Skills and Changing Comparative Advantage

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Abstract: Using U.S. input-output data for the period 1947-1996 and Dictionary of Occupational Titles skill scores by occupation, I examine the skill intensity of U.S. trade. I find that U.S. exports have a high content in cognitive and interactive skills relative to imports and a relatively low content in motor skills. Moreover, the skill gap between exports and imports has widened over time. The results also show that imports are more capital and equipment intensive than exports but in this case the difference has fallen over time. Moreover, by 1987 exports were more intensive in OCA than imports. In contrast, while in 1958 the R&D intensity of U.S. exports was much greater than that of imports, by 1996 it was slightly lower. Labor productivity also rose faster in export than import industries and the unit labor cost of exports declined relative to imports.

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This paper considers the relation between the changing skill base of the U.S. labor force and the country's shifting comparative advantage in the international arena. Standard trade theory predicts that a country will export those products that intensively use those endowments in which a country is favored relative to the other countries of the world and import products which are intensive in endowments that are scarce in that country. It was generally believed, for example, that the U.S. exported capital-intensive goods and imported labor-intensive ones but empirical work showed that U.S. exports tended to be human capital intensive and imports capital intensive (the so-called "Leontief paradox").

In this paper, I investigate the skill composition of exports and imports. Does the U.S. tend to export products that embody high-skill labor and import those that embody low-skill labor? How have these trade patterns changed over time? Do they reflect the changing skill composition of the U.S.labor force, which has shifted in favor of cognitive and interactive skills and away from motor skills? Also, with the growth of the information economy (assuming that we are in the forefront of the world in that dimension as well), is our comparative advantage shifting in that direction as well?

A related issue regards the R&D intensity of U.S. trade. During the 1960s and 1970s the major export strength of the U.S. lay in industries whose research was heavily subsidized by the U.S. government (particularly, the Department of Defense), including aircraft, armaments, mainframe computers, and medical equipment (see Dollar and Wolff, 1993). It will be of interest to see whether this is still the case.

This chapter will present statistics on the skill content and educational content of both U.S. exports and imports over the period from 1950 to 1990. Calculations will also be provided of the share of information workers "embodied" in trade over the same period, as well as the total capital, equipment, computer, and R&D content of U.S. trade flows up to 1996. Statistics on the relative labor costs and productivity performance of U.S. exports and imports will also be provided. On the basis of input-output data, it will be possible to compute both the direct and indirect content of trade.

I find that comparative advantage in U.S. international trade has been in high cognitive and interactive skill industries and in low motor skill industries, and the gap between exports and imports has widened over time. U.S. exports also have a high content in terms of knowledge and data workers and a low content in terms of goods workers relative to imports and the gap has grown over time as well. The results also show that imports are more capital and equipment intensive than exports but in this case the difference has fallen over time. Moreover, by 1987 exports were more intensive in OCA than imports. In contrast, while in 1958 the R&D intensity of U.S. exports was much greater than that of imports, by 1996 the R&D intensity of imports was slightly greater than that of exports. I also find that labor productivity rose faster in export than import industries and the unit labor cost of export industries relative to import industries declined almost steadily over time.

The first section of this paper reviews the previous literature on the skill composition of trade. Section 2 develops the accounting framework used in the analysis. Section 3 presents the results for the U.S. over the period from 1947 to 1996. Concluding remarks are made in the last section.

1. **Review of Previous Literature**

A. The Heckscher-Ohlin Model

There are two distinct approaches used to explain why different countries will specialize in different industries with regard to trade patterns. The first is the Heckscher-Ohlin model with factor-price equalization (see Heckscher [1919] 1949, and Ohlin, 1933). The key assumption in the model is that all countries face the same technology but differ in the relative abundance of factors of production, from which it can be shown that factor prices will be equalized across countries. In the original Heckscher-Ohlin formulation, the proof is based on a two-good, two-factor model. Vanek (1968) extended the model to the multigood, multifactor case. The model is now referred to as the Heckscher-Ohlin-Vanek (or HOV) model. The model was further generalized by Deardorff (1982). The main implication of this model is that trade specialization is dictated by relative factor abundance. In particular, a country will export products that use intensively those factors in which a country is relatively abundant and import products that use intensively those factors which are relatively scarce.

This prediction has been subject to a long series of studies. There are two types. The first involves comparing the resource content of exports with that of the domestic substitutes for imported products in a single country. This is legitimate since by the assumptions of the HOV model, the technology used in a country to produce products which are imported is the same as that used in other countries to produce these products. Moreover, the factor prices faced in the countries are the same, so that relative costs are identical.

The most widely known tests of the effects of relative factor endowments on trade patterns were conducted by Leontief (1956, 1964) using input-output data for the United States. The main finding is that despite the fact that the U.S. was then the most capital-intensive country in the world, it exported goods that were relatively labor-intensive and imported goods that were relatively capital-intensive. This phenomenon became known as the "Leontief paradox." Many explanations were offered for the Leontief paradox. These include (1) R&D differences among countries; (2) skill differentials between countries; (3) differences in educational attainment and other human capital attributes; and (4) relative abundance of land and other natural resources (see Caves, 1960, for more discussion). The first three factors will be examined in the next section.

The second type of test involves comparing trade patterns between two or more countries and relating these patterns to differences in factor abundance. One of the earliest of these studies was by MacDougall (1951, 1952), who compared British and American exports to see whether the British share of capital-intensive exports was smaller than the American share, as the model would predict due to the higher capital-labor ratio in the United States. He did not find any systematic evidence to support this prediction.

