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The Structure of Foreign Trade

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World merchandise exports amounted to $5.3 trillion in 1997 and exports of commercial services amounted to $1.3 trillion. These are unprecedented volumes that have expanded much faster than income in the postwar period. Figure 1 presents long-term trends in the real volumes of merchandise trade and output. While trade grew at an annual rate of 2.6 percent during this period, output grew at only 1.5 percent. More than half of the volume of merchandise trade flows amongst developed countries and less than 15 percent flows amongst developing countries. The rest, about one third, represents North-South trade between developed and developing countries.

What explains these large volumes of trade? Why do some countries export computers while others export footwear? Can exports of airplanes be explained in the same way as exports of paper products? Questions of this type have been examined for many years. In attempting to answer them, economists have developed an elaborate analytical apparatus that has been greatly enriched in the last two decades. They have used the insights from trade theory to examine ever richer data sets in order to discover systematic patterns of trade flows and to evaluate how well available theories match these data. Nevertheless, although we do have today better answers to some of these questions than our predecessors had 40 years ago, the evolving structure of world trade defies simple explanations. I describe in this paper what we know about foreign trade and in what ways our understanding has improved as a result of the last 20 years of research.

The paper is in five parts. In the next section I briefly review early insights: David Ricardo's theory of comparative advantage and a simplified version of the

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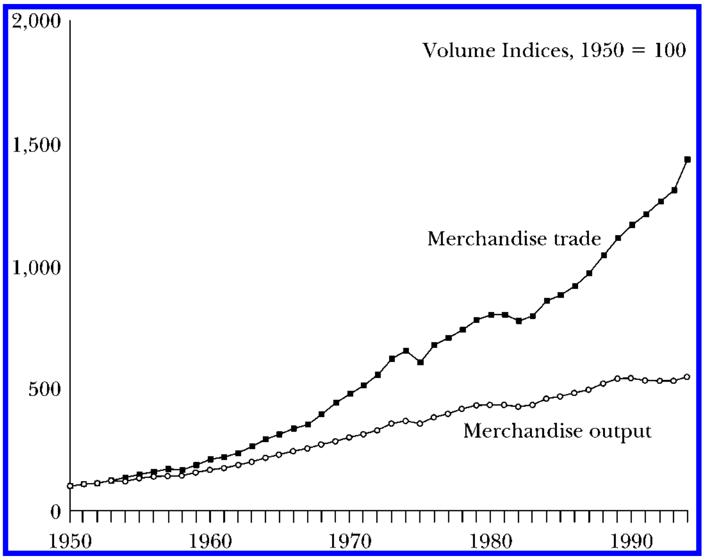
Figure 1
Long-term Trends of World Merchandise Trade and Output, 1950–1994



Source: WTO, Trends and Statistics 1995.

Heckscher-Ohlin theory. In the following section I discuss and evaluate further developments of the Heckscher-Ohlin approach during the 1960s, 1970s and 1980s. While the first two decades provided mostly theoretical insights, major empirical innovations appeared in the 1980s. The third part of the paper is devoted to a discussion of the most recent developments on this front. Next, in part four, comes a discussion and evaluation of research based on economies of scale and product differentiation. This work was done mostly in the 1980s and 1990s. An emphasis on the interplay between theoretical and empirical research characterizes the entire presentation. Conclusions are provided in the closing section.

Early Insights

David Ricardo's theory of comparative advantage, developed at the beginning of the 19th century, has played a major role in modern thinking about trade. Ricardian trade models assume that only labor is used to produce goods and services, with a given fixed coefficient between labor and output of a particular product in each country. The theory predicts that a country will export products in which it has a comparative advantage; that is, products where its labor productivity is high relative to its labor productivity in other products. The simple Ricardo model remains useful for thinking about a host of issues, such as the effects of technological progress on patterns of specialization and the distribution of gains from trade.

However, there are hardly any empirical studies of trade flows that build strictly on Ricardo's insights. A few appeared in the 1950s and '60s (McDougall, 1951, 1952; Stern, 1962), but it quickly became apparent that such models are of limited use in employing data to analyze the overall structure of foreign trade. The main difficulty is that Ricardo's theory is mute on a key ingredient: what causes labor productivity to differ across countries?[1] Differences in the use of capital comprise an important source of variation in labor productivity. Capital-rich countries are able to allocate more capital per worker to all economic activities than capital-poor countries, but they may do so to a different degree in various lines of business. This raises the question: what determines the allocation of capital to industries and thereby labor productivity? But once the role of capital is taken seriously, it may be best to abandon the exclusive focus on labor productivity and think about what determines trade flows amongst countries that have additional inputs besides labor.

Eli Heckscher (1919) and Bertil Ohlin (1924) provided a framework for thinking about trade in this situation. They emphasized the roles of labor, capital and land in agriculture and industry, trying to explain how their availability shapes a country's pattern of specialization and trade. Paul Samuelson and his followers elaborated a two-factor two-sector version that became the cornerstone of modern trade theory (Samuelson, 1948; Jones, 1956-57, 1965). Samuelson's version is crisp and elegant. By focusing on labor and capital as inputs and on export- and import-competing sectors, it cuts to the heart of the matter. The model was widely adopted as the workhorse of the profession. According to the two-factor, two-sector version of the Heckscher-Ohlin theory, a country should export the product that is relatively intensive in using the factor with which the country is relatively well-endowed. Thinking about labor and capital as the two inputs, it means that a capital-rich country—a country that has more capital per worker than its trade partners—should export the capital-intensive product.

The argument can be made in two parts. First, if factor prices are not equalized, then the rental rate on capital relative to the wage rate is lower in the capital-rich country.[2] As a result, it uses in all product lines more capital per worker than the capital-poor country. But, as shown by Lerner (1952), under these circumstances the capital-rich country has a cost advantage in the capital-intensive products, which it ends up exporting. This implies that its exports are more capital-intensive than its imports. That is, if we were to calculate how much capital and labor are embodied in the country's exports and how much capital and labor are embodied in its imports, we should find that for the capital-rich country the ratio of capital to labor is larger in exports than in imports. Second, if factor prices

[1] Eaton and Kortum (1997) provide the first study of a Ricardian model that contains an explanation of labor productivity based on a country's technology level. Using extreme value distributions for labor productivity they derive an equation for bilateral trade flows. They estimate this equation for a sample of OECD countries, using cumulative investment in R&D and the number of scientists and engineers as proxies for technology levels. The fit appears to be good.

