 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.

Four-country model

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 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, and for labor it is 0.07. 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 the 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. Overall, the model produces only a small divergence in output correlations between core and periphery regions. The difference in cross-country correlations across the two pairs of countries (i.e.: $corr(X_1, X_3) - corr(X_1, X_2)$ for variable X) is 0.05 for GDP, 0.16 for labor, and 0.13 for investment.

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 0.05 under the baseline parametrization to 0.01. Substitutability between inputs in production of good v implies that the output correlation between countries 1 and 3 becomes negative, as that 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. This is because complementarity between inputs of countries 1 and 3 associated with production sharing is now only partially offset by substitutability in the production of the x good. Column 4 in Table 6 reports a modified parametrization of the baseline calibration, where we double the share in GDP of value added contributed by the production sharing sector in country 3 from 15% to 30%, and the import share of x_{31} remains constant at 15%. The difference in output cross-correlations across the two pairs of countries increases from 0.05 to 0.11 (for labor, this difference increases from 0.16 to 0.35).

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 countries falls from 0.05 to 0.03.

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. Columns 4 through 6 in Table 7 consider 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 tends 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 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 (0.05 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 more successful in terms of generating a larger 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 (0.14). 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. If instead we assumed that technological diffusion affects all firms in country 3, and not only those involved in production sharing, then the output correlation between countries 1 and 3 would increase significantly more.

What do we learn from this model about the connection between international business cycles and trade? First, the direction of the transmission of the business cycle via trade (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 as is suggested in the data, but these are quantitatively small in our benchmark parametrization. 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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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 Estadísticas de Contabilidad Nacional, Producto Interno Bruto Serie Historica Desde 1900.

b. European aggregate includes: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Lux, 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
<u>A. US imports and exports from the following countries as a percent of total imports and exports</u>								
EU15	21.7%	20.0%	18.6%	18.7%	26.5%	25.1%	22.5%	21.4%
Eastern Europe			0.3%	0.4%			0.3%	0.3%
North America	26.3%	23.2%	27.0%	30.4%	25.3%	25.4%	30.8%	36.7%
Canada	23.1%	17.8%	18.9%	19.0%	20.9%	19.3%	21.1%	22.6%
Mexico	3.2%	5.4%	8.1%	11.3%	4.4%	6.1%	9.6%	14.1%
Asia	29.5%	39.4%	42.8%	39.8%	25.2%	29.9%	31.8%	28.1%
<u>B. EU15 imports and exports from the following countries as a percent of total imports and exports</u>								
Eastern Europe			6.5%	8.2%			8.1%	9.5%
North America	23.1%	21.9%	21.9%	21.5%	20.9%	23.6%	22.0%	27.1%
US	19.4%	18.6%	19.5%	19.1%	17.1%	20.2%	18.9%	23.5%
Canada	3.4%	2.2%	1.9%	1.7%	2.8%	2.5%	2.0%	2.1%
Mexico	0.3%	1.1%	0.6%	0.7%	1.0%	0.9%	1.1%	1.5%
Asia	34.0%	36.6%	37.6%	39.3%	24.1%	29.8%	30.8%	28.5%
<u>C. Canadian imports and exports from the following countries as a percent of total imports and exports</u>								
EU15	11.4%	11.1%	10.3%	10.8%	13.2%	8.7%	6.4%	4.6%
Eastern Europe			0.1%	0.2%			0.1%	0.1%
North America	70.2%	70.2%	68.8%	67.5%	68.4%	72.6%	80.5%	87.7%
US	69.8%	69.0%	66.6%	64.0%	67.9%	72.2%	80.0%	87.2%
Mexico	0.3%	1.2%	2.3%	3.5%	0.5%	0.5%	0.5%	0.6%
Asia	10.0%	12.3%	14.2%	14.7%	10.8%	12.2%	9.6%	5.4%
<u>D. Mexican imports and exports from the following countries as a percent of total imports and exports</u>								
EU15			10.4%	8.1%			5.1%	3.4%
Eastern Europe			0.1%	0.1%			0.1%	0.1%
North America			75.9%	79.7%			85.6%	90.6%
US			74.1%	77.8%			83.2%	88.7%
Canada			1.7%	1.9%			2.4%	2.0%
Asia			8.8%	5.9%			3.0%	1.4%
<u>E. East European imports and exports from the following countries as a percent of total imports and exports</u>								
			1997-99	2000-03			1997-99	2000-03
EU15			66.3%	64.6%			73.8%	78.1%
North America			4.7%	4.2%			3.7%	3.9%
US			4.1%	3.7%			3.3%	3.4%
Canada			0.4%	0.3%			0.3%	0.3%
Mexico			0.2%	0.2%			0.1%	0.2%
Asia			19.2%	23.4%			10.4%	7.6%

