

THE GROWTH OF WORLD TRADE

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Abstract

The growth in the trade share of output is one of the most important features of the world economy since World War II. We show that an important propagation mechanism for this growth is vertical specialization. Simply put, vertical specialization occurs when imported inputs are used to produce goods that are then exported. We show that many of the standard trade models - the Ricardian model, the monopolistic competition model, and the international real business cycle models - cannot explain the growth in trade unless very high elasticities of demand and substitution are assumed. We then use case studies and other empirical evidence to demonstrate the quantitative significance of vertical specialization in trade. Finally, we develop a model of vertical specialization that can explain the growth in trade under reasonable elasticities, which suggests that vertical specialization has important implications for the gains from trade.

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I. INTRODUCTION

Almost all discussions of globalization and the internationalization of production highlight the growing trade shares of output. Indeed, trade's growing share is one of the most striking features of the world economy since World War II. Figure 1 illustrates that for the last half century world merchandise trade has grown two per cent faster per year than world merchandise output. World manufactured trade has outpaced manufactured output even more, by about three percent per year.¹ Most countries, and many types of countries - small and large, rich and poor, fast growers and slow growers - have experienced increases in their trade share of GDP.

The main driving forces responsible for trade's rising share are generally thought to be lower trade barriers and improved transportation and information technologies. Perhaps even more important than the driving forces are the *propagation mechanisms* through which the driving forces have led to the increased trade. Understanding these mechanisms is central to understanding the gains from trade, the linkages from openness to long run growth, as well as the linkages from productivity growth to trade. The usual propagation mechanism that comes to mind is one in which comparative advantage or increasing returns to scale facilitates horizontal specialization - different countries specialize in producing different goods and services.

This paper shows that *vertical specialization* has also been an important propagation mechanism in the growth of world trade. By vertical specialization, we mean that goods require more than one sequential stage of production; a country specializes in producing some, but not all, stages of the good; and at least one stage crosses an international border more than once. More concisely, vertical specialization arises when imported inputs are used to produce intermediate or final goods that are then exported. Vertical specialization is related to outsourcing, which we view as the re-location of production to other countries. While increased outsourcing is usually associated with increased vertical specialization, neither necessarily implies the other.

We first show the limitations of particular static and dynamic models of the world economy in explaining the growth in world trade. The models we investigate include the

¹ See Harris (1993) and World Trade Organization (1996). World manufactured trade has grown about 4% per year faster than GDP.

Ricardian, monopolistic competition, and international real business cycle models. These models do not explicitly allow for vertical specialization. Under a scenario of a reduction in tariffs of 25 percentage points over 35 years we calculate the implied growth rates of the export share of GDP.² In order to generate growth rates of the export share equal to the actual growth rate of the world manufacturing export share, the models require elasticities of demand and substitution on the order of *five to ten*. These elasticities are much higher than what is estimated in import demand regressions or employed in computable general equilibrium models.

We then present empirical evidence that vertical specialization is quantitatively significant. Our evidence focuses on four case studies: the U.S.-Canada Auto Pact of 1965, U.S.-Mexico maquiladora trade, recent Japan-Asia electronics trade, and GM Opel's expansion into Spain in the early 1980s. The case studies allow us to obtain direct empirical counterparts to our definition of vertical specialization. To calculate the amount of vertical specialization-based trade, measures of imported inputs and of the fraction of exported goods produced with the imported inputs, as well as measures of exported intermediate goods and the fraction of imported goods produced with the exported intermediates, are needed. Using industry level data is problematic primarily because most databases do not have data on intermediate exports that are embodied in imports. Also, the data do not distinguish between imported inputs used in goods sold domestically (no vertical specialization) and imported inputs used in other goods from the same industry that are exported (vertical specialization). For the two U.S. case studies and in the Opel España case study, our calculations indicate that more than 40% of trade is due to vertical specialization generated by the agreements. In the Japan case study over \$55 billion of trade in 1995 is due to vertical specialization.

We argue that vertical specialization provides an important additional channel by which lower trade barriers and improved transportation and information technologies can generate a more plausible explanation for trade growth. Lower barriers and improved technologies push countries to break up their production processes and specialize in particular stages; hence, a good traverses multiple borders before its final destination. As with horizontal specialization, the underlying motive for vertical specialization can be either increasing returns or comparative

² This is about twice as large as the reduction in tariffs in the developed countries since the early 1950s.

advantage. Our point is that regardless of the driving forces and regardless of the underlying motive for specialization, *vertical* specialization matters a great deal.³

To illustrate this we develop a model that extends the basic Ricardian model. There are two stages of production for each good. Each country has a technology for producing either or both stages. Each good can be produced by one of four methods, representing different combinations of the stages and the countries. In the model, under a broad range of tariffs final goods are traded, but there is no vertical specialization. This is because of the ‘back and forth’ nature of vertical specialization: the intermediate goods are taxed twice.⁴ At a critical threshold level of trade barriers, both traded and non-traded goods that were previously made within one country have their production process broken up. One stage of production is now re-located, or outsourced, to the other country. For example, the first stage might now be produced at home, exported to the other country, and then re-imported as a final good. These effects lead to a non-linear surge in trade. Further reductions in trade barriers lead to more vertical specialization, and this increase can match the actual growth in trade.

There are two main welfare implications from our research. If the standard trade models employ the high elasticities needed to match the increase in world trade, the welfare gains are small, probably even smaller than the small gains the computable general equilibrium models already imply. Because our model can capture the growth in world trade with smaller elasticities, the gains from trade in our model are higher. Second, the layered production nature of vertical specialization provides additional gains from trade beyond the usual gains from horizontal specialization. Instead of specializing in particular goods, countries can also specialize in particular stages of the goods.

Section II conducts our tariff experiments with the existing international trade and macro models. Section III defines vertical specialization and relates it to outsourcing and vertically

³ In recent years, developments in macroeconomics and international trade question whether technological improvements and lower tariff rates can be thought of as exogenous. Rather, the perspective of endogenous growth theory and the political economy of protectionism literature is that innovations to transportation and communications technologies are the results of decisions taken by profit maximizing firms, and that lower trade barriers are the equilibria of a game involving political parties and constituents. Devereux (1992) develops a model with endogenous growth and endogenous protection. Even if technological innovations and tariff reductions are explicitly modeled, we argue that vertical specialization is still important as a propagation mechanism.

⁴ Corden’s (1966) development of measures of effective protection are based on this feature of models with vertical specialization.

integrated multinationals. Section IV contains our case study evidence. In Section V, we present our model of vertical specialization. Section VI discusses the implications of increased vertical specialization and offers extensions to the research.

II. CAN STANDARD TRADE MODELS EXPLAIN THE GROWTH IN TRADE?

We know that manufactured export growth has exceeded manufactured output growth by 3% per year for almost 50 years. Can the standard, workhorse models in international trade and international macroeconomics explain this growth? We examine whether the Ricardian trade model, the basic monopolistic competition model, and an international real business cycle model can generate the manufactured export share growth rate. For each model we simulate reductions in tariffs rates corresponding to the post-World War II reduction of trade barriers, and then calculate the implied increase in trade.

More specifically, we assume that the models apply to the manufacturing sector only. We can operationalize this assumption in a general equilibrium context by assuming that preferences and technology are separable between manufacturing and non-manufacturing, and that non-manufacturing goods are intrinsically non-tradable. We are agnostic about whether the forces driving the increase in trade were political (tariffs and other trade barriers) or technological (transportation and communications costs). But proportional tariffs are convenient to implement across all three models.⁵ In the dynamic trade model, we assume tariff revenue finances lump sum transfers. In the two static trade models, we assume the tariff revenue finances government purchases that generate no productive or consumption value to the private sector. In this case, tariffs operate in the same way as ‘iceberg’ transportation costs. According to El-Agraa (1994) and Whalley (1985), tariffs on manufactured goods in the U.S. and other OECD countries have fallen by about 12-15 percentage points over the last 35-40 years; to include for reductions in transportation costs and non-tariff barriers, as well as improvements in communications technologies, we examine the effects of a bilateral decrease in tariffs from 25% to zero. To

⁵ Rose (1991) and Bergstrand (1996) are two formal empirical studies that address the causes of the growth of trade. Rose finds that lower tariff barriers are statistically and economically significant in raising trade among (only) small OECD countries. Bergstrand finds that both lower tariffs and lower transportation costs are significant.

calculate the annualized growth of export's share of GDP, we assume the tariff reductions take place over 35 years. We conduct our tariff experiments across several elasticities of substitution; elasticities of 1.5 and 2 are typically what is estimated in the literature and employed in large scale models.⁶

A. Ricardian Model

We use the Dornbusch, Fischer, and Samuelson (DFS, 1977) framework. There are a continuum of goods on the unit interval. Each good is produced from labor with constant returns to scale; the unit labor requirement differs across the two countries. Markets are perfectly competitive. DFS show that tariffs (and iceberg transportation costs) lead to a range of endogenously determined non-traded goods. As tariffs fall, that range narrows, leading to more trade. To obtain a quantitative estimate of the effects of lower tariffs in this model, we specify the following preferences and technologies. Preferences are given by:

$$U(c) = \int_0^1 \frac{c(z)^\theta - 1}{\theta} dz \quad 0 < \theta < 1; \quad U(c) = \int_0^1 \ln[c(z)] dz \quad \theta = 0 \quad (1)$$

$1/(1-\theta)$ is the elasticity of substitution between any two goods. On the technology side, we employ a specification related to what is employed in Eaton and Kortum (1997)⁷:

$$a(z) = 1 + z, \quad a^*(z) = 2 - z \quad (2)$$

$a(z)$ ($a^*(z)$) denotes the unit labor requirements in the home (foreign) country. The production technologies are mirror images of each other. We also assume the home and foreign labor forces are the same size. These symmetries imply that free trade yields relative wages = 1, $z = 0.5$ will be the cutoff determining specialization in each country, and the export share of GDP = 0.5.