[2] Capital accumulation in conjunction with international (financial) capital mobility tend to reduce divergent rental rates on capital. Nevertheless, differences can persist for long periods of time.

are equalized, then the capital-rich and capital-poor countries use the same ratios of capital to labor to produce identical products. But because the capital-rich country has a disproportionately large amount of capital relative to labor, it ends up producing a disproportionately large amount of capital-intensive products. Otherwise it cannot maintain full employment of labor and capital. It then follows that with a similar composition of demand (that results, for example, from identical homothetic preferences in all countries), the capital-rich country exports capital-intensive products in this case too. So we find again that in the capital-rich country the ratio of capital to labor embodied in exports is larger than the ratio of capital to labor embodied in imports.

There are two concepts of trade in this theory: trade in goods and trade in factor content. Trade in goods is standard; wheat and airplanes are goods, and they can be imported or exported. Trade in factor content is different. It refers to the inputs that are embodied in exports or imports. For example, if a unit of imported wheat is produced with half a unit of land, three units of labor and five units of water, then the factor content of the imported wheat is half a unit of land, three units of labor and five units of water. Using this approach one can calculate the factor content of exports, the factor content of imports, and the factor content of net exports, which is the difference between the two.

Leontief (1954) put the prediction that a capital-rich country should export capital-intensive products to a test. He calculated labor-output and capital-output ratios for various sectors of the U.S. economy, and then—with the aid of these coefficients—calculated how much labor and capital are embodied in exports and how much in imports. Surprisingly, Leontief found that in 1947 the capital-labor ratio embodied in imports exceeded the ratio embodied in exports by 60 percent! The surprise emanated from the fact that after the war, the United States was considered to be the most capital-rich country in the world and the Heckscher-Ohlin theory predicts for such a country a higher capital intensity of exports than imports. His finding became known as the "Leontief paradox."

There were attempts to examine additional data sets, but while the paradox is less pronounced in later data sets, it does not disappear. Leontief proposed his own resolution for the paradox. He had used the assumption that the U.S. input-output coefficients also apply to imports, which is the case when foreign suppliers use the same techniques of production as domestic producers. When countries have access to the same technologies and factor prices are equalized, this assumption is justified. But, pointed out Leontief, if a U.S. worker is much more productive than a foreign worker, then the U.S. should export relatively labor-intensive products. Why would, however, U.S. workers be so much more productive, especially after controlling for capital availability? This explanation seems to resolve one paradox by introducing another.

Further Developments: 1960s, 1970s and 1980s

The two-factor two-sector version of the Heckscher-Ohlin theory was extended in the 1960s and '70s; Ethier (1984) offers a review of the literature at this time. These studies had a variety of purposes, but what is central for this paper is the fact that from these studies grew a surprisingly simple theoretical specification, in which two types of relationships could provide the underpinning for an analysis of the generalized Heckscher-Ohlin theory.

The first set of relationships involves production. Let a_{ij} represent the quantity of input i used in the manufacturing of one unit of output j. I ignore intermediate inputs. Therefore these coefficients describe primary inputs only, which would include various types of capital, such as machines and structures; various types of labor, such as high school dropouts and college graduates; and various types of land, such as pasture and arable land. Cost-minimizing manufacturers choose these coefficients from the available technology, taking factor prices as given. As a result, these coefficients depend in a particular country on its technology and factor rewards. In the simplest version of this model, the technology is taken to be the same everywhere and factor prices are assumed to be equalized across countries.[3] In this case, the same coefficients are used in all countries. Then, if an economy fully employs its resources, we can derive a factor-market clearing condition. (If a resource is not fully employed, replace its quantity with the actually employed value.) Let V_i^k represent the quantity of input i in country k. Similarly, let X_j^k represent the output of good j in country k. Then full employment of resources implies

$$\sum_j a_{ij} X_j^k = V_i^k$$

for all inputs i and all countries k.

The second set of relationships comes from consumption. Preferences are assumed to be the same in all countries and homothetic; that is, a ray drawn from the origin of an indifference map will intersect all indifference surfaces at points with the same slopes. These assumptions are strong ones. They imply that the composition of consumption (the share of spending going to a product) is the same everywhere. Namely, if we denote by s^k the share of country k in consumption, then consumption of good j in country k is given by

$$C_j^k = s^k \bar{X}_j$$

[3] Factor prices are not the same in all countries, not even in the OECD countries. But as O'Rourke and Williamson (1999) demonstrate, trade and migration are powerful forces that lead to convergence of factor prices. See Williamson (1998) for a review.

for all goods j and all countries k, where $\bar{X}_j = \Sigma_k X_j^k$ is aggregate world output of good j. When trade is balanced, the share s^k equals country k's share in world income.

These two sets of fundamental relationships imply empirical specifications. Each country's production of any good is determined by its primary factor endowments, while each country's consumption of goods is determined by overall spending.[4] Exports will be those products where the country produces more than it consumes, and imports will be those products where the country produces less than it consumes. The model allows countries to run trade deficits or surpluses. The model implies a linear set of relationships between net exports and factor endowments. Each relationship, for petroleum products, forest products, machinery or chemical products, can be estimated from cross-country data. We do not need data on production coefficients or technology, because these are assumed to be the same in all countries. We do need data on net exports, which are readily available, and data on factor endowments, which are not readily available—at least not in comparable form.

Ed Leamer has done more than anybody else to promote a research agenda centered on the construction of such data sets. For example, Leamer (1984) started a new line of empirical research by estimating this linear relationship using a newly constructed data set. The simple linear specification performs very well in explaining actual patterns of trade on a cross section of 60 countries in his data set, for both 1958 and 1975. Examples of the type of effects that were estimated include the availability of oil raising net exports of petroleum products, but also reducing net exports of machinery in 1975; and the abundance of literate, non-professional workers raising exports of labor-intensive manufactures, such as apparel and footwear. Leamer's estimation maintains the assumption of linearity, which works well for most sectors. In some sectors, however, such as chemicals, the data favor a non-linear specification.

While estimates of this type are interesting, they do not provide a test of the generalized Heckscher-Ohlin theory. The reason is that the theory predicts a relationship between endowments and trade mediated by *technology*. To test it therefore requires independent information about all three objects: technology, endowments, trade.