Data Sources: Source OECD, International Trade in Commodities

Footnotes:

- European aggregate includes: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and the UK.
- Eastern Europe Aggregate is composed of Czech Republic, Hungary, Slovakia, and Poland
- 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 Value Added				
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, Lux, 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
<u>A. Sales by US affiliates to the US, as a share of total sales of affiliates (manufacturing)</u>					
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
<u>B. US Exports from parents to affiliates/Total sales of affiliates (manufacturing)</u>					
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
<u>C. Importance of Production Sharing in Local Value Added in Manufacturing</u> (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. Manufacturing GDP from Source OECD.

Table 5: Two country model

	1 Substitutes $\rho = 0.5$	2 Complements $\rho = -20$
Steady state statistics		
GDP_3/GDP_1	0.15	0.15
Value added of exports ₁ / GDP_1	0.15	0.15
Value added of exports ₃ / GDP_3	0.00	0.00
Value added of exports from 1 to 2 / GDP_1	0.15	0.15
Exports ₁ (including v_{11}) / GDP_1	0.15	0.15
Exports ₃ (including v_{11}) / GDP_3	0.01	0.01
Country 1 moments		
St. dev. (C) / St. dev. (GDP)	0.27	0.41
St. dev. (I) / St. dev. (GDP)	3.66	3.52
Correl. (TB, GDP)	-0.32	-0.37
Country 3 moments		
St. dev. (C) / St. dev. (GDP)	0.32	0.32
St. dev. (I) / St. dev. (GDP)	3.10	3.10
Correl. (TB, GDP)	-0.69	-0.49
International cross correlations, country 1 and 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 and 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, $\text{correl.}(X_1, X_3) - \text{correl.}(X_1, X_2)$		
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