The top half of Figure 2 shows the effects of a 25% decline in tariffs on the export share of GDP under several elasticities of substitution. When the elasticity is one (Cobb-Douglas preferences) the export share rises from 0.29 to 0.5. Over a 35 year period, this implies an annual growth rate of the export share of about 1.6 percent, which is only one-half of the actual growth rate of the manufacturing export share of output. The elasticity needs to be *five* to yield an annual growth rate on the order of 3 percent and higher.

⁶ See Marquez (1996) and Whalley (1985).

⁷ We also employ a technology similar to that in Djankov, Evenett and Yeung (1996), in which $a(z) = 2$ and $a^*(z) = 1/z$. Our results are similar.

B. Basic Monopolistic Competition Model

We employ the Krugman (1980) ‘love of variety’ model. Each of two countries has one factor (labor) and can produce a number of goods with an increasing returns technology:

$$l_i = \alpha + \beta x_i \quad (3)$$

l is labor, α is the fixed cost, β is the marginal cost and x is the amount of output. The number of goods produced n is endogenous and depends on the interplay of free entry and the zero profits condition with profit maximization in a monopolistic competition setting. The utility function is:

$$U(.) = \sum_{i=1}^n c_i^\theta, \theta < 1. \quad (4)$$

$1/(1-\theta)$ is the elasticity of substitution (and demand) between goods and $1/\theta$ is the firms’ gross markup. We again assume that the size of the labor force in the two countries is identical.

Tariffs do not affect the number of goods produced or output of each good. They only affect the level of imports and exports, and their tariff inclusive relative prices. When tariffs fall, the fraction of spending on imported goods increases; this is driven primarily by substitution effects.

The bottom half of Figure 2 shows the results of our tariff experiment across eight different elasticities. An elasticity of two implies that the annualized growth rate of the export share is just 0.44% per year. Only elasticities on the order of *six and seven*, which imply growth rates of 2.8% and 3.5%, respectively, can replicate the manufacturing export share growth rate.

C. International Real Business Cycle Model

Our model draws from Backus, Kehoe, and Kydland (BKK, 1994), which is a two-country real business cycle model in which home and foreign goods are imperfect substitutes. We solve the deterministic steady-state version of the BKK model modified to include for tariffs on imports. In this model tariff reductions have additional propagation effects, beyond the usual static channels, through endogenous capital accumulation.

The model is presented in detail in BKK, so we only summarize its features here. Preferences for the representative agent in the home country are characterized by:

$$\sum_{t=0}^{\infty} \beta^t U(c_t, 1 - n_t) \quad (5)$$

where $U(c,1-n) = [c^\mu(1-n)^{1-\mu}]^{1-\gamma}/(1-\gamma)$, and c and n represent consumption and hours worked. Each country produces a distinct good. The home good production function is:

$$Y_t = A_t K_t^q n_t^{1-q} \quad (6)$$

A and K represent total factor productivity and capital. Output can be used domestically (D) or it can be exported (X). The equilibrium condition for home output is:

$$Y_t = D_t + X_t \quad (7)$$

The domestic output and the imported output are combined via an Armington aggregator to produce a non-traded final good that is used for consumption and investment:

$$C_t + I_t = [w_1 D_t^{1-\alpha} + (1-w_1) X_t^{*1-\alpha}]^{1/(1-\alpha)} \quad (8)$$

where $\alpha \geq 0$ and the asterisk denotes the imported good (foreign country's exported input). $1/\alpha$ is the elasticity of substitution between domestic and imported goods. The export share of GDP is given by: X_t/Y_t . Capital is accumulated in the standard way:

$$K_{t+1} = (1-d)K_t + I_t \quad (9)$$

We assume all proceeds from the tariffs are returned as lump sum transfers:

$$p_t \tau X_t^* = TR_t \quad (10)$$

where p is the relative price of the imported good in terms of the domestic good, τ is the tariff rate, and TR are transfers. Net foreign assets are accumulated in the standard way. Finally, we assume an initial and final net foreign asset position of zero. The set up for the foreign representative agent is symmetric. Appendix I details the parameterization of the model, which follows BKK and King, Plosser, and Rebelo (1988).

Table 1 presents the results of our tariff experiment for several elasticities of substitution. The table shows that the elasticity of substitution between home and foreign goods needs to be *eight* to match the growth in the manufacturing export share. In Appendix I we note that simulating the stochastic, dynamic, incomplete markets version of the model implies an even higher elasticity, *ten*, needed to match manufactured export share growth.

III. VERTICAL SPECIALIZATION

The usual notion of specialization is *horizontal* specialization - firms or countries specialize in producing from scratch different final goods and services, for example. However, we argue that a key mechanism in the growth of world trade is *vertical* specialization. When a) goods are produced via multiple sequential stages, b) countries specialize in some, but not all, stages, and c) at least one stage crosses a national border more than once, we call this vertical specialization.⁸ In other words, vertical specialization occurs when a country uses imported inputs to produce goods that are then exported, or alternatively, when the rest-of-the-world exports intermediate goods that are used to produce goods it imports. For two countries, and a particular final good like automobiles, vertical specialization-based trade is equal to **the sum of: Each country's parts (intermediate inputs) imports multiplied by the fraction of vehicles produced (output) that is exported multiplied by two.**

The multiplication by two captures the fact that the parts cross the border twice, once as a parts import and once embodied in a vehicle export.

Consider a two-country world. The share of trade that is vertical specialization-based trade would be 0% if neither country exports goods relying on imported intermediate inputs. Assuming there is no other trade, it would be 50% if, for example, each country imports inputs equal to one-third of gross output and exports 100% of the output, or if each country imports inputs equal to one-half of gross output, and exports 50% of the output. It would be 100% if each country adds an infinitely small amount of value to the imported inputs, and then exports 100% of its output. (In the latter case each country's GDP would arise from producing intermediates).

From the above it should be clear that not all trade in intermediate goods involves vertical specialization. If intermediates are imported to produce a final good that is not exported, there is no vertical specialization; rather, this is an example of the usual horizontal specialization. On the other hand, final goods trade can involve vertical specialization if some of the inputs to the final goods are imported.

⁸ Balassa (1967, p. 97) was perhaps the first to coin the term 'vertical specialization'. His definition encompasses a) and b), but not c), of our definition.

Vertical specialization is related to, but distinct from, outsourcing, an important topic that has garnered much recent attention in both the academic and popular literature.⁹ While definitions of outsourcing vary, we view outsourcing as the *re-location* of one or more stages of production that were formerly produced at home. Technology transfer can be part of the re-location, as well. A key difference between the two is that vertical specialization, but not outsourcing, is always associated with an increase in trade. For example, when Honda's U.S. plants, which rely heavily on imported inputs, export a greater fraction of vehicles to Japan, vertical specialization has increased, but outsourcing has not. On the other hand, when Mercedes Benz builds a factory in the U.S. to produce solely for the U.S. market, outsourcing has occurred, but vertical specialization has not, even if Mercedes uses imported inputs. Third, when Samsung sets up a television plant in Tijuana, Mexico, and this plant imports inputs from Asia and exports most of its production to the U.S., both vertical specialization and outsourcing have occurred.

How does vertical specialization relate to vertically integrated multinationals (MNC) and vertical foreign direct investment (FDI)? These concepts are linked by the issue of where to locate different stages of production. Indeed all of our case studies involve vertical multinational activity. We also suggest in Appendix II that the types of industries that multinationals are engaged in - manufacturing, especially chemicals, machinery, and equipment - are the industries in which vertical specialization-based trade occurs.¹⁰ Nevertheless these concepts are distinct. Like outsourcing, vertical MNC and FDI are not necessarily associated with an increase in trade. Indeed, the total U.S. multinational share of U.S. trade has declined from 1977 to the present.¹¹ In addition, while vertical MNC and FDI creates intra-firm trade in intermediate inputs, we noted above that trade in intermediate inputs is not sufficient for vertical specialization-based trade. All three of our examples above are examples of vertical MNC and FDI, but only the last example involves vertical specialization-based trade. Intra-firm trade in intermediate inputs is also not

⁹ See Feenstra and Hanson (1995), Kim and Mieszkowski (1995), Slaughter (1995), and Glass and Saggi (1996). Most of these models address the wage inequality debate.

¹⁰ In 1989, chemicals and allied products, machinery, and transportation equipment accounted for about 60% of manufacturing multinational gross product and about 35% of total multinational gross product. See Mataloni and Goldberg (1994).