Two concepts of trade have surfaced so far: trade in goods and trade in factor content. The former is a natural focus of trade theory, and was examined by Leamer. The latter was examined by Leontief. Leontief's procedure can be generalized by constructing measures of the factor content of net exports, as suggested by Vanek (1968). With identical technology coefficients in all countries, this procedure is straightforward. Just convert net exports of goods into the factor content of net exports, by multiplying the quantity of net exports of each good with the input coefficient a_{ij} and summing over all goods, using the common technology

[4] Uniqueness of the production structure requires additional assumptions, such as the equality of the number of inputs and outputs.

matrix. What Vanek has shown, is that under the model's assumptions this measure of *factor content* should equal the economy's measure of *factor abundance*. The latter is constructed as follows. Begin with the total factor content of production, which equals the economy's factor endowment, and then subtract out the factor content that goes into domestic consumption, where consumption of each input is proportional to the country's share of world spending. The result will be a measure of factor abundance. On net, inputs that are relatively abundant are exported while those that are relatively scarce are imported. Vanek's key equation is

$$F_i^k = V_i^k - s^k \bar{V}_i$$

for all inputs i and all countries k, where F_i^k is the factor content of net exports of input i in country k and $\bar{V}_i = \Sigma_k V_i^k$ is the aggregate endowment of input i in the world economy.

Vanek's (1968) equation was used by Leamer (1980) to point out a shortcoming of Leontief's procedure: whenever there are more than two inputs, that is, more than just labor and capital, a comparison of the ratio of the embodied quantities of just two of them in imports and exports does not provide the relevant metric for rejecting the theory. This may sound like a possible neat resolution of the Leontief paradox. It is not. As pointed out by Brecher and Chaudhri (1982), the fact that the United States was a net exporter of labor services has an implication for consumption per worker; that is, U.S. consumption per worker should fall short of world consumption per worker, which is not born out by the data.

Bowen, Leamer and Sveikauskas (1987), who were the first to use independent information about endowments, technology and trade, performed two types of tests on Vanek's (1968) key equation. They used the U.S. technology matrix to calculate the factor content of net exports F_i^k for all countries. Their tests involved comparing these measures of factor content with the measures of factor abundance $V_i^k - s^k \bar{V}_i$. They were done with data for 12 inputs and 27 countries (for 1967). One test compared the signs of the two calculations—that is, whether a factor that was predicted to be exported by the factor abundance measure was also exported by the factor content measure (and similarly for imports)—and found disagreement one-third of the time. Another test compared the rank order of the inputs in the calculated measures of the factor content of net exports with the measures of factor abundance and found disagreement about half the time. This appears to be bad news for the expanded Heckscher-Ohlin theory. But how bad the news is is hard to gauge, because in this exercise the theory is not tested against a well-specified alternative. For this reason it is also possible to take a more positive attitude and to argue that the theory explains a reasonably large fraction of the variation—across factors and countries—of the factor content of net trade flows.

Recent Advances

Although Bowen, Leamer and Sveikauskas (1987) pointed out difficulties with the Vanek equation, they did not investigate whether the data deviate systematically from the theoretical predictions. This important task was undertaken by Trefler (1995). He compiled a new data set, for 33 countries, that disaggregates endowments into nine inputs. The countries in the sample accounted for three-quarters of world exports and nearly 80 percent of world income in 1983. Again, Trefler first calculated the factor content of net exports, using the U.S. technology matrix for all countries, and then compared them to the factor abundance measures. Vanek's (1968) theoretical prediction is that the two measures should have a correlation of 1. Trefler found instead a correlation of .28.[5] A sign test of the Bowen, Leamer and Sveikauskas (1987) type was successful in only about one-half of the cases. It therefore appears that Trefler's data fits the expanded Heckscher-Ohlin theory as well or as badly as Bowen, Leamer and Sveikauskas's data does.

Trefler (1995) showed clearly in what ways these data deviate from the theoretical predictions. First, the measures of the factor content of net exports are compressed towards zero relative to the factor abundance measures. That is, even in cases in which both variables have the same sign, the former is much smaller in absolute value than the latter. This compression is striking. It is not unusual in these data for the absolute value of the factor abundance measure to be 10 to 50 times higher than the absolute value of the factor content of trade, as one can see in Figure 2, which presents these measures for capital (every point represents a country). Second, whenever a poor country exports an input on net, it exports less than predicted by its factor abundance measure. And whenever it imports an input on net, it imports more than predicted by its factor abundance measure. For rich countries the opposite is true. If one takes the factor content measure of net exports derived from trade flows and then subtracts from it the factor abundance measure, derived by subtracting the factor content of domestic consumption from the domestic factor endowment, that difference has a correlation of .87 with per capita GDP. Third, poor countries tend to be abundant in more factors than rich countries, in the sense that they have more inputs for which the domestic endowment exceeds the quantity of the factor embodied in domestic consumption. Indeed, the correlation between the factor abundance measure and per capita GDP is −.89.[6]

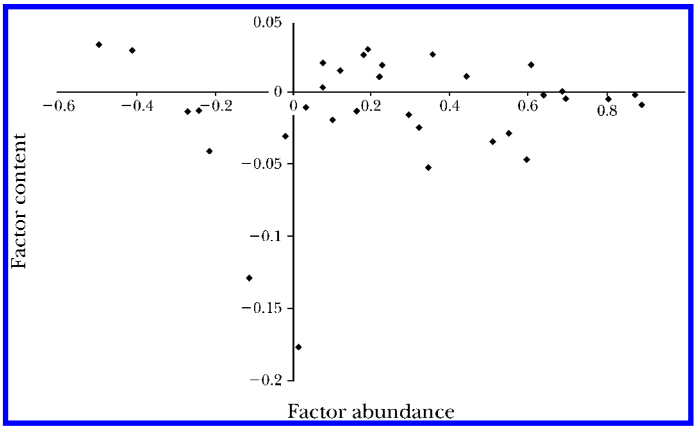
[5] All the reported calculations use normalized data, which is obtained from the original data by dividing every input by the standard deviation across countries of the difference

$$F_i^k - (V_i^k - s^k \bar{V}_i)$$

and by the measure of country size $(s^k)^{1/2}$. Here relative country size is measured by its share in aggregate GDP.

[6] These results cannot be explained by trade imbalances, which are much too small for this purpose.

Figure 2
Factor Abundance and Factor Content Measures: Capital data



Source: Trefler (1995). Every observation has been divided by the quantity of the input in the country.

This characterization is of lasting value. It gives us a better understanding of the ways in which the data do not match the theory. It provides a clear theoretical challenge: How should the model be modified to better fit the data?