In a much more comprehensive study, Leamer (1984) examined trade patterns for over 100 economies and found that actual patterns could be explained fairly well by an endowment-based model with 10 factors, including capital, several types of natural resources and land, and three skill classes of labor. However, Leamer did not test for correspondence between the factor content of trade and the relative abundance of these factors within a country. In a later study, Bowen, Leamer, and Sveikauskas (1987) computed the amount of each of twelve factors of production embodied in the net exports of 27 countries in 1967 on the basis of the U.S. input-output matrix of total input requirements for that year. These factor contents were then compared to the relative factor abundance of the 27 countries. Using regression tests, they failed to find any correspondence between the two (in contradiction to the HOV model).

Trefler (1993, 1995) used another technique to investigate the Leontief paradox. Like Bowen, Leamer, and Sveikauskas (1987), he first computed both the labor and capital requirements of the net exports of a set of countries on the basis of the technology matrix of a single country (the United States). He then compared the labor and capital requirements with the national endowments of both labor and capital to determine whether the Leontief paradox held. This was generally confirmed. He then relaxed the assumption of factor-price equalization and showed that cross-country differences in factor prices could account for the fact that more capital abundant countries had net exports that were labor intensive, and conversely.

C. <u>The Technology Gap Model</u>

The second approach for analyzing trade patterns among countries derives from Ricardian trade theory, which emphasizes inter-country differences in technology and factor prices. The modern variant of the Ricardian approach is the technology gap model, whose central premise is that technology gaps and differences in innovativeness between countries will be a major source of trade flows (see, for example, Posner, 1961, or Fagerberg, 1988). While the HOV model is essentially a static model, the technology gap model emphasizes technical change as the key source of (changing) comparative advantage.

Empirical analysis of this model relies on using cross-national data to compare trade patterns and technology indicators. Dosi, Pavitt, and Soete (1990) regressed a country's export share (of total OECD exports) for each of 40 manufacturing industries on that country's share of total OECD patents in that industry over the 1963-77 period. With the exception of several resource-based industries and several in which patents are not a reliable indicator of innovative activity, the patenting variable proved to be a significant determinant of export share. Other variables that also proved generally significant are labor productivity and capital intensity.

In later work, Amable and Verspagen (1995) reported that patents proved to be a significant determinant of export share in a majority of 18 manufacturing industries for 5 countries covering the period 1970 to 1991. Wage costs were significant in a third of the sectors, while investment played a role in only a few sectors. Verspagen and Wakelin (1997) also found a significant effect of R&D intensity on net exports among a sample of nine OECD countries over the period 1970-88 for 11 of 22 manufacturing industries.

Other trade economists emphasize the role of relative unit labor costs in international competitiveness. Fagerberg (1988) found that a country's relative unit labor costs were statistically significant as a determinant of a country's trade balance but that the effect was much weaker than that from technological variables. Dosi, Pavitt, and Soete (1990) also found a much stronger effect of labor productivity than unit labor costs on exports of total manufacturing.

Three recent studies of mine also examined some of the implications of the technology gap model. Wolff (1995) looked at long-term data on aggregate export and productivity performance for France, Germany, Japan, the United Kingdom, and the United States over the period 1870 to 1987. Once controlling for country size, I found that aggregate export performance was positively and significantly related to relative labor productivity and total factor productivity

(TFP) growth rates, the growth in capital intensity, and change in R&D intensity, and negatively related to the age (vintage) of capital.

Wolff (1997) used industry level data for 13 manufacturing industries in 14 OECD countries over the period 1970 to 1992. The study used Balassa's (1965) Revealed Comparative Advantage (RCA) index, which measures a country's share of a given export commodity in total world exports of that commodity as a ratio to a country's share of manufacturing exports in total world manufacturing exports, as an index of trade specialization. A similar index (RPA) was used for total production (output) shares by industry. The results showed that TFP growth was a powerful predictor of the change in RPA. It was also significantly related to the change in RCA for the 1982-92 period but generally not for the 1970-82 period. On the other hand, the change in relative labor costs was generally negatively related to the change in RCA and in RPA for the 1970-82 period but was not significant for the 1982-92 period.

In a follow-up study, Wolff (1999) found that improvement in relative labor productivity was a powerful predictor of the change in RPA among 33 manufacturing industries in 14 OECD over the period 1970-1993. The rate of capital formation also played an important role in the determination of RPA for low-tech industries but was less significant for medium-tech industries and not significant for high-tech ones. The results also showed that relatively higher unit labor costs generally reduced competitiveness in a particular industry and hence RPA among low-tech industries.

C. The Skill Content of Trade

Growing out of the HOV model, several papers have investigated the skill content of trade. One of the earliest, Keesing (1965), used American data on employment for five occupational groups and 15 industries to classify workers into a skilled and unskilled category. Comparisons of the skill content of exports were made among 9 OECD countries for 1957. Keesing found that relative to other countries, U.S. exports were the most skill intensive, followed by West Germany, Sweden, and the United Kingdom. Japan ranked last in this group in 1957.

Engelbrecht (1996) looked at the skill content of German exports and imports. Using German input-output data for 1976, 1980, and 1984 and detailed occupational data by industry for those years, he concluded that comparative advantage resulted more from specialization in particular skill types than from the overall human capital endowment of a country. In particular, German exports were strongly endowed with labor from skilled manual occupations (such as metal workers, tool makers, and mechanics) and engineers.