¹¹ Zeile (1993,1995) shows that U.S. affiliates of foreign multinationals are becoming increasingly important; their share of U.S. business GDP has risen from about 2% in 1977 to over 6% in 1993. Their share of U.S. trade has been increasing as well. U.S. affiliates of foreign multinationals tend to rely more on imported inputs than do U.S. multinational parents. The foreign multinationals, however, only partially offset the declining U.S. multinational share of trade, so that the overall U.S.+foreign multinational share of U.S. trade has still declined.

necessary for vertical specialization-based trade. By most definitions, Nike, for example, is not a vertical MNC with intra-firm trade because the footwear production occurs through arms length relationships. Yet, to the extent the producing firms import Nike services and other inputs, and export the footwear, vertical specialization-based trade occurs.

IV. EMPIRICAL EVIDENCE: CASE STUDIES

A review of trends in trade certainly suggests that vertical specialization has increased. At the aggregate level, we know that countries with export shares of GDP > 1 , like Hong Kong and Singapore, must have vertical specialization-based trade. Other small countries like Belgium, Ireland, Luxembourg, Malaysia, and Netherlands by now have export shares close to one. Because of the large presence of non-traded goods in GDP, it can be argued that any country whose export shares are greater than $1/3$ must have a good deal of vertical specialization.¹² The number of OECD countries fitting this criteria has increased from five in 1962 to twelve today.

To the extent that vertical specialization-based trade is linked to MNC vertical integration, and to the extent the latter is driven by factor cost considerations, one might expect to see increased trade between rich and developing countries. Appendix II (Table A.1) shows that this is indeed the case. The share of Latin American, South and South East Asian manufactured exports to developed market economies rose from 2.6% to 10.3% between 1970 and 1992. The share of developed market economies' manufactured exports to these countries increased, as well.

In Appendix II, we further discuss trends in disaggregate trade data; here we overview the main results. From industry level data we know that export shares and imported input shares have been increasing over time. Appendix II (Tables A.2 and A.3) provides export share evidence for several rich and developing countries. These shares have been increasing in manufacturing, generally, and in machinery and equipment, in particular. Export share growth accounting decompositions for these countries, also listed in Appendix II (Tables A.5 and A.6), show that machinery and equipment, along with chemicals, account for over 80% of the increase in manufactured exports, and about 50% of the increase in overall exports between the 1970s and the 1980s. In the rich countries, these sectors account for only about 40-50% of manufacturing

¹² See Krugman (1995).

value added and only about 10% of overall GDP. These industries produce goods which require many sequential stages of production and it is natural to expect vertical specialization to occur in them.

While the aggregate and disaggregate data are suggestive of vertical specialization, much of these data are consistent with horizontal specialization, as well. The direction-of-trade evidence only really tells us that developing countries in Latin America, and South and South East Asia increasingly trade manufactured goods. In any event the lion's share of manufactured trade continues to be between developed market economies; this trade is usually presumed to be a result of horizontal specialization. Second, it is possible for export shares to increase through horizontal specialization; countries could be specializing in increasingly fine subsets of industries. Third, each industry produces different goods at different stages of production. While the industry could have increasing imported input and exported output shares, it might be the case that the imported inputs are used to produce goods that are not exported, and the exported goods are produced solely from domestic intermediates. In the extreme, it is possible for an industry to have no increase in vertical specialization-based trade even with growing shares of imported inputs and exported outputs. Finally, the accounting decompositions prove conclusively only that specialization has increased; again, we cannot infer whether horizontal or vertical specialization has increased.

These aggregation problems are not present in our case studies. In each case we can accurately measure the quantitative significance of vertical specialization. Our calculations are, if anything, underestimates of vertical specialization-based trade. Appendix III provides additional details on data sources for each case study. Appendix III also provides an additional case study on Hong Kong - China trade.

Case Study 1: 1965 U.S.-Canada Auto Agreement

Prior to the 1965 U.S.-Canada Auto Agreement there was virtually no auto trade between the two countries. Tariffs between the two countries were high: 17.5% on Canadian automotive imports from the United States and 6.5% to 8.5% on U.S. automotive imports from Canada. Canadian auto producers (affiliates of GM, Ford, Chrysler, and AMC) produced exclusively for the Canadian market, and almost all vehicles sold in Canada were also produced there. The 1965

agreement reduced the tariffs facing producers to zero.¹³ Now viewing the U.S. and Canada as one integrated market, U.S. auto companies immediately consolidated production. In Canada production was narrowed to just a few models with the output serving the entire market. Figure 3 shows that in just four years auto trade soared, the percentage of Canadian vehicle production exported to the United States increased from 7% to 60%, and the percentage of the Canadian automobile market consisting of imported cars increased from 3% to 40%.¹⁴ Figure 3 also shows that the share of automobile trade in total bilateral trade rose immediately from approximately 8% to 30%.¹⁵

On the face of it, this experience seems like a textbook example of horizontal specialization driven by economies of scale and increasing returns. Nevertheless the basic data provide a hint that vertical specialization also occurred. Currently, 60% of U.S. auto exports to Canada are engines and parts (1994), while 75% of U.S. auto imports from Canada are finished cars and trucks (1995). To proceed further, we use data from Ward's Automotive Yearbook, the United Nations (UN) trade database, and the Bureau of Economic Analysis (BEA) to estimate the level of U.S.-Canada vertical specialization-based trade following the Auto Agreement. The U.N. and BEA trade data distinguish between parts trade and vehicles trade, which is key to our calculations. Our calculation has two steps. Prior to the agreement virtually all trade consisted of engines and parts, which we conservatively attribute entirely to the repair market. Because this trade is not vertical specialization-based, in our first step we estimate trade in the repair market from 1965 to the present, and subtract that from the raw trade numbers. We calculate the ratio of U.S. parts imports from Canada (and the ratio of Canada parts imports from the U.S.) to total U.S. auto and truck output in 1964, and then assume that the ratios stay constant over time. Then repair parts trade in future years can be estimated by multiplying these ratios by U.S. auto and

¹³Economic Council of Canada (1975, p. 197). The agreement included two important restrictions: total production in Canada had to roughly match total sales in Canada and 60% of the value added in Canadian-made cars had to be of Canadian origin. See Wonnacott and Wonnacott (1967). It is reasonable to think that removal of these restrictions would have led to even more vertical specialization-based trade, if we take the presence of the Big Three's affiliates in Canada as given.

¹⁴Beigie (1970, pp.4-5).

¹⁵U.S. vehicles, engines, and parts exports to Canada as a fraction of total exports to Canada increased from 13% in 1964 to 30% in 1968. U.S. vehicles, engines and parts imports from Canada as a fraction of total imports from Canada increased from under 3% in 1964 to about 30% in 1968. Today, engines and parts account for about 40% of U.S./Canada automotive trade. Total U.S. trade in vehicles, engines, and parts relative to U.S. auto and truck

truck output in those years. We subtract these estimates from the actual parts trade numbers; the difference is our estimate of the increase in parts trade destined for auto assembly due to the Auto Agreement. In our second step, we apply the definition given in the previous section:

Vertical specialization-based trade induced by the Auto Agreement =

$$2\{[\text{increase in Canada parts imports}][\text{fraction of Canada vehicle production exported to U.S.}] + [\text{increase in U.S. parts imports}][\text{fraction of U.S. vehicle production exported to Canada}]\}$$

The fraction of Canadian production exported to the U.S. is currently about 80-90%. By contrast, only a small fraction of U.S. production is exported to Canada; this means that our estimates of vertical specialization-based trade are primarily driven by the Canadian imported inputs-cum-exported outputs. Figure 4 illustrates the percentage of total auto trade that is vertical specialization-based trade induced by the Auto Agreement from 1965 to 1994. Within six years, vertical specialization due to the Auto Agreement was more than 20% of total auto trade. Vertical specialization has continued to trend upwards. In recent years, over 40% of auto trade, or about \$30 billion, has been a result of vertical specialization induced by the Auto Agreement. Vertical specialization has been almost as important as horizontal specialization.

Further evidence of the importance of vertical specialization-based trade is provided by the Grubel- Lloyd (GL) intra-industry trade index. The index gives the proportion of total trade that is intra-industry trade and it ranges from zero to one:

$$\frac{\sum_i \alpha_i + M_i - |X_i - M_i|}{\sum_i \alpha_i + M_i} \quad (11)$$

X and M denote exports and imports, i indexes the industry. We compute the index using 3-digit Standard International Trade Classification (SITC) rev. 1 data on U.S.-Canada trade. This is shown in the left column of Table 2. The sharp increase in the index reflects the surge in intra-industry auto trade following the agreement. We also compute an adjusted GL index where we subtract our estimates of vertical specialization-induced auto trade from overall auto trade. Comparing the un-adjusted and adjusted GL indices in Table 2, we can see that the increase in the adjusted index between 1965 and 1970 is about 17% less than the increase in the un-adjusted

output increased from 9% in 1960 to 61% in 1994. Engines and parts alone account for more than 45% of total trade.

index. Recall that in 1970 about 20% of auto trade, or about 6% of overall U.S.-Canada trade, was vertical specialization induced by the Auto Agreement. This means that the effect of vertical specialization on intra-industry trade was about three times larger than its proportion in overall trade.