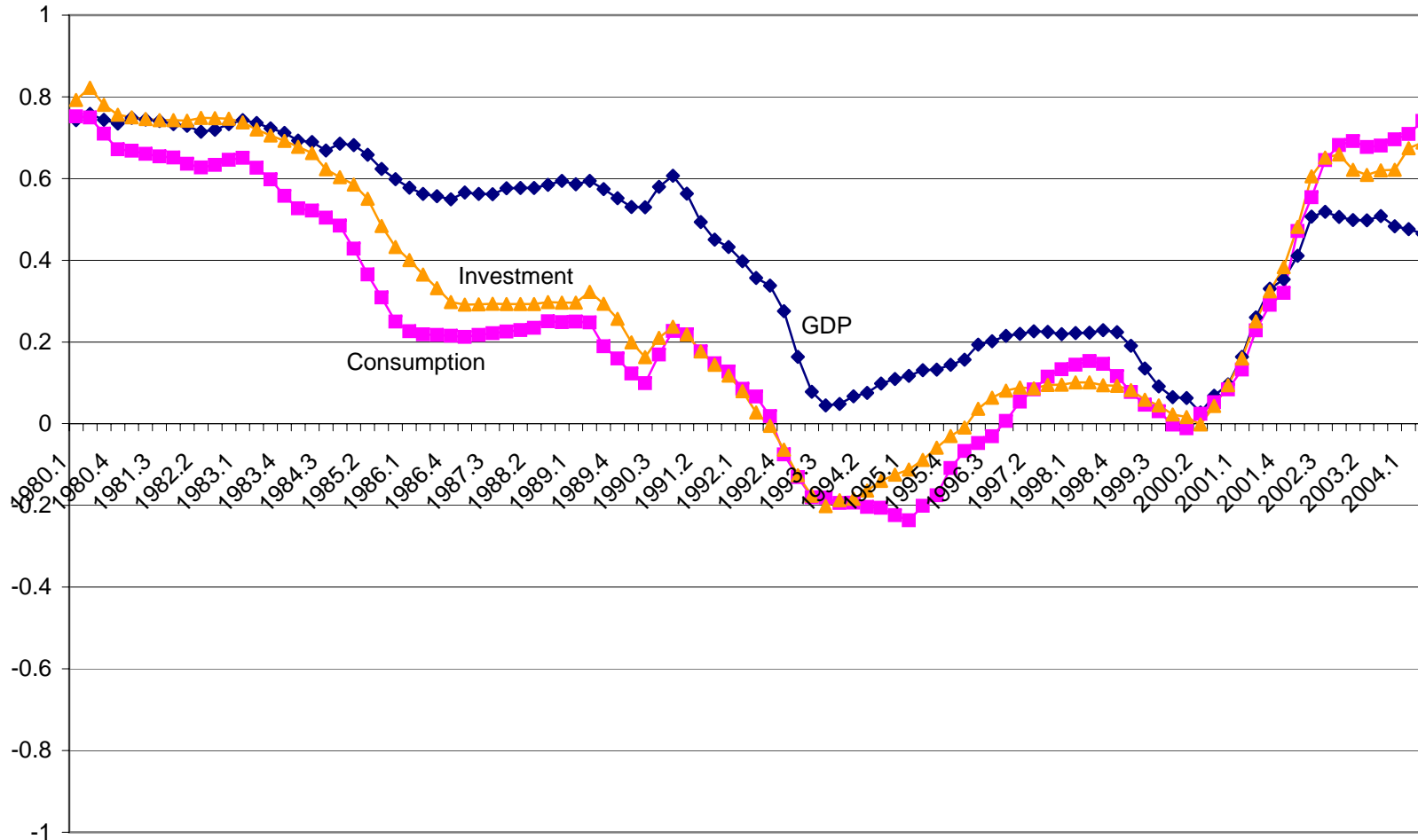
	1	2	3	4	5
	Complete Markets				
	No trade	Benchmark	$\rho = \zeta = 0.5$	Higher share of v_{13} in GDP_3	Lower trade shares
Steady state statistics					
GDP_3/GDP_1	0.15	0.14	0.14	0.15	0.14
Value added of exports ₁ / GDP_1	0.00	0.15	0.15	0.13	0.08
Value added of exports ₃ / GDP_3	0.00	0.15	0.15	0.31	0.08
Value added of exports from 1 to 2 / GDP_1	0.00	0.13	0.13	0.11	0.07
Exports ₁ (including v_{11}) / GDP_1	0.00	0.21	0.21	0.26	0.11
Exports ₃ (including v_{11}) / GDP_3	0.01	0.60	0.60	1.23	0.32
Country 1 moments					
St. dev. (C) / St. dev. (GDP)	0.32	0.27	0.27	0.28	0.29
St. dev. (I) / St. dev. (GDP)	3.10	3.62	3.63	3.56	3.33
Correl. (TB, GDP)	-0.01	-0.35	-0.33	-0.34	-0.25
Country 3 moments					
St. dev. (C) / St. dev. (GDP)	0.32	0.30	0.26	0.35	0.31
St. dev. (I) / St. dev. (GDP)	3.10	3.50	3.57	3.59	3.29
Correl. (TB, GDP)	-0.69	-0.48	-0.25	-0.45	-0.49
International cross correlations, country 1 and country 2					
GDP	0.00	-0.04	-0.04	-0.04	-0.03
Consumption	0.00	0.29	0.28	0.27	0.20
Investment	0.00	-0.27	-0.27	-0.22	-0.14
Labor	0.00	-0.09	-0.08	-0.09	-0.07
International cross correlations, country 1 and country 3					
GDP	0.00	0.02	-0.02	0.07	0.01
Consumption	0.00	0.06	0.19	-0.06	0.04
Investment	0.00	-0.14	-0.18	-0.22	-0.07
Labor	0.00	0.07	-0.05	0.26	0.03
Difference in cross correl, correl. (X₁, X₃) – correl. (X₁, X₂)					
GDP	0.00	0.05	0.01	0.11	0.03
Consumption	0.00	-0.23	-0.10	-0.34	-0.16
Investment	0.00	0.13	0.09	0.00	0.07
Labor	0.00	0.16	0.04	0.35	0.10