Trefler also followed up on the earlier suggestion of Leontief that perhaps these differences could be explained by differences in productivity across inputs and countries. Suppose, as suggested by Leontief, that inputs are not equally productive in all countries. If U.S. labor is, for example, two times as productive as labor in Italy, then 1000 hours of U.S. labor services are equivalent to 2000 hours of labor services in Italy. Taking one country as the benchmark, we can then convert the endowment of all other countries into equivalent units of the benchmark country. It is then possible to use Trefler's data to calculate what the productivity differences would have to be between countries so that a modified Vanek equation would hold exactly.[7] Using this approach, Trefler (1993) first calculated labor and capital productivity coefficients for a set of countries relative to the United States, and he then compared them with the wage rate and the return to capital in these countries relative to the United States. According to the theory,

[7] Taking one country as the benchmark, we can convert the endowment V_i^k of country k into $\pi_i^k V_i^k$ equivalent units of the benchmark country, where π_i^k is the productivity of input i in country k relative to the same input in the benchmark country. Under these circumstances Vanek's equation in the text becomes

$$F_i^k = \pi_i^k V_i^k - s^k \sum_l \pi_i^l V_i^l$$

for all k and i, where the factor content of net exports F_i^k is calculated using the benchmark country's technology.

if there is factor price equalization, then in a cross-country comparison the relative rewards should equal the relative productivity parameters. Indeed, Trefler found the relative factor rewards to be highly correlated with the calculated relative productivity parameters.

In a later paper, Trefler (1995) took several alternative approaches to estimating productivity parameters. In one approach, he assumed that the productivity parameters are country-specific but not factor-specific; that is, if U.S. labor is two times as productive as Italian labor, so is U.S. capital and land. Thus, each country's productivity is represented by a common productivity advantage in all lines of business, and this advantage can be thought of as a Hicks-neutral technical difference. Trefler's second observation—namely, that poor countries appear to export too little of their abundant factors while rich countries export too much—suggests that Hicks-neutral productivity differences can help explain these data. Trefler's second approach was to divide countries into two sets, developed and developing, so that the factor-specific productivity parameters are the same in each group of countries, but differ across the two groups. Of these two choices, Trefler concluded that the Hicks-neutral specification performs better.[8]

To better account for the "missing trade"—that is, the finding that the factor content of net exports as measured from trade statistics is so much smaller than the difference between total factor endowments and factors that are embodied in domestic consumption—Trefler also introduced a home bias in demand. He found that this bias, together with the Hicks-neutral productivity differences, provides the best explanation of the data. I find the use of a home bias in demand unappealing. There is plenty of independent evidence that technologies differ across countries (for example, Harrigan, 1997). There is no such evidence for demand patterns, except for biases that are related to income levels.

Trefler uncovered patterns in the gaps between the Heckscher-Ohlin theory and the actual data on factor content and factor abundance. Apparently, technological differences between countries help to explain these gaps. The work by Davis, Weinstein, Bradford and Shimpo (1997) supports this emphasis. These authors set out to evaluate the two fundamental relationships discussed earlier in this paper: the production relationship in which sectoral output levels are used to calculate aggregate demands for inputs which are then required to equal factor endowments; and the consumption relationship that consumption vectors in different countries are proportional to each other.

They evaluated the production relationship in a cross-section of countries and a cross-section of Japanese regions, using Japan's technology matrix in all cases. They used output data to calculate the demand for inputs. According to the theory, this vector of input demands should match the vector of factor endowments. To examine how close these two vectors are to each other they performed on them rank order tests of the type introduced by Bowen, Leamer and Sveikauskas (1987).

[8] Bowen, Leamer and Sveikauskas (1987) also examined productivity differences. Unfortunately, due to a programming error their results are not correct.

They found that the match is not good in the international data, but is remarkably accurate in the Japanese regions. One plausible interpretation of this finding is that techniques of production are very similar across Japanese regions but differ significantly across countries. The failure of the common technology model to work in the international data can emanate either from lack of factor price equalization (which we know to be true from data on wages) or from differences in technological opportunities (which we also know to be the case). At the moment there are no estimates of how much of the failure is attributable to each of these potential causes.[9]

In looking at the consumption relationship, Davis, Weinstein, Bradford and Shimpo (1997) considered how accurately the structure of consumption can be captured by a model which posits that the share of consumption going to different goods is the same in all areas. In one exercise, they tested whether regional "absorption" (consumption plus investment) vectors in Japan are proportional to the aggregate Japanese absorption vector, concluding that they are. Next they tested whether the Japanese absorption vectors are proportional to world production, concluding that they are.

Since both the fundamental production and consumption relationships seem to hold well for the regions of Japan, Davis, Weinstein, Bradford and Shimpo (1997) went on to test a Vanek-style (1968) relationship with Japanese data, comparing a measure of the factor content of net exports with a measure of factor abundance. What they found was that even though the fundamental underlying production and consumption relationships hold across regions of Japan, the Vanek relationship does not fit the Japanese data well. As in Trefler's data set, this case too exhibits "missing trade;" namely, the computed factor content of net exports is much smaller in absolute value than what is predicted by factor abundance (that is, by the total factors subtracting out factors used for domestic consumption). For example, while net exports of noncollege labor services amount to 3.6 percent of this factor endowment, the factor abundance calculation predicts imports of 31 percent of this factor endowment—a large deviation indeed.

How can these different findings be reconciled? Davis, Weinstein, Bradford and Shimpo (1997) propose a partial resolution. The test just described used Japanese production coefficients, assumed to be the same for all countries. If one instead recognizes that other countries may use different production coefficients, it is possible to obtain a modified Vanek equation in which the world's aggregate factor endowment is replaced with the inputs that would have been used if every country were to use Japan's technology matrix. With this modification in place the puzzle of the "missing trade" is reduced, although not eliminated.

It is clearly possible to use a Heckscher-Ohlin modeling approach to explain the trade data if one allows arbitrary differences in techniques of production across countries. But this answer is not useful; after all, any and every pattern of factor

[9] Impediments to trade can cause differences in factor prices. But such impediments have declined systematically over time. And regional wage differentials persist for long periods of time within countries.

content can be explained with arbitrary differences in techniques of production. The challenge is to use key features of countries to explain the reason for differences in techniques of production, and in turn, to have these differences better explain the trade data.