Most recently, Lee and Schluter (1999) looked at the skill content of U.S. trade. They constructed a dichotomous variable for skilled and unskilled workers on the basis of nine major occupational groups. The former consisted of executive, administrative, managerial, professional, and technical workers; and the latter consisted of sales, clerical, craft, operative, and service workers, laborers, and farmers. Using U.S. input-output data for the period 1972-1992, they found that the ratio of high-skilled to low-skilled workers was greater for exports than imports but the difference in the ratios remained relatively unchanged over this period.

2. **Accounting Framework and Skill Measures**

The input-output model can be introduced as follows, where all vectors and matrices are 45-order and in constant (1992) dollars, unless otherwise indicated, are (see the Data Appendix for sources and methods).

X = column vector of gross output by sector.

Y = column vector showing the final output by sector.

E = column vector of exports by sector.

M = column vector of imports by sector.[1] 1

D = column vector of domestic consumption by sector (household consumption, investment, and government expenditures).

A = square matrix of interindustry input-output coefficients

Then,

(1) $Y = D + E - M$

and

(2) $X = AX + Y$

Also, let:

e = column vector of export coefficients, where $e_i = E_i / \Sigma E_i$.

m = column vector of import coefficients, where $m_i = M_i / \Sigma I_i$.

L = row vector of labor coefficients, showing employment per unit of output.

K = row vector of capital coefficients, showing total capital per unit of output..

R = row vector showing R&D expenditures as a percent of net sales by industry.

S = row vector showing average skill scores of workers by industry.

W = row vector showing average employee compensation in 1992 dollars by industry.

N = 267 by 45 employment matrix, where N_{ij} shows the total employment of occupation

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[1] Technically, there are two types of imports recorded within the U.S. input-output framework. The first, called "competitive" or "comparable" imports, are ones for which there are direct domestic substitutes, such as Japanese cars. These are recorded in the row in which there are domestic substitutes and are summed in the import column in final demand. It is not possible to identify the destination of these imports by industry or final user. The second, called "non-competitive", "transferred", or "non-comparable" imports, are ones for which there are no direct domestic substitutes, such as rubber. These are recorded in a separate row in the interindustry matrix by sector of destination. The calculations of skill or capital embodied in imports are performed only for competitive imports.

i in industry j and where $L_j = \Sigma_i N_{ij}$.

n = 267 by 45 employment coefficient matrix, showing employment by occupation per unit of output, where $n_{ij} = N_{ij}/X_j$.

B = 267-order column vector of total employment by occupation, where $B_i = \Sigma_j N_{ij}$.

Then,

(3) $B = nX = n(I - A)^{-1}Y$

where I is the identity matrix.

I use the fourth (1977) edition of the Dictionary of Occupational Titles (DOT) for my skill measures. For some 12,000 job titles, it provides a variety of alternative measures of job-skill requirements based upon data collected between 1966 and 1974. This probably provides the best source of detailed measures of skill requirements covering the period 1950 to 1990. On the basis of this source, three measures of workplace skills are developed for each of 267 occupations, as follows (see Wolff, 1996, for more details):

1. Substantive Complexity (SC) is a composite measure of skills derived from a factor analytic test of DOT variables. It was found to be correlated with General Educational Development, Specific Vocational Preparation (training time requirements), Data (synthesizing, coordinating, analyzing), and three worker aptitudes - Intelligence (general learning and reasoning ability), Verbal and Numerical.

2. Interactive Skills (IS) can be measured, at least roughly, by the DOT "People" variable, which, on a scale of 0-8, identifies whether the job requires mentoring (0), negotiating (1), instructing (2), supervising (3), diverting (4), persuading (5), speaking-signaling (6), serving (7) or taking instructions (8). For comparability with the other measures, this variable is rescaled so

that its value ranges from 0 to 10 and reversed so that mentoring is now scored 10 and taking instructions is scored 0.

3. Motor Skills (MS) is another DOT factor-based variable. Also scaled from 0 to 10, this measure reflects occupational scores on motor coordination, manual dexterity and "things" - job requirements that range from setting up machines and precision working to feeding machines and handling materials.

Average industry skill scores are computed as a weighted average of the skill scores of each occupation, with the occupational employment mix of the industry as weights. Computations are performed for 1950, 1960, 1970, 1980, and 1990 on the basis of consistent occupation by industry employment matrices for each of these years constructed from decennial Census data. There are 267 occupations and 64 industries.

4. Mean Years of Schooling. These are derived directly from decennial Census of Population data for years 1950, 1960, 1970, 1980, and 1990.

3. **Results**

A. The Changing Make-Up of U.S. Exports and Imports

Let us first look at the changing composition of U.S. trade. Results for exports in current dollars are shown in Table 1. In 1996, the most important U.S. export was (non-electrical) industrial machinery, which made up 12.6 percent of all exports. This category includes office, computing, and accounting equipment (OCA). In 1996, OCA by itself comprised 5.1 percent of all exports. The second most important export was electrical and electronic equipment, accounting for 9.3 percent, followed by shipping and other transportation services (at 8.2 percent), motor vehicles and parts (at 6.9 percent), chemicals and chemical products (at 5.6

percent), other transportation equipment such as aircraft (at 5.4 percent), and wholesale and retail trade (at 4.8 and 4.6 percent, respectively). Altogether, industrial machinery, electrical and electronic and transportation equipment, and chemicals made up almost 40 percent of all exports.