Table 7: Extensions to the four country model

	1	2	3	4	5	6
	Complete Markets			Financial Autarky		
	Intermediate			Intermediate		
	Benchmark	Goods	Diffusion	Benchmark	Goods	Diffusion
Steady state statistics						
GDP_3/GDP_1	0.14	0.14	0.14	0.14	0.14	0.13
Value added of exports ₁ / GDP_1	0.15	0.15	0.15	0.15	0.15	0.15
Value added of exports ₃ / GDP_3	0.15	0.15	0.15	0.15	0.15	0.15
Value added of exports from 1 to 2 / GDP_1	0.13	0.13	0.13	0.13	0.13	0.13
Exports ₁ (including v_{11}) / GDP_1	0.21	0.21	0.21	0.21	0.21	0.27
Exports ₃ (including v_{11}) / GDP_3	0.60	0.60	0.60	0.60	0.60	1.07
Country 1 moments						
St. dev. (C) / St. dev. (GDP)	0.27	0.27	0.28	0.30	0.30	0.31
St. dev. (I) / St. dev. (GDP)	3.62	4.16	3.67	2.92	2.95	2.99
Correl. (TB, GDP)	-0.35	-0.44	-0.33	0.01	-0.01	0.01
Country 3 moments						
St. dev. (C) / St. dev. (GDP)	0.30	0.30	0.31	0.28	0.29	0.37
St. dev. (I) / St. dev. (GDP)	3.50	4.02	3.65	2.76	2.85	3.65
Correl. (TB, GDP)	-0.48	-0.47	-0.23	0.00	-0.02	-0.01
International cross correlations, country 1 and country 2						
GDP	-0.04	0.01	-0.04	0.04	0.15	0.04
Consumption	0.29	0.36	0.28	0.15	0.27	0.15
Investment	-0.27	-0.39	-0.28	0.13	0.24	0.13
Labor	-0.09	-0.05	-0.09	0.13	0.24	0.13
International cross correlations, country 1 and country 3						
GDP	0.02	0.09	0.10	0.06	0.25	0.32
Consumption	0.06	0.10	0.11	0.25	0.44	0.10
Investment	-0.14	-0.20	-0.12	0.22	0.40	0.07
Labor	0.07	0.16	-0.03	0.22	0.39	0.07
Difference in cross correl, correl. (X_1, X_3) – correl. (X_1, X_2)						
GDP	0.05	0.08	0.14	0.02	0.09	0.28
Consumption	-0.23	-0.26	-0.17	0.10	0.17	-0.04
Investment	0.13	0.19	0.16	0.09	0.16	-0.06
Labor	0.16	0.21	0.06	0.09	0.16	-0.06

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.