Case Study 2: U.S.-Mexico Maquiladoras Trade

Mexico's maquiladoras have allowed U.S. firms to capitalize on vertical specialization by outsourcing a large percentage of the assembly of manufactured goods. Maquiladoras are foreign-owned production plants that complete processing or secondary assembly of imported components for re-export.¹⁶ Maquiladoras benefit from Mexican laws excusing from Mexican tariffs parts and materials imported by Mexico for use in maquiladoras. U.S. firms that use maquiladoras receive favorable tax treatment also from the United States.¹⁷ Under this law, the U.S. components of maquiladora-made goods re-exported to the United States are exempt from tariffs. Consequently, the only part of the two-way transaction that is dutiable is the Mexican value added (wages, domestic materials, rents, and utilities) in the goods re-exported to the U.S.

The principal maquiladora industries include electric/electronics, transportation equipment and textiles. These three industries employ more than 73% of all maquiladora workers and account for 81% of total maquiladora production. The electric/electronics industry is the largest, accounting for almost half of total maquiladora production in 1994. The transportation sector has grown the fastest in recent years, increasing its share of employment from 10% in 1982 to 22% in 1995.

From its inception in 1965 until the early 1980's, maquiladora growth was steady but not striking. Propelled by the increased priority given to them by the de la Madrid administration, maquiladora growth took off in the mid-1980's. From 1985 to 1994, employment growth in maquiladoras averaged 11.6% per year, and in 1995 over 600,000 workers were employed. Increases in gross production were equally striking, with an average annual growth of 18.3%

¹⁶The vast majority of maquiladoras are owned by United States firms, although there is increasing ownership by firms from other countries, such as Japan, Korea, and some European nations.

¹⁷Harmonized Tariff System (HTS) items 9802.00.60 and 9802.00.80. These were formerly known as items 806.30 and 807.00 of the Tariff Schedule of the United States (TSUS). Item 9802.00.60 concerns tariff treatment for metal of U.S. origin processed in a foreign location and returned to the U.S., while Item 9802.00.80 involves goods that contain U.S. - made components. (Hufbauer and Schott, (1992) p. 93).

during the same period; in 1995 gross production was \$25.8 billion.¹⁸ The growth in production has been accompanied by strong growth in total trade between the United States and Mexico, especially since 1982, as Figure 5 indicates. By the late 1980's, U.S. maquiladora imports represented 45% of total U.S. imports from Mexico and about 60% of total non-oil imports.¹⁹

Our maquiladora data includes imported inputs and gross production. In addition we know that almost all imported inputs are from the U.S. and almost all production is exported to the U.S. We assume that these percentages are 100%.²⁰ Our calculations follow the formula given in the previous case study, except we note that the maquiladoras cover only one direction of vertical specialization. We do not have data on U.S. imported inputs from Mexico which are used to produce goods exported back to Mexico. Figure 5 shows that between 1975 and 1979, the percentage of total U.S.-Mexico trade attributable to maquiladora vertical specialization-based trade averaged about 22% per year. The following decade saw an increase to about 31%; and in first half of the 1990's, approximately 40% of total trade was due to vertical specialization. Currently, this represents about \$35 billion. Because there is surely non-maquiladora vertical specialization-based trade, it is likely that more than half of U.S.-Mexico trade is due to vertical specialization.

Our first two case studies deal with bilateral relationships. However, vertical specialization-based trade can occur when country A exports goods to country B, which uses them as inputs to produce goods that are exported to country C (and possibly country A). Our second two case studies have this geography.

¹⁸ Much of the data that follows originate from Instituto Nacional de Estadística, geografía e Informática (INEGI). We thank Lucinda Vargas-Ambacher for providing us with this information. Hanson (1996) draws from this data, as well.

¹⁹ Hufbauer and Schott, pp. 96-97.

²⁰ Over the last decade, various provisions have been passed in attempts to alter the amount of maquiladora output sold domestically. Two provisions eased restrictions and one tightened restrictions on the amount of output that could be sold in Mexico. While there are no hard figures on the results of these rule changes, through anecdotes of factory managers in Mexico it seems that virtually all of production is still exported to the U.S. See Wilson (1992), pp. 40-41; also, we thank Lucinda Vargas-Ambacher for providing us with this information.

Because of the presence of non-U.S. owned firms in the maquiladora industry, it is likely that some of the inputs imported by Mexico are from non-U.S. sources. For example, in 1989, approximately 4% of maquiladoras were Japanese or Korean owned. These non-U.S. firms often establish the Mexican plants as a way to export products to the U.S. efficiently by cutting delivery times and capitalizing on inexpensive labor. (Hufbauer and Schott, 1992). On the other hand, a majority of Japanese and Korean maquiladoras are operated through their U.S. subsidiaries. Hence, it is likely that the amount of imported inputs from non-U.S. sources is small.

Case Study 3: Japan-Asia Electronics Trade

In an effort to reduce costs, many of Japan's manufacturing industries have been rapidly outsourcing different stages of production, especially final assembly, to Southeast Asia and other countries. Currently two-thirds of Japanese offshore electronics production facilities are located in just nine developing Asian countries. Using data obtained from the Electronic Industries Association of Japan and the Japan Electronics Bureau, we show patterns of production and exports for the Japanese electronics industry between 1985 and 1995 in Figure 6. The export share of components has increased, while the export share of equipment has remained virtually constant or even decreased during this period. Developing countries in Asia have played an increasingly significant role in the rising importance of components. Exports of components and devices to Asia now account for over three-fourths of all exports to Asia, over half of all exports of components and devices, and over one-third of total electronics exports.

These components are used primarily for production of more complicated components or final goods such as VCRs and color televisions. Offshore employees now account for almost 40% of total Japanese electronics industry employees; this is up from just 25% in 1989. It is no surprise, then, that offshore production has surpassed domestic production in both color televisions (1988) and VCRs (1994). Most of this offshore production is then exported back to Japan or to third countries such as the U.S.

To estimate the amount of vertical specialization-based trade induced by the industry's relocation of production, we make two assumptions. We assume that all Asian electronic components imports from Japan are used as inputs for further production. Wells (1993) reports that Japanese electronics subsidiaries in Indonesia export 71% of their production. Our second assumption is that this percentage applies to all Asian countries with Japanese subsidiaries. Under these assumptions vertical specialization-based trade is equal to:

$$2[\text{Exports of components to Asia}][0.71]$$

The bottom of Figure 6 shows that in the last ten years vertical specialization-based trade due to the Japanese electronics industry has almost quadrupled in yen terms and risen by a factor of nine in dollar terms; it is now on the order of \$55 billion. By contrast total electronics exports from Japan during this period increased by only 23% in yen terms and by about 81% in dollar terms.

Case Study 4: Opel España

Opel is General Motors' affiliate for continental Europe. Anticipating Spain's entry into the European Union, Opel began operations in Spain in 1982. As of 1994, Opel España produced about 22% of Spain's total production of 1.8 million passenger cars.

From the beginning, Opel España was an important participant in vertical specialization-based trade, relying heavily on imported inputs to produce final vehicles and other parts, most of which are exported. We have obtained Opel España data on net sales of vehicles and parts, exports of vehicles and parts, and imported parts for 1983 to 1995. As with the two previous case studies we can account for vertical specialization in only one direction: Opel España imports inputs, and uses them to produce goods that are then exported. It is likely that vertical specialization-based trade in the other direction is also significant. Using this data, we estimate the amount of Opel España's vertical specialization-based trade to be significant and increasing: \$0.6 billion in 1983, \$1.8 billion in 1993, \$2.7 billion in 1994, and \$3.6 billion in 1995.

All auto companies in Spain are affiliates of other American or European corporations (Ford, Renault, etc.). These companies export a somewhat smaller fraction of their passenger car production than Opel España, about 70% versus 90%. Using Opel España's market share of 22%, and assuming that these other companies rely on imported inputs to the same degree as Opel, we can estimate Spain's total vertical specialization-based traded in autos: $3.6 + 3.6*(.7/.9)*(.78/.22) = \13.5 billion in 1995, (\$6.8 billion in 1993 and \$10.2 billion in 1994). This compares against total Spanish auto trade in 1993 of about \$21 billion and in 1994 of about \$25 billion (no data is available for 1995). At least 40% of Spanish auto trade is vertical specialization-based trade.

Case Study Summary

Our case study evidence shows that vertical specialization exists between developed countries, as well as between developed and developing countries. It involves countries whose industry level export shares of output have been increasing. It shows that there is a significant amount of 'back-and-forth' trade within autos and electronics. Finally, all the case studies involve machinery and equipment, in particular, and manufacturing more generally, which are the accounting sources of trade growth. The case study evidence, then, suggests a new interpretation of the inconclusive aggregate and industry-level evidence highlighted earlier; that evidence does

indeed reflect vertical specialization-based trade. The case studies are not special, but representative.

V. STYLIZED MODEL OF VERTICAL SPECIALIZATION

To explain the growth in trade, standard static and dynamic models of trade need to employ elasticities of substitution between home and foreign goods on the order of five to ten, which are much higher than what is typically employed and estimated in the literature. In this section, we present a stylized Ricardian model of vertical specialization that nests the DFS Ricardian model as a special case. We show that this model can explain the growth in trade with an elasticity of just one.