Table 1. Percentage Composition of U.S. Exports, with Industries Ranked by 1996 Exports

Industry	1947	1958	1967	1977	1987	1996
Industrial machinery exc. Electrical	9.2	12.7	14.3	12.8	10.9	12.6
Electric and electronic equipment	3.2	4.5	5.4	6.5	7.4	9.3
Shipping and other transport services	13.0	12.0	10.6	6.7	8.8	8.2
Motor vehicles and equipment	5.7	4.8	5.5	7.9	7.6	6.9
Chemicals and allied products	3.8	5.3	6.0	5.3	5.9	5.6
Other transportation equipment	2.4	4.5	5.5	5.8	7.4	5.4
Retail trade	2.9	3.7	3.6	4.4	4.4	4.8
Wholesale trade	2.9	3.7	3.6	4.4	4.2	4.6
Real estate	0.3	1.3	1.6	2.6	3.4	4.6
Instruments and related products	1.1	1.4	2.4	2.4	4.0	4.1
Agriculture, forestry, and fishing	9.5	9.8	9.0	9.2	4.5	3.7
Food and kindred products	10.9	6.7	5.2	5.1	3.8	3.5
Rubber and plastic products	1.6	2.9	2.7	2.2	2.6	3.0
Fabricated metal products	2.2	2.9	3.6	4.0	3.4	2.4
Insurance	0.2	0.1	0.1	0.2	2.4	2.1
Banking, credit & investment companies	0.2	0.1	0.1	0.2	2.4	2.1
Primary metal products	9.0	5.0	4.4	2.6	1.7	1.9
Paper and allied products	1.7	1.6	2.0	1.8	2.1	1.8
Petroleum and coal products	3.1	3.4	2.1	2.3	2.1	1.5
Business & repair services, exc. Auto	0.2	0.7	0.6	1.0	0.7	1.1
Professional services & non-profits	0.2	0.6	0.6	1.0	0.7	1.1
Apparel and other textile products	1.8	0.8	0.7	0.7	0.5	1.1
Lumber and wood products	1.0	0.6	1.0	1.4	1.2	0.9
Tobacco products	1.3	2.3	1.6	1.2	0.8	0.9
Amusement and recreation services	0.7	1.3	0.9	0.3	0.4	0.8
Textile mill products	5.5	1.3	0.9	1.2	0.8	0.8
Printing and publishing	0.4	0.5	0.7	1.0	0.7	0.7
Miscellaneous manufactures	1.0	0.6	0.9	0.9	0.9	0.7
Stone, clay, and glass products	1.0	0.9	0.9	0.8	0.6	0.6
Telephone and telegraph	0.2	0.3	0.4	0.7	1.1	0.6
Oil and gas extraction	1.2	0.2	0.3	0.2	0.5	0.6
Coal mining	2.1	1.7	0.8	1.5	0.8	0.3

Correlation with 1996 export composition:	0.64	0.83	0.89	0.91	0.97	1.00

Note: Exports are in current dollars. Industries are classified according to a 45-sector aggregation. Only industries which account for one percent or more of exports in any year are listed.

There have been some very striking changes in export composition over the half century. In 1947, the most important U.S. export (excluding transportation services) was processed food products, at 10.9 percent; followed by agriculture, forestry, and fishing (at 9.5 percent); (non-electrical) industrial machinery (at 9.2 percent); primary metal products such as steel (at 9.0 percent); motor vehicles and parts (at 5.7 percent); and textile mill products such as fabrics (at 5.5 percent). Since 1947, agriculture and food exports have steadily declined in relative importance, from 20.3 percent to 6.5 percent in 1996, as did exports of primary metal products, from 9.0 to 1.9 percent. Textile mill products plummeted from 5.5 to 0.8 percent. Both industrial machinery and motor vehicles remained high over the half century, actually increasing their share. The biggest gains were made by electrical and electronic equipment, from 3.2 to 9.3 percent.

As shown in Table 2, the three leading imports in 1996 were motor vehicles and parts, at 14.2 percent, industrial machinery except electrical (at 14.1 percent), and electric and electronic equipment (at 13.2 percent). Together, this group constituted 41.5 percent of all imports. It is also of note that these three industries were also among the leading four industries in terms of exports. In a somewhat distant fourth place in terms of imports was oil and natural gas (at 8.4 percent), followed by apparel and other textile (at 6.7 percent) and chemicals and chemical products (at 5.8 percent).

There have been even more dramatic changes in import composition than exports over the period from 1947 to 1996. In 1947 the leading import sector was, by far, processed foods and food products, accounting for 29.0 percent of all imports. This was followed by agricultural, forestry, and fishing products (at 15.4 percent), paper and paper products (at 14.5 percent), primary metal products, like steel (at 10.3 percent), and metal mining including iron and copper (at 7.1 percent). Agriculture, food products, and primary metal products were also among the leading four exports in 1947.

Table 2. Percentage Composition of U.S. Imports, with Industries Ranked by 1996 Imports, 1947-1996