One possible approach is to look at models where the differences in techniques of production come about because factor prices are not equalized across countries. To give an example, consider a world of two countries, two inputs and two outputs, in which differences in factor composition are wide enough that there is no factor price equalization. Let the factors be capital and labor, let the products be food and clothing, and let clothing be capital-intensive. The technologies are the same in both countries. However, since country A has a high capital-labor ratio and therefore a relatively low rental rate on capital, it employs more capital and less labor than country B would employ in the same line of business. Suppose also that due to the extreme differences in factor endowments, country A manufactures only clothing and B produces only food. It can be shown that under these circumstances the capital-rich country A exports on net less capital services than predicted by Vanek's factor abundance measure and imports on net less labor services than predicted by this measure (Helpman, 1998b). A similar conclusion is obtained from an analysis of the labor-rich country. To see why, note that using the factor coefficients from country A introduces no bias in the calculation of the factor content of A's *exports*. But it biases the calculation of the factor content of A's *imports*, because foreign manufacturers use different input-output coefficients—they use less capital and more labor per unit output. Therefore the use of A's coefficients overstates the amount of capital and understates the amount of labor embodied in its imports. As a result *net* exports of capital services are understated and so are *net* imports of labor services. This is why differences in techniques of production that result from factor price differences help to explain the phenomenon of "missing trade."

But how much "missing trade" can be explained by cross-country variations in factor rewards? At the moment there is no clear answer to this question. Davis and Weinstein (1998a) have recently shown that, indeed, countries with more capital per worker use more capital-intensive techniques than countries with less capital per worker. And moreover, adjustments of technology matrixes for such differences in factor endowments help to explain the factor content of net exports. However, Hicks-neutral differences in technology are also required for a good fit, and such productivity differences remain extremely important even after accounting for differences in factor composition.[10]

[10] The problem of missing trade appears to be much too severe to be explained with moderate differences between countries. For example, using a regression approach to look at Trefler's (1993) data set of 33 countries, Gabaix (1997) estimated the affects of factor endowments on the factor content of net exports. He allows factor-specific productivity levels to differ across countries, but assumes that they are proportional to factor rewards. Under these circumstances the model predicts a coefficient of 1 on the factor-augmented endowment measures. Gabaix finds instead coefficients close to zero. In addition he shows that Trefler's (1993) calculation of cross-country differences in productivity of inputs is

Things do not look so bleak when attention is focused on the pattern of specialization in domestic production rather than trade. Reeve (1998) estimated a relationship between outputs and inputs for a sample of 20 OECD countries, using data on 15 sectors and five types of inputs: capital, three grades of labor and arable land. He found that cross-country variations in factor endowments explain over 40 percent of the variation in output levels. If one allows for cross-country differences in Hicks-neutral productivity levels—that is, the productivity of a factor is country-specific but does not vary across inputs in a country—the fit improves significantly and an additional 7 percent of the variation in output levels is explained. In decomposing output changes from 1970 to 1985, Reeve finds that shifts in factor endowments and the techniques of production explain over 80 percent of the changes in the sectoral output levels. Interestingly, changing factor endowments contributes about twice as much as changing techniques of production.

This suggests that as imperfect as the theory is, some of its components fare well empirically. My conclusion from the evidence is that to close the gap between the theory and the data, we need to model more carefully the cross-country differences in techniques of production that are driven by both technological differences and differences in factor rewards. This view is strengthened by Hakura's (1997) findings, as well as by Davis and Weinstein (1998a). Using data for five of the original European Union countries, she first confirms the Bowen, Leamer and Sveikauskas (1987) finding that a Vanek-style (1968) comparison of the factor content of net exports with a factor abundance calculation has the correct sign pattern in only about one-half of the observations. But this fraction rises to 70-80 percent when each country's techniques of production are used instead of a common technology matrix. This fraction rises even further when allowance is made for non-traded intermediate inputs. Evidently, allowing for differences in techniques of production can dramatically improve the fit of factor content equations. Now economists need to identify the forces that induce countries to choose different techniques of production.

Economies of Scale and Product Differentiation

Concurrent with the refinement of the Heckscher-Ohlin trade theory and the development of its empirical implications for the factor content of net trade flows, a new trade theory that emphasizes economies of scale and product differentiation emerged in the 1980s. Helpman (1984) offers a review of the literature on trade with economies of scale and Krugman (1995) reviews the literature on trade with differentiated products and monopolistic competition. At the early stages of its development, the new theory seemed to threaten the Heckscher-Ohlin orthodoxy.

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insensitive to the factor content of net exports, in the sense that virtually identical numbers are obtained when the factor content of net exports is assumed to be zero.

But it became clear that these new explanations of trade were actually complementary to the explanations provided by factor endowments. This called for an integrative view of foreign trade that would allow for an interplay between economies of scale, product differentiation, and factor proportions. Helpman and Krugman (1985) developed such an approach, making allowance for sectors that differ in their sources of scale economies, in conduct, and in market structure.

Much of this research was originally motivated by the observation that large volumes of trade flow between countries with similar factor proportions and that significant trade overlap exists within industries, which seemed to imply that a considerable portion of trade was not being driven by factor endowment differences. These facts have not changed. In 1996, the 15 countries of the European Union exported (and imported) a little over $2 trillion worth of merchandise, and about 65 percent of this trade was within the EU. Europe's imports from Japan alone exceeded its imports from *all* of Africa and were more than twice as high as its imports from *all* of the Middle East (WTO, 1997, Table A10). Evidently, the EU countries trade with countries that are similar to themselves more than they trade with the very different economies of Africa and the Middle East. More broadly, the industrial countries trade with each other much more than they trade with less developed countries.

Measures of trade overlap within industries have remained high. These measures consider imports and exports within each industry, evaluate how much overlap there is in every sector, and provide a summary statistic of the share of total trade that consists of such overlaps.[11] To construct such an index for bilateral trade between two countries k and l, take the minimum of the bilateral import volumes; for example, if in one industry country k imports $20 billion from l and country l imports $30 billion from k, choose the $20 billion. Add these volumes up. Divide by the sum over all industries of all bilateral imports. Multiply by two, to adjust for the fact that the numerator refers to imports of only one country, while the denominator refers to imports of both countries. By construction, this index is between zero and one with higher values representing more trade overlap. To take a couple of examples, the share of intra-industry trade in the United Kingdom was 53.2 percent in 1970, and then increased to 74.4 percent in 1980 and 84.6 percent in 1990. In Germany, it increased from 55.8 percent in 1970 to 56.6 percent in 1980 and 72.2 percent in 1990 (OECD, 1996, Table 1.8). These two countries represent a general trend of rising shares of intra-industry trade. Declines in this index are rare, but it happened in Norway as a result of the oil boom. Shares of intra-industry trade are especially high in some sectors. In pharmaceuticals, for example, intra-industry trade accounted for 98 percent of trade in finished products in the United States in 1991, 70 percent in France and 32 percent in Japan. In the same year, intra-industry trade accounted for 70 percent of trade in intermediate pharmaceu-

[11] According to the Heckscher-Ohlin theory such overlaps should not exist. Davis (1995) has proposed, however, that small differences in individual product-related technologies can produce such overlaps even in a Heckscher-Ohlin framework.

tical products in the United States, 82 percent in France and 64 percent in Japan (OECD, 1996, Table 2.12).