There are two countries, one factor of production, and a continuum of goods on the unit interval. Utility is given by (1). Production of each good requires two stages.²¹ For the home country, first stage output is given by

$$Y_1(z) = L_1(z)/a_1(z), \quad z \in [0,1] \quad (12)$$

where the subscripts denote the stage. $a_1(z)$ is the unit labor requirement for stage one. In the second stage, output from the first stage is combined with labor to produce the final good. We assume a Leontieff relation between the second stage inputs:

$$Y(z) = \min[Y_1(z), L_2(z)/a_2(z)]. \quad (13)$$

The above technology applies if both stages are made at home. In this case, the production function reduces to the usual formulation:

$$Y(z) = L(z)/a(z), \text{ where } L(z) = L_1(z)+L_2(z), \text{ and } a(z) = a_1(z) + a_2(z). \quad (14)$$

If both stages are made in the foreign country, the production functions are similar. Asterisks (*) denote foreign outputs, unit factor requirements, and labor supplies.

Now suppose stage 1 is produced at home, and stage 2 is produced abroad. Then, second stage production is:

$$Y^*(z) = \min[Y_1(z), L^*_2(z)/a^*_2(z)]. \quad (15)$$

²¹ Our model formalizes some of the discussion in Jones and Kierzkowski (1990). There are other models of vertical specialization related to the DFS model. Among the first were Dixit and Grossman (1982) and Sanyal (1983). In these models, there are only two goods, but a continuum of stages for at least one of them. Some of the

Similarly, stage 1 could be produced abroad, and stage 2 at home. All together, there are four possible production techniques for each good. Vertical specialization occurs when goods produced according to either of the latter two techniques are exported.

Analogous to DFS, we order the goods according to declining home country comparative advantage in stage 1. For convenience, we make two additional assumptions:

A1] The comparative advantage ordering is the same in stage 2 as it is in stage 1.

A2] The home country is always relatively more productive in stage 1 production.

Figure 7 illustrates our assumptions under free trade. $A_i(z) = a^*_i(z)/a_i(z)$ is the ratio of the foreign to the home unit labor requirements in stage i . If $A_1(z) = A_2(z) \forall z \in [0,1]$, then the model reduces to the standard DFS model. Assumption A2 means that vertical specialization will occur in just one ‘direction’ - only one country will import intermediate inputs, produce, and then export some of the output; this assumption reduces the trade effects of vertical specialization, but it is consistent with three of our case studies.

With these assumptions and under free trade, the model implies that there will be two critical levels of z (z_l, z_h) that divide the unit interval into 3 regions:

1] Home country produces both stages: $[0, z_l]$

2] Home country produces 1st stage, exports it to foreign country, which produces 2nd stage (vertical specialization region): $[z_l, z_h]$

3] Foreign country produces both stages: $[z_h, 1]$

It is easy to see that trade is higher in this model than in the standard DFS model. If the elasticity of substitution is 1, then free trade yields an export share of $GDP = 1 - z_l$. The fraction of trade due to vertical specialization is given by:

$$2 \int_{z_l}^{z_h} (z)c(z)dz / [2(1 - z_l)wL] \quad (16)$$

where the integral in the numerator is the value of home exports of stage one production that will be re-imported as final goods, L is the endowment of labor and w is the home country wage.

Tariff rates are introduced to the model as in section II. Tariffs create ‘wedges’ around each free trade critical level of z so that there are now four critical levels to solve for. It is

recent models of outsourcing and vertical FDI are related as well. However, these models do not address the growth of trade nor do they nest the basic DFS model as a special case.

necessary to distinguish between goods or stages the home country makes for home consumption and goods or stages the home country makes for foreign consumption, and similarly for the foreign country. Tariffs raise the cost of vertical specialization by relatively more than they raise the cost of horizontal specialization, because in the vertical case, tariffs eat away at the first stage of production twice - once when the first stage is exported to the foreign country, and once when the final good is imported back to the home country. Hence, tariffs reduce the range of vertical specialization more quickly than it reduces the range of horizontal specialization. If tariffs are high enough, vertical specialization does not occur at all, and the model becomes essentially the standard DFS model with tariffs.

Assume that tariffs are initially very high so that only final goods are traded and there are some non-traded goods. Now let tariffs fall gradually to zero. At first, trade increases because the range of non-traded goods shrinks. For some range of tariffs, horizontal specialization occurs, but vertical specialization does not. As tariffs continue to fall, however, a critical tariff rate will be reached at which vertical specialization starts to occur. The home country will then start specializing in stage one production, and the foreign country on stage two production. Trade jumps because intermediates good trade now adds to final goods trade.

To obtain numerical estimates of the effects of lower tariff rates, we conduct the same tariff experiment (25 percentage point bilateral tariff reduction over 35 years) as before. We let (2) represent the production functions if both stages were produced in one country. We specify stage one and stage two production as follows:

$$\begin{aligned}
 a_1(z) &= (1+z)/(1+k) & a^*_1(z) &= k(2-z)/(1+k) \\
 a_2(z) &= k(1+z)/(1+k) & a^*_2(z) &= (2-z)/(1+k) & k \geq 1 & (17)
 \end{aligned}$$

We examine two cases of k , $k = 1.5$ and $k = 1.9$, corresponding to ‘some’ and ‘high’ gains to vertical specialization. Again, $k = 1$ corresponds to the standard DFS model of section II.

Figure 8 illustrates the results when the elasticity of substitution = 1. For comparison, the results from the DFS model for two elasticities of substitution are illustrated as well; they are labeled ‘elasticity = 1’ and ‘elasticity = 5’. In the ‘some’ gains case, vertical specialization occurs after tariffs fall below 25%; in the ‘high’ gains case vertical specialization has already occurred at the initial 25% tariff rate. When vertical specialization occurs the export share of GDP sharply

increases. In the ‘some’ gains case, for example, when tariffs fall from 25% to 17.5% the export share increases by only about 20%, which is the same implication delivered by the DFS model. But when tariffs fall from 17.5% to 10%, vertical specialization occurs, and the export share rises by about 70% (versus 18% in the DFS model). The implied annual growth rates of the export share are 2.9% and 2.8%, respectively, and under free trade, vertical specialization represents 37.5% and 48.2% of total trade, respectively. This is approximately double the implied growth rate in the unitary elasticity case in the standard DFS model.

VI. DISCUSSION AND EXTENSIONS

Our empirical evidence establishes the importance of vertical specialization in accounting for the growth in trade’s share of output. Our theoretical evidence shows that standard trade models cannot explain trade growth without employing counterfactual elasticities of substitution. On the other hand, we show that a model with vertical specialization can explain trade growth with reasonable elasticities.

It matters whether a model employs low or high elasticities, because the implied gains from lower tariffs depend on the elasticities.²² For example, in the monopolistic competition model, elasticities of one-and-a-half or two imply that agents would need 14-15% higher consumption of every good, relative to free trade, to make the agent indifferent between tariffs of 25% and free trade. On the other hand, if the elasticity of substitution is ten, the consumption need only be 7% higher than the free trade level. From our calibration of the DFS model, if the elasticity of substitution is one, agents need 12% higher consumption to compensate them for tariffs of 25%. But if the elasticity of substitution is nine, agents only need 7% higher consumption to compensate them. Existing models can only rationalize the large growth in trade by implying small gains from such trade! Moreover, the gains from trade are larger with vertical specialization than without. In our model when the elasticity of substitution is one, agents need 20% higher consumption than the free trade level to compensate them for tariffs of 25% in the ‘some’ gains case, and 35% higher consumption in the ‘high’ gains case. Hence, our model provides two channels to produce relatively high gains from trade: first, it does not need high

²² Wei (1996) makes a case for using high elasticities - on the order of 10 - to assess the cost of home bias in trade.

elasticities of substitution to be consistent with the growth in trade, and second, it includes vertical specialization, which provides an additional source of gains from trade.²³

As mentioned earlier, other models of vertical specialization exist. Two sets of models that are of interest are the Ethier (1982) and the CGE models. Can these models also explain the increase in trade? A model in the spirit of Ethier (1982) would interpret equation (3) as the first stage of production. Then an equation like (4) converts outputs from the first stage into the final good. Imagine that each of two countries produces one distinct final good from identical production functions (3) and (4). Consumers value both goods with a CES utility function. It is not difficult to see that exports as a share of GDP would be higher in this model. In fact it is not difficult to parameterize the model so that exports as a share of GDP are twice as large as in the Krugman (1980) model. However, the *growth* rate of the export share in response to tariff reductions will be the same as in the Krugman model. Like the Krugman model, an Ethier-type model with vertical specialization cannot explain the growth in trade unless very high elasticities of substitution are assumed.