Industry	1947	1958	1967	1977	1987	1996
Motor vehicles and equipment	0.2	6.0	3.3	12.2	18.9	14.2
Industrial machinery exc electrical	1.2	2.9	7.6	5.2	10.9	14.1
Electric and electronic equipment	0.1	1.3	6.7	7.6	11.5	13.2
Oil and gas extraction	5.1	11.4	6.0	23.8	7.2	8.4
Apparel and other textile products	0.4	0.4	0.3	4.1	6.5	6.7
Chemicals and allied products	3.1	3.7	4.3	3.6	4.9	5.8
Primary metal products	10.3	12.8	20.5	8.1	4.5	4.3
Instruments and related products	1.8	1.8	2.0	2.0	4.0	3.9
Miscellaneous manufactures	2.2	2.4	3.2	2.5	3.8	3.5
Food and kindred products	29.0	12.4	7.5	5.5	4.5	3.4
Rubber and plastic products	0.4	0.7	1.9	2.1	2.9	3.2
Agriculture, forestry, and fishing	15.4	8.4	5.7	1.9	1.7	2.6
Fabricated metal products	0.3	1.7	3.1	2.0	2.8	2.5
Other transportation equipment	0.3	1.2	1.8	1.5	2.4	2.1
Leather and leather products	0.5	0.5	0.5	1.8	2.3	2.0
Paper and allied products	14.5	9.6	7.2	2.6	2.5	2.0
Petroleum and coal products	2.7	6.2	5.5	7.6	3.3	1.8
Lumber and wood products	4.5	4.9	4.6	2.4	1.6	1.6
Transportation	0.3	0.1	0.6	0.2	0.6	1.3
Stone, clay, and glass products	0.9	1.6	1.6	1.2	1.6	1.3
Furniture and fixtures	0.0	0.0	0.2	0.5	1.3	1.2
Textile mill products	3.4	5.5	4.8	1.1	1.2	0.9
Banking, credit & investment companies	1.1	0.2	0.2	0.2	0.4	0.3
Insurance	1.0	0.2	0.2	0.2	0.4	0.3
Mining of nonmetallic minerals	2.9	1.9	1.1	0.4	0.2	0.2
Tobacco products	2.9	0.3	0.1	0.2	0.2	0.1
Metal mining	7.1	7.0	4.9	1.3	0.3	0.0
Correlation with 1996 import composition:	0.13	0.38	0.49	0.70	0.96	1.00

Note: Imports are in current dollars. Industries are classified according to a 45-sector aggregation. Only industries which account for one percent or more of imports in any year are listed.

Between 1947 and 1996, processed foods and food products declined steadily from 29.0 to 3.4 percent of all imports, agriculture from 15.4 to 2.6 percent, paper and paper products from 14.5 to 2.0 percent, and metal mining from 7.1 to 0.0 percent. The share of primary metal products in total imports, after doubling from 10.3 to 20.5 percent between 1947 and 1967, tailed off to 4.3 percent in 1996. In contrast, the import share of non-electrical industrial machinery rose steadily between 1947 and 1996, from 1.2 to 14.1 percent, as did that of electrical and electronic equipment, from almost zero to 13.2 percent and apparel, from 0.4 to 6.7 percent. Imports of motor vehicles and parts were volatile, first increasing from virtually zero in 1947 to 6.0 percent in 1958, dropping to 3.3 percent in 1967, expanding to 18.9 percent by 1987 (a reflection of the surge in Japanese car imports), and then diminishing to 14.2 percent in 1996. The other notable change is that oil imports swelled from 5.1 percent of all imports in 1947 to 23.8 percent in 1977, reflecting the steep oil price increases of the mid-1970s, and then abated to 8.4 percent in 1996.

Overall, import composition changed much more than export composition. The correlation in import shares between 1947 and 1996 is a meager 0.13. The correlation in import shares between 1958 and 1996 reaches only 0.28; that between 1967 and 1996 is 0.49; that between 1977 and 1996 is 0.70; and, finally, that between 1987 and 1996 is 0.96. In contrast, the correlation in export shares between 1947 and 1996 is a fairly high 0.64, and the correlation coefficient between 1996 export shares and those of other years rises to 0.83 with 1958 export shares, 0.89 with 1967 export shares, 0.91 with 1977 import shares, and 0.97 with 1987 import shares. In sum, while the composition of U.S. exports has remained fairly constant since the mid-1960s, import composition has stabilized only since the late 1980s.

B. The Factor Content of U.S. Exports and Imports

I next turn to the skill content of U.S. exports and imports. The calculation is performed in two ways: The first is based on the direct labor requirements of each industry (matrix n). The vectors nE and nM give the direct labor requirements by occupation to produce the exports and the same array of domestic goods that correspond to the imports of a given year, respectively. The second technique is to compute the total (direct plus indirect) labor requirements of exports and of the domestic substitutes for imports. This is sometimes referred to as the "total labor content" or the "total embodied labor." From (3), the total labor requirements by occupation to produce the export vector E is given by $n(I - A)^{-1}E$ and to produce the domestic equivalent of the import vector M is given by: $n(I - A)^{-1}M$.

It should be stressed that, as in previous studies, the subsequent analysis of comparative advantage is based on a comparison of the factors of production needed to produce exports with those needed to produce the domestic equivalent of imports. However, as discussed in Section 1, the technique receives theoretical justification in the HOV model by the assumption that technology is the same among countries that trade with one another. Another limitation of this kind of analysis is that a large part of trade is intra-industry. With the available data, we cannot distinguish between low-end and high-end imports or exports. With the data at hand, it is necessary to assume that the skill content (and other input content) of exports from an industry is the same as the skill (and other input) content of the domestic substitutes of the imports.[2]1

[2] A further limitation, as noted in footnote 1 above, is that non-competitive imports cannot be included in the analysis, since, by definition, such imports do not have domestic substitutes. However, this is a relatively small share of total imports -- only 12 percent in 1996.

Both the export and import vector include retail and wholesale trade margins and transportation margins.[3]1 The former represents the value added of domestic wholesale and retail activities involved in the sales of the exports; and the latter represents the shipping costs borne by American-based shippers. Since retail, wholesale, and shipping inputs will accompany any set of exports (and imports), they are not really indicative of comparative advantage. It makes sense to exclude these margins when analyzing comparative advantage, which I do in the tables that follow. Calculations were also performed for total exports and imports and for exports and imports excluding retail and wholesale trade margins only but are not shown here. The pattern of results are, by and large, very similar to those shown in the text tables.