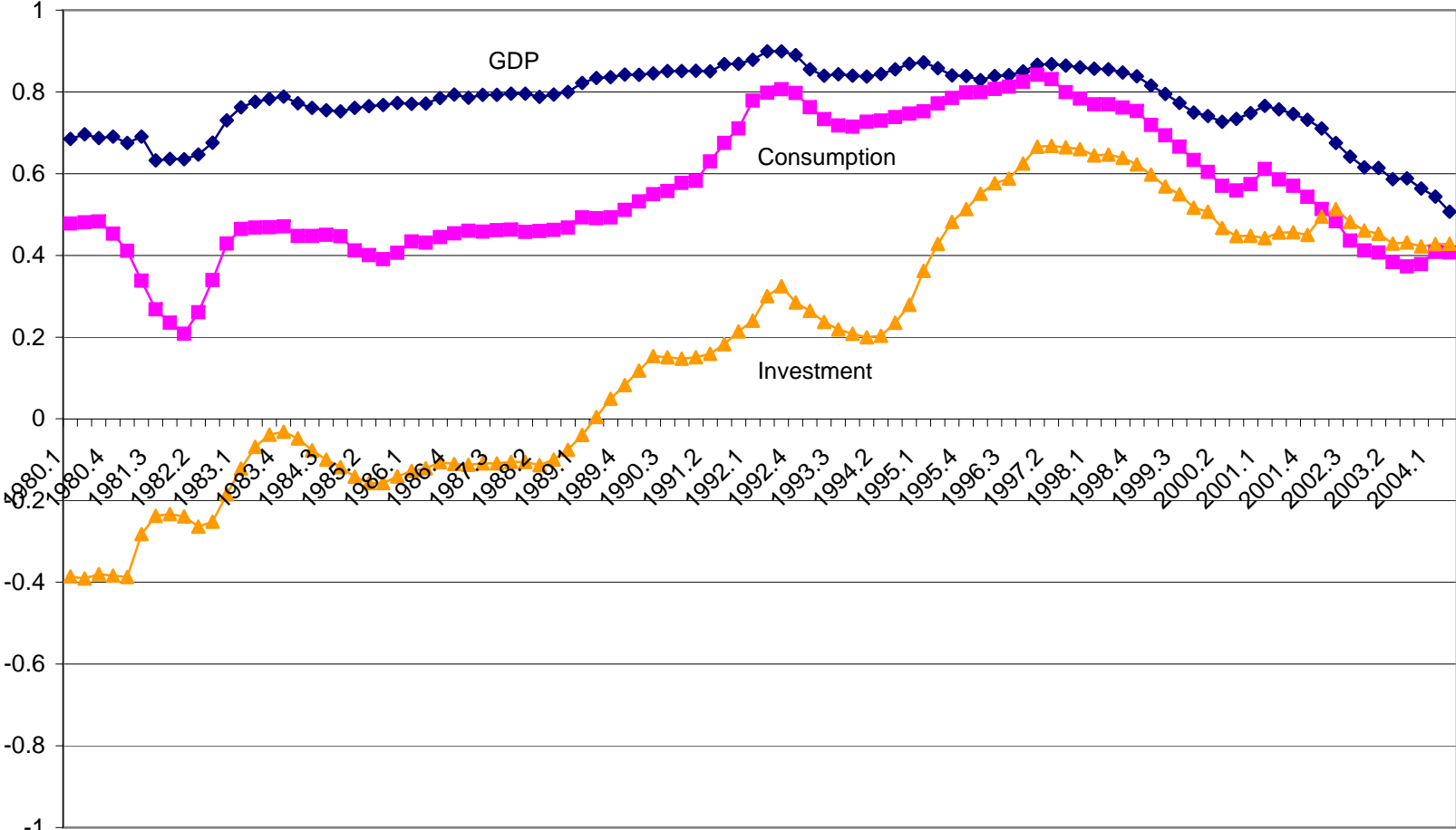


Source: Quarterly National Accounts, SourceOECD

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 and Mexican Industrial Production
Annual growth rates**