The models of Whalley (1985, 1986) and Deardorff and Stern (1986) are two important and widely used CGE models. Whalley (1985) simulates the effects of a U.S. reduction in tariff barriers from their mid-1970s levels to 0. The model predicts only a small increase in U.S. trade, on the order of \$10 billion or about 0.5% of GDP. Deardorff and Stern (1986) simulate a tariff reduction of approximately 2.5-5 percentage points, and this leads to only a 2.5% increase in exports. In these two cases, if we assume that these tariff reductions take several years to be implemented, the implied annualized growth rate of trade is quite low, far lower than what even the models of section II would imply.²⁴ Finally, Kouparitsas (1997) develops a dynamic CGE

²³ However, the trade growth that ensues with vertical specialization actually overstates these gains. This is because the multiple border crossings associated with vertical specialization implies double-counting in trade flows. One of us is pursuing further research on the extent of double counting.

²⁴ Markusen and Wigle (1990) use the Whalley model to simulate the effects of global free trade; tariffs in the developed countries decrease by 5-10 percentage points on machinery and equipment. Also, they assume a rather high elasticity of substitution of three. This leads to about a \$180 billion increase in developed country trade with each other, equivalent to 2-3 percentage points of developed country GDP. To calculate the implied annualized trade share of GDP growth rates, we would need to know the increase in GDP. If GDP increases by even one percentage point, then the increase in the trade share is only about 1-2 percentage points, which would again imply a small annualized trade share growth rate.

In an interesting paper, Blonigen and Wilson (1996) show that the presence of foreign-owned affiliates in an industry is associated with higher estimates of the elasticity of substitution between domestic and foreign goods.

model, one of the first to combine the international real business cycle literature with the CGE literature. He simulates the effects of the North American Free Trade Agreement and finds the output and trade increases are “roughly twice as large as those predicted by the” static CGE models.²⁵ Even these increases are not large enough to replicate the observed increase in trade.

How do we explain the contrasting results from these models of vertical specialization with our model of vertical specialization? In our model trade and production patterns are determined endogenously. In the above mentioned models, some stages of production involve distinct, imperfectly substitutable, inputs, combined via the Armington aggregator; this virtually assumes the existence of trade. Hence, even with high trade barriers, vertical specialization exists. At tariff rates of 15-25%, these models imply that most of the growth in trade (and gains from trade) relative to autarky have already occurred. Further tariff reductions generate relatively small trade growth. In our model, however, there are two external margins, one from non-traded to traded final goods, and one from no-vertical specialization to vertical specialization. If this latter margin occurs at relatively low trade barriers, our model can capture the growth of trade when tariffs are reduced from 15-25%, as we have shown. These two ‘external’ margins, which we can think of as margins where outsourcing begins to occur, lead to non-linear increases in trade. Like the standard horizontal specialization models, vertical specialization models relying heavily on CES aggregators must use counterfactually high elasticities of substitution to explain trade growth.

We have worked out two extensions of our model. First, we solved a version of our model with endogenous capital accumulation. In steady-state the model has similar properties to our one-factor model.²⁶ Second, in Appendix IV, we solve a stylized dynamic model of vertical specialization and outsourcing in which the driving force is not tariff reduction, but lower fixed costs. Our results are similar.

Four further extensions would be useful. Implicit in our case study calculations is the assumption that final goods are produced through just two stages with at most two international

To the extent foreign affiliates of MNCs engage in vertical specialization, it is possible that the high elasticities employed, especially for machinery and equipment, may themselves be a sign of increased vertical specialization!

²⁵ Kouparitsas (1997) p. 21. Crucini and Kahn (1996) is another dynamic model with vertical specialization. In their model, tariff increases of 20 percentage points in both countries lead to declines in the export share of GDP of 8 percent.

border crossings. In other words, we assumed that parts become inputs into final goods. Many goods, of course, require more stages. For example, most of the Japanese offshore production facilities in Asia are components plants; they use imported components from Japan to produce and export more complicated components, which eventually find their way into final goods. Along the way, other countries' borders may be crossed. To the extent that goods production requires more than two stages, and more than two borders are crossed, it is likely that our vertical specialization-based trade calculations are under-estimates. These phenomena point towards conducting even more detailed case studies. In addition, it would be useful to construct broad country-wide measures of vertical specialization-based trade.

Theoretically, it would be useful to build a model of openness and growth in which the number of stages of production is endogenously determined. It is clear that goods today are more complex, requiring more stages of production, than in the past. Also, more countries are open to trade today than in the past. More stages and more countries provide more channels by which lower trade barriers and improved information technologies can lead to a greater trade share of GDP and greater gains from trade. We can use such a model to examine whether the ability to specialize in stages of production makes it easier for developing countries to join the high growth path. Finally, it would be useful to do a detailed comparison of trade growth during 1870-1913 to trade growth in the last half century. Gagnon and Rose (1990), Krugman (1995), and Irwin, (1996), among others, have noted that for many countries, the trade shares of GDP for most of the post-World War II era have not been high relative to their levels in the late 19th century. While both periods experienced unprecedented trade growth, it seems that the driving forces may have been different. For example, the relative importance of declining transportation costs was greater in the earlier period. In addition, vertical specialization might be more important in the present era. Comparing the driving forces and the propagation mechanisms from the late 19th century to those in the present era would tell us more about how the nature of production has changed, about the gains from trade, and about the linkages from openness to growth and from productivity growth to trade.

²⁶ See Baxter (1992) for a more formal discussion of how dynamic Heckscher-Ohlin models become Ricardian in steady-state.

APPENDIX I

International Real Business Cycle Model

1. **Parameterization:** Our parameters draw from BKK and King, Plosser, and Rebelo (1988); the parameters are adjusted to reflect the annual period length in our setting. The key parameter is the elasticity of substitution between the home and foreign good in the Armington aggregator, $1/\alpha$. We use $1/\alpha = 1.5$ as our benchmark case, (as in BKK), but we also examine the implications of higher elasticities. We set β , the discount factor, = .96. The share of consumption in utility, μ , is set to .25, which insures that $n = .2$ in the steady-state. The intertemporal elasticity of substitution, $1/\gamma = .5$. The depreciation rate on capital, $\delta = .1$. The coefficient on capital in the production function, $\theta = .42$. The initial steady-state level of net foreign assets, $B = 0$. We set w_1 so that the initial steady-state trade ratio is .42, which was the median trade ratio for the OECD countries in 1950.

2. **Stochastic, Dynamic, Incomplete Markets Version of Model:** We assume the four exogenous variables - the tariff rate and total factor productivity in both countries - follow a unit root process in their logarithmic deviations from the deterministic steady-state (with zero covariance across the shocks). We assume agents have access to one-period risk-free bonds; this is more realistic than assuming complete Arrow-Debreu contingent claims.

We solve the model using the familiar Blanchard and Kahn (1980) and King, Plosser, and Rebelo (KPR) (1988) linearization and solution techniques. These techniques involve log-linearizing the first order conditions and one (or more) of the equilibrium conditions of the model around the variables' deterministic steady-states. The resulting matrix of difference equations are solved according to well known formulas.

Given the initial steady-state of zero net foreign assets, we simulate the effects of a bilateral 25% reduction in tariff rates. Our results are even stronger than the deterministic, steady-state exercise in the text. Elasticities of substitution need to be *ten* to match the growth of the manufactured export share of output.

APPENDIX II

A. Export Shares of Value-Added Output. Tables A.2-A.3, A-5.

The left half of Table A.5 lists export shares of value-added output for manufacturing and non-manufacturing for the 1970s and 1980s for eight countries: United States, Japan, United Kingdom, Sweden, Canada, Australia, Korea, and Mexico. The sample includes large and small developed countries, and middle income developing countries. It is clear that manufacturing export share growth was much greater than non-manufacturing export share growth. Table A.3 shows that in Malaysia the manufacturing export share rose from 1.03 in 1986 to 2.14 in 1993.

We examine two-digit International Standard Industrial Classification (ISIC) manufacturing export share data spanning 1970 through 1990 for all countries except Malaysia. Table A.2 provides the export shares of value added output for initial and final years, as well as decade averages. Virtually all industries in all countries experienced export share increases over time, but this is especially true for ISIC 38, fabricated metal products, machinery, and equipment - hereafter ‘machinery and equipment’. Table A.3 shows that Malaysia has also experienced rising export shares in machinery and equipment. Between 1986 and 1993, the export share in electrical machinery rose from 3.54 to 4.84; In transportation equipment it rose from 1.08 to 1.86.