The text tables show the computations for the direct factor content of trade. Calculations on the total factor content are shown in appendix tables. In almost all cases, the pattern of results is very similar to that of the direct labor content. However, differences in the factor content of exports and imports are more muted, because the average skill content is now based on employment both in the actual export (import) industries as well as in the industries that supply the export (import) industries. I do not comment on the results for the total factor content, except when they are exceptional.

<u>C. Skill Composition</u>

Results are shown in Table 3 for the direct skill content of U.S. trade (also see Appendix Table 1 for total skill content). The average skill content of exports is given by: SL*E/LE, where E is the total direct employment generated by exports, a star (*) indicates a diagonal matrix with

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[3] Technically, the wholesale and retail margins also include the value added of the "Rest of the World" sector. In the case of imports, these margins appear as negative entries, since imports generally generate domestic value added in American retailing, wholesaling, and transport industries.

the indicated vector on the diagonal, and S is a row vector showing average skill levels by industry. The average skill content of imports is given by: SL*M/LM.

The main result is that comparative advantage in U.S. international trade has been in industries intensive in their use of both high cognitive and high interactive skill workers. Moreover, the comparative advantage in high cognitive and interactive skill industries has been

Table 3. Average Skill Content of Exports and Imports: Direct Labor Input Only, 1950-1990

Skill Type	1950	1960	1970	1980	1990	Percent Change 1950-1990
A. Substantive Complexity (SC)						
Exports	3.40	3.59	3.80	3.92	4.21	23.6
Imports	3.27	3.32	3.52	3.59	3.72	14.0
Difference	0.14	0.27	0.28	0.33	0.48	
Total Economy	3.75	3.81	4.07	4.23	4.38	16.9
B. Interactive Skills (IS)						
Exports	1.37	1.48	1.57	1.65	1.90	38.6
Imports	1.33	1.33	1.38	1.42	1.58	18.8
Difference	0.04	0.15	0.19	0.23	0.32	
Total Economy	2.19	2.21	2.27	2.31	2.37	8.0
C. Motor Skills (MS)						
Exports	5.43	5.44	5.47	5.46	5.33	-1.9
Imports	5.31	5.39	5.52	5.52	5.43	2.2
Difference	0.13	0.05	-0.05	-0.06	-0.10	
Total Economy	5.11	5.13	5.17	5.10	5.01	-1.9
D. Mean Educational Attainment						
Exports	9.29	10.11	11.02	12.12	12.86	38.4
Imports	9.04	9.91	10.88	11.89	12.47	38.0
Difference	0.25	0.20	0.14	0.23	0.38	
Total Economy	9.40	10.30	11.50	12.50	13.00	38.3

a. Computations are based on direct labor requirements only. Exports and imports exclude wholesale and retail trade and transportation margins.

rising over time.

Panel A shows trends in the average Substantive Complexity (SC) of employment directly generated by both exports and imports. In 1950, the average SC content of exports was 3.40, compared to an average SC score of 3.27 for imports -- a difference of 0.14. By 1990, the average SC level of exports grew by 24 percent to 4.21 and that of imports by 14 percent to 3.72, so that the gap more than tripled to 0.48.

Another interesting comparison is that between the cognitive skill content of exports and imports and the average cognitive skill content of all output. At first blush, the results are surprising --- the average SC content of both exports and imports are lower than that of the total economy. However, the reason is that the highest SC scores are found in services such as finance, insurance, real estate, business services, and the government, which are too a large extent non-tradables.

Results for interactive skills (IS) are quite similar to those for cognitive skills (Panel B). The interactive skill content of total exports is greater than that of total imports and the gap has widened over time, in this case from a difference of 0.04 in 1950 to 0.32 in 1990. Here, too, both exports and imports have a lower interactive skill content than the whole economy. The reason is, as for cognitive skills, that the industries with an especially high IS content are finance, insurance, real estate, business services, and the government, which primarily serve the domestic market.

The results for motor skills (MS) are just the opposite of those for SC and IS. In 1950, exports were more motor skill intensive than imports. However, by 1970 the average motor skills of imports were higher, and by 1990 the gap had enlarged to -0.10. In this case, the motor skill content of both exports and imports is greater than that of the total economy, because of the high concentration of blue-collar workers in goods-producing industries, which are more heavily involved in international trade than services.

The results for actual educational attainment are a bit of a surprise. They do show that workers in export industries have a higher mean schooling level than those employed in import industries. The gap does increase a bit over time but much less than that for SC.

Table 4 shows a decomposition of the change in the average skill levels of exports and imports into two effects. This is derived as follows. The change in the average skill level generated by exports is given by:

$$(4) \quad [(S^1 L^{*1} e^2 / L^1 e^2 - S^1 L^{*1} e^1 / L^1 e^1) + (S^2 L^{*2} e^2 / L^2 e^2 - S^2 L^{*2} e^1 / L^2 e^1)] +$$

$$[(S^2 L^{*2} e^1 / L^2 e^1 - S^1 L^{*1} e^1 / L^1 e^{1)}) + (S^2 L^{*2} e^2 / L^2 e^2 - S^1 L^{*1} e^2 / L^1 e^2)]$$

where a superscript 1 indicates period 1 and a superscript 2 indicates period 2. The first term (the "trade effect") measures how much the average skill content of exports would have grown from the change in the composition of exports over the period (from e^1 to e^2), while holding technology constant. The second term (the "technology" effect) measures how much the average skill content of exports would have increased from the change in both the average skill level of export industries and their labor coefficients over the period, while holding export composition constant.[4]1 A similar decomposition can be used for the change in the average skill levels of imports.