Helpman and Krugman (1995) have shown that economies of scale, product differentiation, and various forms of conduct are compatible with factor price equalization and, as a consequence, with Vanek-type equations for the factor content of trade. For this reason the empirical evidence that I reviewed so far is also relevant for the richer theory developed in the 1980s. Grossman and Helpman (1991) show conditions under which the Vanek-type equations also remain valid in economies that invest in research and development.

Although factor price equalization and the employment of identical techniques of production in all countries can take place with economies of scale, their presence makes this less likely. Scale economies drive countries to specialize in different products, which enhances the incentives for foreign trade. For this reason, they help to explain large trade volumes between similar countries. At the same time, economies of scale make it more likely that countries will employ different techniques of production. This is especially so when there are dynamic economies of scale, be they driven by learning-by-doing or investment in research and development, in which case some companies have access to technologies that are not available to rivals.[12] Since the empirical evidence does not appear to be consistent with the use of identical techniques of production worldwide, or even within groups of relatively homogeneous countries, the study of country-specific technological developments becomes important for understanding international trade.

Intra-Industry Trade

The first comprehensive study of the extent of trade overlap was done by Grubel and Lloyd (1975). They devised the index of intra-industry trade described a moment ago, and showed that the index was high in many countries. Even before the theory of intra-industry trade was properly developed, Loertscher and Wolter (1980) had established some patterns about trade overlap. In particular, they found that the share of intra-industry trade is high when the trading partners are highly developed and at a similar level of development, and when the trading partners are large and do not differ too much in size.

To explain extensive intra-industry trade, sectors with product differentiation were introduced into the theory. Many products are differentiated by brand, from simple goods such as breakfast cereal, toothpaste or clothing, to sophisticated ones such as cars, computers or magnetic resonance imaging machines. Many producer goods are differentiated in some way as well, including capital goods such as drilling machines and intermediate inputs such as microprocessors. The theory applies to all such goods. It starts by noting that product differentiation typically involves economies of scale. A brand has to be developed, such as a lightweight laptop, or

[12] Such advantages exist at least temporarily, as is evident from a variety of technological races in the electronics and pharmaceutical industries. See Grossman and Helpman (1995) for a review of the literature on the links between trade and technology.

it has to be designed, such as a dress fashion. In either case, the company that develops the product gains some monopoly power, because the market does not provide a perfect substitute for its unique brand. Moreover, companies are driven to differentiate their creations from the brands of rivals.

Economies of scale limit the range of products that are profitably supported by the market; the smaller the economies of scale, the more brands become available. With international trade, countries specialize in different brands. When every country demands a wide spectrum of varieties, international trade leads naturally to trade overlap: brand-specific economies of scale lead to intra-industry trade. Although empirical researchers have sought an association between the degree of economies of scale in a sector and the extent of its intra-industry trade, the theory does not appear to imply such a relationship. What matters is that economies of scale exist, not their size.

According to the theory, the share of intra-industry trade is larger between countries that are similar both in composition of factor endowments and in size. Helpman (1987) examined the empirical validity of these results. He used the absolute difference in GDP per capita to capture the composition of factor endowments and the size of each country's GDP to capture the size variables. For a sample of 14 industrial countries he estimated such a relationship to assess how well these variables predicted the share of intra-industry trade in bilateral trade flows between nations. He found that the partial correlations had the predicted signs for most of the years between 1970 and 1981; that is, the extent of trade overlap was larger the more similar were the countries' income per capita, the smaller was the larger country and the larger was the smaller country.

However, this relationship may not be robust. In Helpman's (1987) results, the magnitude of the findings appears to weaken over time. Moreover, Hummels and Levinsohn (1995) both confirm Helpman's findings and call them into question. They find that Helpman's results continue to hold, for example, if instead of using income per capita to capture factor differences, one uses income per worker or absolute differences in capital-labor and land-labor ratios. But when they inserted country-pair dummy variables into the specification, it appeared that most of the variation in the share of intra-industry trade could be explained by country-pair dummies. That is, unspecified characteristics of country pairs explain more than the variables emphasized by the theory! This finding raises an obvious need to broaden the theory to arrive at a better empirical specification.

Volume of Trade

Economies of scale and product differentiation strengthen the tendency to specialize, and in turn, specialization encourages a greater volume of international trade. To see how trade volumes are determined by specialization, consider an extreme case in which every country is completely specialized in a subset of products, each country has the same homothetic preferences for consuming goods, and trade is balanced, so that spending levels on each good are proportional to GDP levels (as in the fundamental consumption relationship given earlier). This relationship implies that a given percentage increase in the GDP of a country will raise its volume of trade (exports plus imports) with any other country by the same percentage amount; it is called a "gravity equation."[13] Gravity equations go back to Tinbergen (1962); Linnemann (1966) provided a comprehensive analysis. Typical specifications estimate the effects of income on trade, controlling for the distance between the trade partners. Distance has a negative effect on the volume of trade.

Equations of this form—aggregated in various ways—have been estimated time and again, providing a good fit to many data sets. Helpman (1987) used it to calculate the volume of trade amongst 14 industrial countries as a fraction of their aggregate income. According to the theory, this fraction is larger the more similar are the countries' income levels as measured by a similarity index $1 - \Sigma_k (s^k)^2$.[14] To see how this works as an income similarity index, take the case of two countries. In this case the index is very close to zero whenever one country is much bigger than the other, since s^k is close to zero for the small country and close to one for the large country. When the two countries are equal in size $s^k = ½$ for each, and the similarity index obtains the value ½, which is the largest possible value in the presence of two countries. Helpman found that between 1956 and 1981, this index increased and the fraction of income traded within the group increased as well. This co-movement is consistent with models of product differentiation in which specialization in production is driven by brand proliferation.

A reexamination of Helpman's (1987) evidence with a focus on *bilateral* trade flows was performed by Hummels and Levinsohn (1995). They confirmed Helpman's finding for a group of industrial countries. But they also applied the same approach to a group of mixed countries—some developed, others less developed—arguing that if product differentiation is the main reason for the good fit, the equation should not perform well in the mixed sample, since trade between different economies should presumably be based more on factor differences and less on trade in similar differentiated products. Although their main equation did not fit the mixed sample as well as it did the homogeneous sample, it was remarkably good nevertheless. They concluded that the evidence does not lend support to

[13] Assuming that all countries have the same homothetic preferences and that there is complete specialization implies that country k imports from l the fraction s^k of l's output. The volume of trade (imports plus exports) between these two countries therefore equals $Q^{k,l} = s^k Y^l + s^l Y^k$, where Y^k is the GDP level of country k. If, in addition, spending levels are proportional to GDP levels, $s^k = Y^k / Y$ and $Q^{k,l} = 2 Y^k Y^l / Y$, where Y is the world's GDP.