B. Export and Import Share Accounting Decompositions. Tables A.4-A.6

We proceed in two steps. We first calculate the contribution of manufacturing and non-manufacturing to the increase in the total export share of GDP between the 1980s (decade average) and 1970s (decade average) in our eight country sample and Malaysia. We then calculate the contribution of each of the 2-digit ISIC manufacturing industry export shares to the total increase in the manufacturing export share in our eight country sample. In both steps we employ the familiar within and between accounting. For example, for the first step calculations we have:

$$\frac{X_t}{Y_t} = \frac{\sum_i X_{it}}{\sum_i Y_{it}} = \sum_i w_{it} \frac{X_{it}}{Y_{it}} \quad (\text{A.1})$$

where X_t and Y_t are total exports and GDP in period t , i indexes manufacturing or non-manufacturing, X_{it} and Y_{it} refer to sector i 's exports and output, and w_{it} is sector i 's share of total GDP in period t . Next, note that:

$$\frac{X_{t+1}}{Y_{t+1}} - \frac{X_t}{Y_t} = \sum_i (w_{it+1} \frac{X_{it+1}}{Y_{it+1}} - w_{it} \frac{X_{it}}{Y_{it}}) \quad (\text{A.2})$$

Equation (A.2) shows how to decompose the change in the total export share into sectoral changes. We can further divide the contribution of each sector into a contribution due to changes in the sectoral export share (within), and a contribution due to the changes in the sectoral output share (between):

$$w_{it+1} \frac{X_{it+1}}{Y_{it+1}} - w_{it} \frac{X_{it}}{Y_{it}} = \left(\frac{X_{it+1}}{Y_{it+1}} - \frac{X_{it}}{Y_{it}} \right) \left(\frac{w_{it+1} + w_{it}}{2} \right) + (w_{it+1} - w_{it}) \frac{\left(\frac{X_{it+1}}{Y_{it+1}} + \frac{X_{it}}{Y_{it}} \right)}{2} \quad (\text{A.3})$$

The right half of Table A.5 presents the results of this decomposition, where the sectoral contributions given by equation (A.3) are converted into percentages of the change in the total export share. Three patterns emerge. First, in all six developed countries the change in the manufacturing export share accounts for more than 100% of the change in the total export share of GDP! Second, while every developed country - including Japan - experiences a decline in the manufacturing share of GDP, in four of the six countries the decline is more than offset by the increase in the manufacturing export share. For Canada, Japan, Sweden, and the U.S., manufacturing - responsible for only about 20-30% of GDP - accounts for over 60% of the increase in the total export share. Third, in Korea and Malaysia, manufacturing accounts for an even larger share of the increase in the total export share, but much of manufacturing's contribution is through an increase in the manufacturing share of GDP.

The results of the decomposition of the manufactured export share are in Table A.6. For brevity, we have combined ISIC industries, 31-33, 36-37, and 39 into one. We again see two patterns. In all eight countries, changes in the industry export shares are far more important than changes in the shares of industry production. In five of the six developed countries, changes in industry export shares accounted for over 90% of the total change. Second, for all countries, only two industries - chemicals, and machinery and equipment - account for over 80% of the total increase in the manufacturing export share. Of the two, machinery and equipment is clearly more important, except in Australia.

In the developed countries, the chemicals, machinery, and equipment export shares grew by roughly 3% per year (in nominal terms) in the 1970s and 1980s. For these countries, we estimate the contribution of the chemicals, machinery, and equipment industries to the increase in the total export share of GDP. Unfortunately, our manufacturing output data are not completely consistent with the data we used in the previous section. As noted below, our data originates from a different U.N. source. This leads to different manufacturing export ratios, as can be seen by comparing Tables A.2 and A.5. Nevertheless, by using the fact that chemicals and machinery and equipment are about 45-60% of manufacturing in the six OECD countries, and that this ratio did not change across the two decades, we can use the percentages from the two tables to obtain an estimate of the contribution of these two industries to the increase in the overall export/output ratio.

If the chemicals, machinery, and equipment industries had not become smaller, these industries would have accounted for over 100% of the increase in the total export share in each of the six countries. Even accounting for their smaller size, these industries account for over 50% of the increase in the total export share in each country; in Canada and Japan they account for over 100% of the increase. Hence, in all six countries, industries accounting for about 10% of GDP account for more than 50% of the total export share increase.

The U.S. data allows us to look at imports in addition to exports, the 1990s in addition to the 1980s and 1970s, and gross production as opposed to value-added. This data breaks out manufacturing into twenty two-digit SIC industries. The top half of Table A.4 focuses on exports. Here we see that comparing the 1990s to the 1980s yields similar results to comparing the 1980s to the 1970s. Almost two-thirds of the increase in manufacturing exports (as a share of shipments) is accounted for by chemicals, and machinery and equipment. The bottom half of the table focuses on imports. For both sets of comparisons, we see that these two industries account for more than two-thirds of the increase in manufacturing imports (as a share of shipments).

Hence, our other accounting decomposition results appear to be robust to the time period, the measure of trade, and the measure of output.

C. Data Sources and Country List for Export Shares and Accounting Decompositions

For our overall decompositions (Table A.5), we obtained data on manufacturing exports and production, as well as GDP, from various issues of the United Nations' International Trade Statistics Yearbook and National Accounts Statistics, Main Aggregates and Detailed Tables. We obtained data on total exports of goods and services from the IMF's International Financial Statistics Yearbook, 1992 (IFS). For some countries we needed exchange rate data. We used the annual average exchange rate, which was also obtained from the IMF's IFS Yearbook.

For our manufacturing export shares (Table A.2) and decompositions (Table A.6), we use the sources above to obtain export data at the 2-digit ISIC level. Our production data draws from the Industrial Statistics Division of the U.N. This data is available at the 3-digit ISIC level; we aggregate the production data to the 2-digit level. We add up the 2-digit data to get total manufacturing output.

We began with 25 countries:

Australia	Canada	Japan	Sweden	United Kingdom	United States
Hong Kong	India	Indonesia	<i>Malaysia</i>	Philippines	Singapore
	Korea	Thailand			
Argentina	Brazil	Chile	Costa Rica	Mexico	Venezuela
Cote D'Ivoire	Egypt	Kenya	Mauritius	Nigeria	

But data limitations, especially with respect to the 3-digit ISIC production data, forced us to work only with the 11 countries listed in bold. None of the patterns found for the eight countries discussed above are found for Costa Rica, Egypt, and India. These results are available from the authors on request.

The Malaysia data (Table A.3) is from its central bank publication "Quarterly Bulletin".

For the U.S. manufacturing decompositions (Table A.4), Linda Goldberg kindly provided the shipments, exports, and imports data. Her data sources, documented in Campa and Goldberg (1996) draw from the Annual Survey of Manufactures.

APPENDIX III

A. Case Study Vertical Specialization Calculations and Data Sources

1. U.S. - Canada Auto Trade: Our adjusted Grubel-Lloyd index is calculated as follows. We adjust trade in SITC 732 (autos) by subtracting vertical specialization-based trade, which has two components, one involving Canada imports from the U.S., and one involving U.S. imports from Canada. We subtract each component from the corresponding 'raw' auto imports numbers in SITC 732. We re-calculate the Grubel-Lloyd index using the adjusted SITC 732 numbers.

Our trade data is obtained from the United Nations Statistical Division, except for parts data between 1982-1994. Here we used the Department of Commerce Bureau of Economic Analysis (BEA) numbers, because it includes parts that are shipped for use in autos, such as air conditioners, but which are counted by the U.N. in another, non-auto parts, category. The discrepancy between the U.N. numbers and the BEA numbers becomes large only in the 1980s. Our 'fraction of production exported' numbers are obtained from the Ward's Automotive Yearbooks.

2. U.S. - Mexico Maquiladora Trade: Our trade data comes from the World Trade Database CD-ROM by Statistics Canada, and the maquiladora data comes from INEGI.

3. Japan - Asia Electronics Trade: All of our data is obtained from the Electronic Industries Association of Japan and the Japan Electronics Bureau. We thank Tomoko Mischke of the JEB for providing us with much of this data. See Figure 6.

4. Opel España Trade: Our value data on Opel España is obtained through private correspondence with the secretary-general of Opel España. Data on the number of cars produced and exported by all companies in Spain is obtained from the American Automobile Manufacturer's Association. Total Spain auto trade is obtained from the United Nations International Trade Statistics Yearbook, 1994.

B. Case Study 5: Hong Kong-China Trade

Hong Kong has played a significant role in facilitating China's emergence as a major player in international trade.²⁷ In 1977 about 6% of China's exports and less than 1% of imports passed through Hong Kong. By 1990 36% of exports and 25% of imports passed through Hong Kong, including 62% of China's exports to the U.S.. Hong Kong's re-exports have exceeded her exports since 1988.

Hong Kong serves not only as an intermediary linking China to the rest of the world, but also as a partner in vertical specialization-based trade. In 1995, 71% of Hong Kong's exports (not re-exports) to China are products shipped for further processing. 80% of manufacturers in Hong Kong report that they have transferred production to China. Moreover, about 82.2% of Hong Kong's re-exports of products from China in 1995 were part of outward-processing arrangements commissioned by Hong Kong firms.

²⁷ Much of the information below draws from Jones, King and Klein (1993) and from Fung and Ng (1996).

APPENDIX IV

Stylized Dynamic Model of Vertical Specialization and Outsourcing

We find it convenient to use reductions in communications/transportation costs, not tariff rates, as our ‘driving force’. We assume that improvements to transportation and communications technologies occur such that the costs fall at a constant rate. These transportation/communications costs enter the model as a one-time fixed cost of outsourcing. Initially, these costs are high enough so that firms do not outsource. Given that these costs are declining at a constant rate, when do firms decide to outsource, what happens to manufactured and non-manufactured trade when they do, and what is the amount of vertical specialization-based trade?