Between 1950 and 1990, exports shifted toward industries with relatively high Substantive Complexity (SC) levels, such as industrial machinery, electrical equipment, and chemicals. This shift would have raised the average SC content of exports by 0.25 (see Panel A). Both changes in labor coefficients and changes in average SC levels within industry would have raised the

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[4] I use average weights to measure the two effects in order to provide an exact decomposition.

average SC score of exports by another 0.55 points, for a total change in SC of 0.80 over the period. Over the same period, imports shifted slightly toward higher cognitive skill industries, while changes in technology advanced the average SC level by 0.41, lower than that for exports. As a result, of the 0.35 increase in the difference of average SC levels between exports and imports over the four decades, 62 percent was due to changes in export and import composition and the other 38 percent to differences in changes of technology in export and import industries.

Over the 1950-90 period, exports moved slightly in favor of industries with higher interactive skill (IS) levels while imports shifted in favor of lower Interactive Skill industries. The technology effect was somewhat stronger for exports than imports, so that over three fourths of the widening gap in IS levels between exports and imports was due to the trade effect.

Table 4. Decomposition of the Change in Skill Levels Into A Trade Effect And a Technology Effect, 1950-1990

	Decomposition			Percentage Decomposition		
	Trade Effect	Tech. Effect	Total Change	Trade Effect	Tech. Effect	Total Change
A. Substantive Complexity (SC)						
Exports	0.25	0.55	0.80	32	68	100
Imports	0.04	0.41	0.46	9	91	100
Difference	0.21	0.13	0.35	62	38	100
B. Interactive Skills (IS)						
Exports	0.11	0.42	0.53	21	79	100
Imports	-0.11	0.36	0.25	-43	143	100
Difference	0.22	0.06	0.28	77	23	100
C. Motor Skills (MS)						
Exports	0.06	-0.16	-0.10	-55	155	100
Imports	0.22	-0.10	0.12	183	-83	100
Difference	-0.16	-0.06	-0.22	71	29	100

D. Mean Educational Attainment

Exports	0.09	3.48	3.57	2	98	100
Imports	0.05	3.38	3.43	1	99	100
Difference	0.04	0.10	0.13	27	73	100

Note: Decompositions are based on direct labor requirements only. Exports and Imports exclude wholesale and retail trade and transportation margins.

The average motor skill level in export industries declined by 0.10 between 1950 and 1990, while it rose by 0.12 in import industries. Interestingly, both imports and exports shifted in favor of higher motor skill industries but the shift was much stronger among imports (particularly in the 1950-1970 period). Technical change had a relatively small effect on motor skills in the 1950-1970 period but a strong negative effect in the later two decades, causing a greater reduction in motor skills among exporters than among import industries. As a result, about 70 percent of the 0.22 point decline in average motor skills between exports and imports over the four decades was due to a stronger shift of imports to high motor skill industries and the other fourth was due to the greater decline in motor skills among export than import industries.

The pattern for mean educational attainment is quite different. During the 1950-1990 period, both exports and imports shifted slightly in favor of industries with higher schooling levels (the latter due to the rapid decline in imports of agricultural and processed food products, both low schooling industries), and the effect was somewhat larger for exports. The technology effect was strong for both export and import industries but again slightly greater for exports. As a result, of the entire 0.13 increase in the difference in mean education between exports and imports over this period, almost three-fourths was due to the technology effect.

C. Information Workers

The next dimension I analyze is employment by type of worker. I divide workers into four groups: knowledge, data, service, and goods workers. Information workers are the sum of knowledge and data workers. The overall results show that exports are more intensive in their use of information workers than imports and less intensive in their employment of goods producing workers, and the difference has widened dramatically over time.

The basic data are from the U.S. Decennial Censuses of 1950, 1960, 1970 1980, and 1990. In the classification schema, professional and technical workers are generally classified as knowledge or data workers, depending on whether they are producers or users of knowledge. Management personnel are taken to perform both data and knowledge tasks, since they produce new information for administrative decisions and also use and transmit this information. Clerical workers are classed as data workers for obvious reasons. I classify as goods-processing workers all labor that transforms or operates on materials or physical objects. These include craft workers, operatives (including transportation workers who move physical goods), and unskilled labor. The remaining group is made up of the service workers, who, primarily, perform personal services (see Baumol, Blackman, and Wolff, 1989, Chapter 7, for more details on the classification scheme.)

Results, shown in Table 5, are based on the direct employment by occupation generated by exports (nE) and imports (nM). (See Appendix Table 2 for the direct plus indirect employment content). In 1950, exports were slightly more intensive in their use of knowledge workers than imports. The employment of knowledge workers generated directly by exports was 5.2 percent of the total employment directly generated by exports in 1950, compared to 4.4 percent for imports. The share of knowledge workers employed in the production of exports rose from 5.2 to 14.3 percent between 1950 and 1990 -- a gain of 9.1 percentage points. In contrast, the share of knowledge workers producing import substitutes expanded from 4.4 to 10.7 percent -- an increase of only 6.3 percentage points. As a result the gap between the share of knowledge workers employed in export versus import production widened from 0.8 to 3.6 percentage points between 1950 and 1990. It is also of note that the knowledge worker intensity of exports was below the economy-wide average from 1950 to 1980. However, by 1990, it exceeded the overall figure of 12.9 percent.