[14] To derive this similarity index recall from the previous footnote that country k's imports from country l are $s^k Y^l$, where s^k is the share of country k in world spending and Y^l represents income of country l. It follows that k's imports from all other countries equals $s^k(Y - Y^k)$, where Y stands for world income. Next note that assuming that spending is proportional to income implies $s^k = Y^k / Y$. Therefore, the total volume of world trade is given by

$$\sum_k s^k(Y - Y^k) = \sum_k \frac{Y^k}{Y}(Y - Y^k) = Y[1 - \sum_k (s^k)^2] .$$

This implies that the volume of trade equals the fraction $1 - \Sigma_k (s^k)^2$ of world income.

the view that product differentiation is the key to why the volume of trade seems to increase with similarity in size of the trading economies.

Evenett and Keller (1998) developed an alternate estimation procedure that sheds more direct light on whether product differentiation or differences in factor endowments might explain the empirical relationships between the volume of trade and the size distribution of countries. Using a mixed sample of countries (similar to Hummels and Levinsohn), Evenett and Keller divided the observations of country pairs into those that have less than 5 percent of intra-industry trade and those that have more, and they assumed that country pairs in the first sample trade homogeneous products. They then investigated whether the data favors a specification in which differences in factor proportions between the countries in the first sample are large enough to lead to specialization in this group, which would justify a gravity equation (that is, a link between the volume of trade and the size of countries) despite the lack of product differentiation, but failed to find evidence in favor of this hypothesis.[15] They also divided the remaining countries into five classes that differed in the degree of intra-industry trade. They tested whether the gravity equation provides a better approximation to the data for countries with a higher share of intra-industry trade, and found that it does. This finding favors the view that product differentiation is at the core of the relationship between the volume of trade and the size distribution of countries.

As mentioned earlier, developed economies trade mostly with each other rather than with less developed countries, and trade within the group of less developed countries is only a small fraction of total world trade (about 15 percent). To see how product differentiation helps to account for these facts, consider a world that consists of developed countries (the North) and less developed countries (the South). All countries in the North are the same size and have the same factor endowments; the same is true of countries in the South. However, the composition of factor endowments differs between the North and the South. In some sectors, there is product differentiation, in others products are homogeneous. Now suppose that due to differences in factor composition the North specializes in differentiated products while the South specializes in homogeneous products. Since all the developing countries are the same size, and producing the same homogenous products, the countries of the South do not trade with each other. However, each South country imports a fixed fraction of output from each North country. The North countries all import some fixed fraction of output from every country in the North and the same fraction from the South region.

Now, for concreteness, suppose that there are 20 countries in the North, each

[15] Deardorff (1998) made the argument that a gravity equation can be derived from a generalized Heckscher-Ohlin model with large differences in factor composition that lead to specialization in production. Although this is a theoretical possibility, the Evenett-Keller evidence suggests that it has little empirical content. Deardorff's alternative derivation of the gravity equation for economies with homogenous products, which is based on random divisions of imports across the exporting countries, is not even appealing on theoretical grounds. I agree with Grossman's (1998) position on this point.

one accounting for 4 percent of world output. The North accounts therefore for 80 percent of the world's output and it is four times as large as the South. In this setting, trade among the North economies will be a large proportion of world trade, because the North economies are larger to begin with, and they specialize. With these reasonable sizes of economies the volume of trade among the developed countries in the North is about twice as large as their trade with the South.[16] This is a simple calibration, close to the mark. In the data, this ratio is about 1.6.

Of course, assuming no trade at all between economies in the South is an extreme condition. Surely, some internal trade does exist in the South, since factor proportions are not the same in every country. But this extreme formulation helps to make the main point. Generally there will be less intra-group trade in the South the more the South specializes in homogeneous products and the less its countries differ in factor compositions.

A Heckscher-Ohlin approach assuming homogenous products can also be used to explain such volumes of North-North and North-South trade, without any need for product differentiation, by incorporating any necessary differences in techniques of production across goods and sectors as well as suitable cross-country differences in factor endowments. Davis (1997) gives an example. However, while I find such arguments to be an interesting intellectual exercise, they are of little practical value. Explaining the observed trade patterns with only homogeneous products requires too much fine tuning of the technology to be convincing. The broad structure of world trade is more naturally explained with the aid of product differentiation than without it.

To conclude, the available evidence supports the view that economies of scale with product differentiation are valuable components in the explanation of trade flows. However, it still leaves room for factor endowments to play a role.

Economies of Scale

Modern trade theory places significant weight on economies of scale and product differentiation in explaining the structure of foreign trade. Its usefulness has been gauged by a variety of implications that help to interpret various facts, and by the fit of some of its implications in various data sets. However, this research provides no direct evidence on the extent of economies of scale. In fact, most of the implications that have been examined do not depend on the *degree* of economies of scale, just on their existence. Although this is good enough for many purposes, for a variety of welfare-related questions it is important to have a sense of the size of economies of scale. Some micro production studies find economies of scale in single-country data sets. But such studies cannot provide comparable estimates of economies of scale at the sectoral level and may, therefore, underestimate the size

[16] It is shown in Helpman (1998b) that under these assumptions the ratio of North-North to North-South trade equals $s^N(n^N - 1)/2(1 - s^N n^N)$, where s^N is the relative size of a country in the North and η^N is the number of countries in the North. Using $s^N = .04$ and $\eta^N = 20$, therefore implies a ratio of 1.9.

of scale effects because, as suggested by Marshall, economies of scale at the sector level can emanate from the interaction of firms and factor markets within an industry.

Antweiler and Trefler (1997) have developed a methodology for estimating returns to scale at the sectoral level from international data. They constructed a data set for 71 countries, with 37 industries and 11 factors, spanning a period from 1972 to 1992. The key theoretical observation that enables them to estimate the degree of economies of scale is that a variant of the Vanek (1968) equation, which has been mentioned a number of times already, also holds in the presence of economies of scale. The Vanek relationship, of course, is to look first at the factor content of net exports, calculated by applying factor production coefficients to import and export data, and then to compare that result to the difference between total factors in an economy and factors used in domestic consumption. In the Antweiler and Trefler variant of the Vanek approach, the factor content of exports and imports is calculated separately for each and every trade partner, which allows all countries to use different techniques of production.