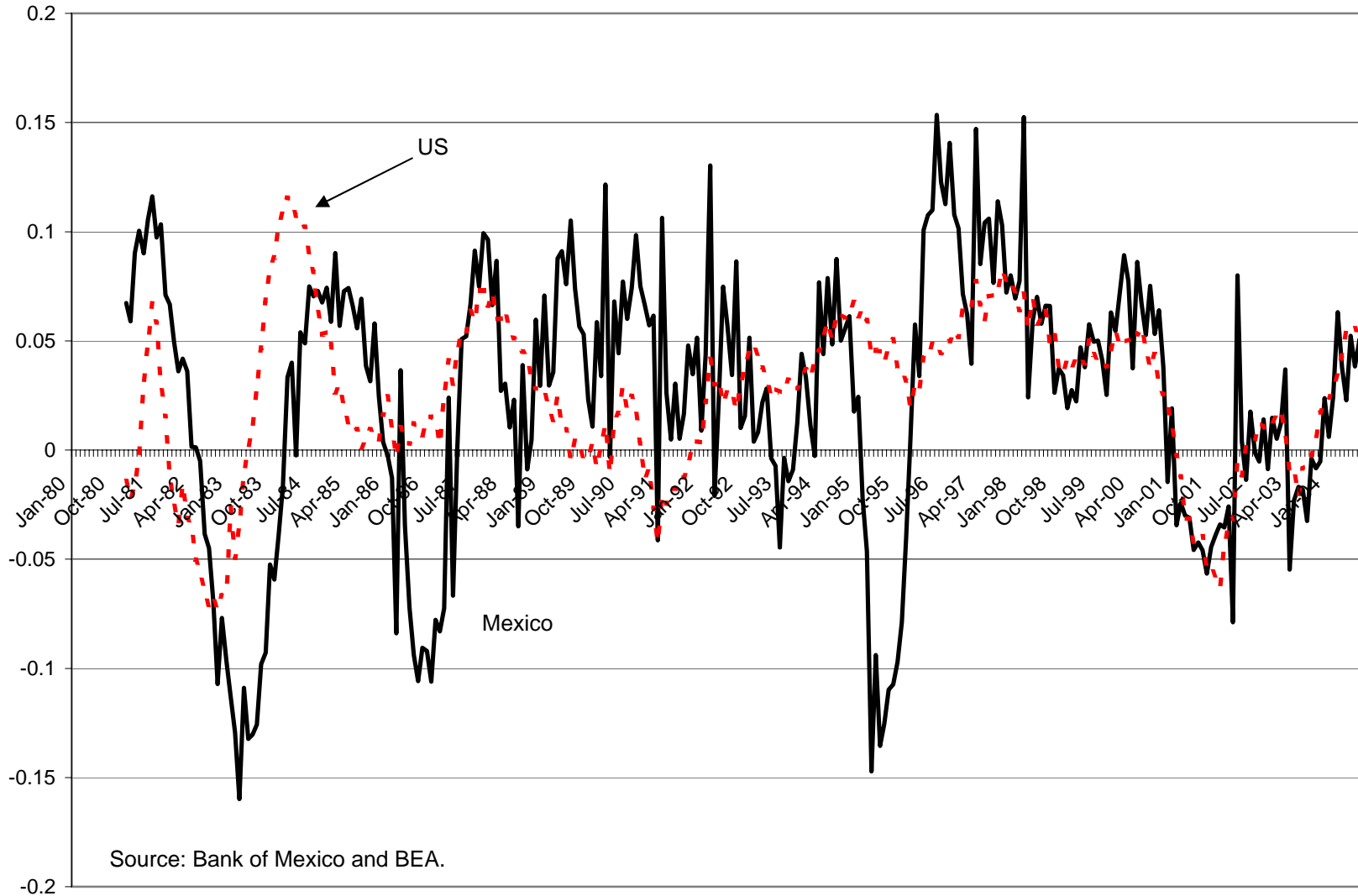


Figure 5: Trade by the Mexican Maquila Sector