We employ a deterministic two-country framework without capital. The representative agent in each country maximizes the following preferences:

$$\sum_{t=0}^{\infty} \mathbf{b}^t U(c_{xt}, c_{yt}) \quad (\text{A.4})$$

$$\text{where } U(c_x, c_y) = \frac{[c_x^\alpha c_y^{1-\alpha}]^{1-\sigma}}{1-\sigma}$$

X and Y are both tradable, α is the share of X in consumption, and $1/\sigma$ is the intertemporal elasticity of substitution. The foreign utility function is identical. (Foreign arguments are denoted by ‘*’).

The representative consumer faces the following period by period budget constraint:

$$c_{yt} + p_{xt} c_{xt} = w_t L \quad \quad \quad c_{yt}^* + p_{xt}^* c_{xt}^* = w_t^* L^* \quad (\text{A.5})$$

Good Y is the numeraire, w is wages, p_x is the relative price of good x, and L and L^* are labor supplies in the home and foreign country. The labor supply in each country is fixed and given. We do not allow for intertemporal asset trade across countries.

Each country can produce good X via a Ricardian technology, but with possibly different productivities:

$$X_t = a_{xt} L_{xt} \quad \quad \quad X_t^* = a_{xt}^* L_{xt}^* \quad (\text{A.6})$$

We think of X as the standard non-manufactured good or service; it is tradable.

We think of good Y as the manufactured good. Only the home country possesses the technology to produce good Y, which is composed of three stages:

$$\begin{aligned} Y_t &= \min[Y_{-1t}, a_{0yt} L_{0yt}] \\ Y_{-1t} &= \min[Y_{-2t}, a_{-1yt} L_{-1yt}] \\ Y_{-2t} &= a_{-2yt} L_{-2yt} \end{aligned} \quad (\text{A.7})$$

Stage 0 is the final stage in the production process. Note that output from stages -1 and -2 serve as inputs into the next stage. Output from stages -1 and 0 are Leontieff functions of the previous stage's output and labor.

The representative household owns the firms, which rent labor from it each period to maximize profits. Positive profits are returned to the household as dividends. Markets are competitive. The competitive assumption and the constant returns to scale production functions imply that Y can be produced through a variety of firm structures. For convenience, we will assume one firm produces all three stages. Note that if $a_{xt} > a_{xt}^*$ and there is incomplete specialization in X production across the two countries, then real wages will be higher in the home country initially; these higher wages create the incentive to outsource.

We will assume that the home country can outsource production of the third stage (stage 0, or final assembly) to the foreign country. To outsource, the home country representative household must pay a one-time fixed cost, ϕ , which is the fraction of Y final output that is lost in the period that the outsourcing is introduced. This fixed cost captures the cost of setting up a transportation and communications infrastructure and network. Hence, for the period, t, in which the 3rd stage is outsourced:

$$Y_t = (1 - f_t) \min[Y_{-1t}, a_{0yt} L_{0yt}] \quad (\text{A.8})$$

The gain to outsourcing is the discounted future profits (from period t+1 on) that occur by implementing this technology in the lower wage country. We assume that the home country pays the foreign workers the same wage the workers are making in the X sector. In other words, the home country firm pays the competitive wage and nothing more.²⁸ Finally, this fixed cost, ϕ , declines at a constant rate ρ . This captures, in a simple way, improvements in the transportation and communications technologies.

We can rewrite the household problem in value function form. The value of not outsourcing in the current period is:

$$\begin{aligned} V^N(\mathbf{f}_t) &= \max\{U(c_{xt}, c_{yt}) + bV(\mathbf{r}\mathbf{f}_t)\} \\ \text{subject to } c_{yt} + p_{xt}c_{xt} &= w_t L \end{aligned} \quad (\text{A.9})$$

The value of outsourcing in the current period is:

$$\begin{aligned} V^O(\mathbf{f}_t) &= \max\{U(c_{xt}, c_{yt}) + bZ\} \\ \text{subject to: } c_{yt} + p_{xt}c_{xt} &= w_t L \\ Y_t &= (1 - f_t) \min[Y_{-1t}, a_{0yt} L_{0yt}] \end{aligned} \quad (\text{A.10})$$

Z is the discounted utility after outsourcing occurs. Finally, we have:

$$V(\mathbf{f}_t) = \max\{V^N(\mathbf{f}_t), V^O(\mathbf{f}_t)\} \quad (\text{A.11})$$

²⁸ We assume that the firm has been granted a monopoly right to enter the foreign country, so foreign wages will not be bid up by competing outside firms.

The model does not have an analytical solution, so we employ numerical methods to solve the model. The parameter values used to calibrate the model are given in Table A.7. Where possible, we employ the ‘usual’ parameters. For convenience we assume that the foreign country is sufficiently small so that after outsourcing, all its workers are employed in stage 0 manufacturing production. Equilibrium wages and prices are straightforward to calculate. We then discretize the state space (50 grid points) and employ value function iteration to solve for the threshold $t = T$ at which outsourcing will occur.

Table A.7 reports the results from our illustrative example. It is apparent that once outsourcing occurs, export share of GDP greatly increases. In the home country, it rises from 0.05 to 0.55 and in the foreign country, from 0.5 to 2.75. Vertical specialization-based trade accounts for the majority of this increase. After outsourcing 2/3 of all trade is vertical specialization-based.

Note that the manufacturing exports and GDP results for the home country are similar, qualitatively, to our numbers in Table A.5 for the OECD. In particular, the home country manufactured industry shrinks, but it exports a greater fraction of its output, so that manufacturing overall accounts for the bulk of the increase in exports. The foreign country results are similar to the numbers in Table A.5 for Korea or Malaysia, as well. In the foreign country, manufacturing also accounts for the bulk of the increase in exports, but it is largely because manufacturing is now a larger sector of the economy.

Altering the parameters, such as the elasticity of intertemporal substitution, the rate of technological progress, and the preference discount rate, affects the date at which outsourcing occurs. For example, reducing the elasticity of intertemporal substitution leads to more elapsed time before outsourcing occurs. The less willingly the household intertemporally substitutes consumption, the more the household will wait before it takes a temporary negative ‘hit’ in consumption during the period it chooses to outsource. Also, faster rates of technological progress imply outsourcing will tend to occur more quickly. However, changes in these parameters do not affect the changes in production and export patterns once outsourcing occurs.

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Table A.7. Dynamic Model of Vertical Specialization/Outsourcing; Parameterization and Results

Parameters:

$$\alpha = .5 \quad \sigma = 2 \quad \phi_0 = .9 \quad \rho = .98 \quad \beta = .96$$

$$a_{xt} = 2 \quad a_{xt}^* = 1 \quad a_{0y} = a_{1y} = a_{2y} = 1$$

$$L = 5 \quad L^* = 1$$

Results:

Firm chooses to outsource when $\phi = .7207$ (in period 12)
 $w = 1/3 \quad w^* = 1/6$ (before and after outsourcing)

Trade and production patterns:

	<u>Home Country</u>		<u>Foreign Country</u>	
	Pre-Outsource	Post-Outsource	Pre-Outsource	Post-Outsource
Exports	1/12	11/12	1/12	11/12
GDP	20/12	20/12	2/12	4/12
GNP	20/12	22/12	2/12	2/12
Manuf. Exports	1/12	8/12	0	11/12
Manuf. GDP	11/12	8/12	0	4/12
Non-Man. Exp	0	1/12	1/12	0
Non-Man. GDP	9/12	12/12	2/12	0
Service Exp (profits)	0	2/12	0	0
Vert. Spec.-Based Trade		Combined:	0	11/9 (2/3 of all trade)

Note: α is the share of good X in the utility bundle
 σ is the reciprocal of the intertemporal elasticity of substitution
 ϕ_0 is the initial fixed cost of outsourcing (fraction of current period Y output)
 ρ is 1 - rate at which this fixed cost declines each period
 β is the preference discount factor

a 's are the production coefficients

Table A.2. OECD Imports from other OECD Countries

ISIC	PRODUCT	(Percentage of Gross Output)	
		1970	1985
324	Leather shoes	12.4	29.7
385	Cameras, clocks, measuring equip., etc.	18.4	26.6
384	Transport equipment	15.3	26.5
351	Basic chemicals	16.2	23.7
323	Leather, except clothing and shoes	13.4	23.1
382	Non-electrical machinery	14.8	23.0
361	Pottery, china, and earthenware	14.9	19.9
390	Misc. Manufactures	13.1	19.1
383	Electrical Machinery	10.3	18.5
322	Clothing	8.3	17.6
372	Basic non-ferrous metals	16.9	17.1
355	Rubber Products	8.3	15.2
321	Textiles	9.7	14.0
362	Glass and glass products	10.6	14.0
341	Paper and paper products	11.6	13.3
371	Basic iron and steel	11.1	12.4
331	Wood products except furniture	9.5	11.0
352	Misc. chemical products	6.6	10.6
354	Misc. products of petroleum and coal	12.6	9.7
332	Wood furniture	4.4	9.7
313	Beverages	5.4	8.0
381	Various fabricated metal products	5.1	7.1
311/2	Food	5.6	6.8
356	Misc. plastic products	5.1	6.0
353	Products of oil refineries	5.7	5.6
369	Cement, clay products, etc.	4.0	5.4
314	Tobacco	1.6	3.7
342	Printing and publishing	2.5	3.1

Source: OECD STAN database; Harrigan (1996). We thank Jim Harrigan for providing the STAN data.