One way to specify the difference in techniques of production is to allow differences in factor productivity levels across countries, as in Trefler (1993). An alternative approach, however, is to attribute cross-country variations in productivity levels to differences in scale. As a result of scale economies, the use of inputs per unit output declines (on average) as output expands. Assuming that the productivity parameters are proportional to factor rewards, then scale economies are the only remaining source of cross-country variations in productivity levels. By parameterizing the effects of scale economies, one can therefore estimate the suitable coefficients from such modified Vanek equations. The results show that productivity is indeed higher the higher the level of output; costs fall by about 0.15 to 0.20 percent when output rises by 1 percent. These estimates are larger than those often obtained from micro studies on economies of scale. Moreover, these estimates have low standard errors. The estimates imply further that output expansion leads to shifts in the techniques of production that raise the demand for skilled relative to unskilled workers.

Some other estimates of economies of scale across national economies are becoming available, as well. Harrigan (1999) uses estimates of production functions for a sample of OECD countries to assess whether economies of scale at the sectoral level or Hicks-neutral differences in the technological efficiency of countries better explain cross-country variations in sectoral levels of total factor productivity. The results are mixed. Differences in total factor productivity are large, and economies of scale do not explain them adequately. Neutral technological differences provide a somewhat better fit. Since one does not exclude the other, it would be interesting to allow for both scale economies and technological differences, but Harrigan's data does not allow estimating this decomposition accurately.

Yet another inquiry into economies of scale based on international data is provided by Davis and Weinstein (1998b). Their point of departure is Krugman's (1980) home-market effect. Krugman introduced transport costs for varieties of a differentiated product that are produced with economies of scale in a two-country model with one input (labor) and two sectors, one differentiated and the other homogeneous. In this sort of environment, where production functions are the same in both countries, the pattern of specialization is undetermined in the absence of transport costs. But with transport costs, the size of local demand determines the profitability of manufacturing differentiated products. The larger country, with its greater demand, supports the development of a disproportionate number of brands and therefore exports them on net. The important role of the size effect is here in demand, not supply.

More generally, in economies where transport costs are important and the size of the home market matters, shifts in the aggregate demand for a country's products will have a disproportionately large effect on its output of products with economies of scale. In pure Heckscher-Ohlin-type economies (no economies of scale and no product differentiation) with no transport costs, such effects are nil, while in Heckscher-Ohlin-type economies with transport costs they are less than proportional. It is therefore possible to discriminate between these alternative models by estimating the effects of aggregate demand on the output of various products.

To estimate the demand for goods in a particular sector of a country, Davis and Weinstein (1998b) first estimate how trade flows are affected by the size of the economy as compared to its trading partners, accounting for distances between countries. Their sample consists of 22 OECD countries and 25 sectors. As is typical for such equations, the trade volume declines with distance. Using these estimates they then construct relative demand levels for every industry and estimate the effect of this demand for the country's products, which emanates from all countries including the home country, on the local supply. Pooling over industries, they find that a 1 percent increase in demand raises local output by 1.6 percent, which provides evidence in favor of scale effects. Performing the same estimation for every industry separately they obtain less accurate estimates. Nevertheless, in 11 out of the 25 sectors the coefficients are significantly larger than one, supporting the presence of economies of scale. Davis and Weinstein (1997) estimated a similar model on regional data from Japan, and also found scale effects in a number of sectors.

Conclusions

Some researchers have argued that the modern theory of international trade with economies of scale and product differentiation is not needed to explain key features of world trade—such as the existence of intra-industry trade, the connection between the growth in economies and the growth of trade volumes, or the difference between North-North and North-South trade volumes. Researchers in this tradition strive to convince us that there is no need to incorporate economies of scale or product differentiation into trade theory, since for any given pattern we can find a structure of a traditional Heckscher-Ohlin model with homogenous goods that also produces it. This is, of course, a legitimate and intellectually interesting debate. But in my view, product differentiation is so prevalent that it is hard to see why it is even necessary to justify its presence in economic models. If anything, it should be necessary to justify the use of models with homogeneous products only. Just think about the products we consume: food, clothing, furniture, home appliances, sports equipment, cars—almost anything—they all are differentiated products. The same can be said about intermediate inputs and capital goods, as well as about a host of services, such as banking, insurance, or travel. Whenever product differentiation helps to explain certain phenomena, it is only natural to embrace this assumption, rather than to insist on the construction of models with homogenous products that also explain them.

All this being said, the ultimate test is in the direct and indirect evidence. There is plenty of direct evidence, from observation and otherwise, that product differentiation is prevalent. But this does not imply necessarily that the available models of international trade with product differentiation provide a good explanation of the data. It is fair to say that none of the existing models does a great job explaining the data. But adding product differentiation does improve the fit between theory and data. Moreover, since the inherent richness of the models with product differentiation has not yet been much explored, such models carry the potential of providing even better explanations.

We now have a rich theory of international trade that emphasizes economies of scale, product differentiation and differences in factor composition as key determinants of the structure of world trade. In combination, these factors explain significant parts of specialization patterns, volumes of trade, factor content of trade, and the broad patterns of trade across regions.

But despite the research effort in the last 20 years, these explanations are still incomplete. This is partly the result of the fact that the nature of world trade is changing rapidly. Technological change has modified the patterns of specialization, reduced trading costs and encouraged larger trade volumes; new countries have joined the trading system; and multinational corporations have spread their nets more widely than ever before. In the new economy there is plenty of man-made comparative advantage and product cycles, which are occasionally short-lived. We need a more technologically-oriented trade theory and more emphasis on dynamics to understand these developments. Such theories have been elaborated in the 1990s and they will undoubtedly affect future empirical research.

■ *This is an extended and elaborated version of the Bernhard-Harms Prize lecture, delivered at the Kiel Institute for World Economics in June 1998. The original lecture was published in Helpman (1998a). Most technical details are missing from this presentation. Many of them can be found in my working paper, Helpman (1998b), which also contains more information about recent studies. Many thanks to Don Davis, Bradford De Long, Gene Grossman, Ed Leamer, Jim Levinsohn, Alan Krueger, Timothy Taylor, Manuel Trajtenberg and Dan Trefler for comments on an earlier draft, to Jaiho Chung for research assistance, to Jane Trahan for editorial assistance, and to the National Science Foundation for financial support.*

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