Table 5. Employment of Information and Goods Workers As a Percent of Total Employment Generated by Exports and Imports: Direct Labor Input Only, 1950-1990

Class of Worker	1950	1960	1970	1980	1990	Percentage Point Change 1950-1990
A. Knowledge Workers						
Exports	5.2	6.2	9.2	10.6	14.3	9.1
Imports	4.4	5.3	8.1	9.2	10.7	6.3
Difference	0.8	0.9	1.1	1.4	3.6	2.7
Total Economy	7.5	8	9.6	11	12.9	5.4
B. Data Workers						
Exports	18.4	18.8	24.3	28.9	31.8	13.4
Imports	16.6	16.8	23	25.9	26	9.4
Difference	1.7	2	1.3	3	5.7	4
Total Economy	29.2	34.2	39.6	41.5	41.9	12.7
C. Goods Workers						
Exports	73.1	69.5	60.8	54.4	47.7	-25.4
Imports	76.6	74.8	65.9	62.1	60.1	-16.5
Difference	-3.5	-5.4	-5	-7.6	-12.4	-8.9
Total Economy	51.7	43.5	36	31.4	29	-22.7

Note: The results are based on direct labor requirements only. Exports and imports exclude wholesale and retail trade and transportation margins. The figures show the direct employment of each class of worker generated by exports (or imports) as a percent of the total direct employment generated by exports (or imports). Service workers are omitted from the tabulation.

The pattern is quite similar for data workers. Exports are more intensive in their use of data workers than imports. While data workers as a share of the total workers producing exports climbed from 18 to 32 percent between 1950 and 1990, the share in producing import substitutes rose from 17 to 26 percent (see Panel B). As a result, the difference in the data worker share between exports and imports enlarged from 1.7 to 5.7 percentage points. Altogether, the gap between exports and imports in the share of information workers swelled from 2.6 to 9.3 percentage points over the four decades.

While exports are intensive in their use of information workers, imports are relatively intensive in goods producing workers, as shown in Panel C. It is first of note that both exports and import substitutes absorb a much higher share of goods workers than the overall economy -- a reflection of the heavy bias of international trade toward manufactures. In 1950, 76.6 percent of the employment generated by import substitutes was goods producing workers, compared to 73.1 percent for export producers -- a difference of 3.5 percent. As for the whole economy, the proportion of goods workers generated by both exports and imports declined over time. For exports, the share fell from 73.1 to 47.7 percent, a drop of 25.4 percentage points; for imports, the share fell much less, by 16.5 percentage points, from 76.6 to 60.1 percent. As a result, the difference between imports and exports in the share of good workers expanded substantially between 1950 and 1990, from 3.5 to 12.4 percentage points. The evidence clearly shows that U.S. exports are becoming relatively more intensive in their use of information workers over time while imports are becoming relatively more intensive in their use of blue-collar workers.

The decompositions shown in Table 6 identify some of the reasons for the changes in the relative share of information and goods workers in export and import industries. The change in the share of employment of a given class of worker generated by exports is given by:

(5) $[(p^1 L^{*1} e^2 / L^1 e^2 - p^1 L^{*1} e^1 / L^1 e^1) + (p^2 L^{*2} e^2 / L^2 e^2 - p^2 L^{*2} e^1 / L^2 e^1)] +$

$[(p^2 L^{*2} e^1 / L^2 e^1 - p^1 L^{*1} e^1 / L^1 e^1) + (p^2 L^{*2} e^2 / L^2 e^2 - p^1 L^{*1} e^2 / L^1 e^2)]$

where p is a row vector showing employment of a given class of worker (such as knowledge workers) as a share of industry employment. The first term (the "trade effect") shows the average effect of changes in export composition on employment shares and the second term (the "technology effect") shows the average effect of changes in both industry labor coefficients and industry skill levels on employment shares. A similar decomposition can be used for the share of employment by class of worker generated by imports.

Table 6. Decomposition of the Change in the Percentage Share of Information and Goods Workers In Total Employment Into a Trade and Technology Effect, 1950-1990

	Decomposition			Percentage Decomposition		
Class of Worker	Trade Effect	Tech. Effect	Total Change	Trade Effect	Tech. Effect	Total Change
A. Knowledge Workers						
Exports	2.1	7.0	9.1	23	77	100
Imports	2.0	4.3	6.3	32	68	100
Difference	0.1	2.6	2.7	3	97	100
B. Data Workers						
Exports	4.8	8.6	13.4	36	64	100
Imports	3.6	5.8	9.4	38	62	100
Difference	1.2	2.8	4.0	30	70	100
C. Goods Workers						
Exports	-7.1	-18.3	-25.4	28	72	100
Imports	-5.3	-11.2	-16.5	32	68	100

Difference	-1.8	-7.1	-8.9	20	80	100

Note: The decompositions are based on direct labor requirements only. Exports and imports exclude wholesale and retail trade and transportation margins. Service workers are omitted from the tabulation.

Between 1950 and 1990, both exports and imports shifted toward industries with a higher share of knowledge and data workers and a lower share of goods workers. The trade effect for knowledge workers was about the same for exports and imports but for data and goods workers the effects were stronger for exports than imports. The technology effects for both exports and imports were positive for knowledge and data workers and negative for good workers, but here the effects were considerably larger among export industries. Moreover, the technology effects dominated the trade effects for both exports and imports. As a result, of the 2.7 percentage point rise in the difference between exports and imports in the share of knowledge workers, over 95 percent was attributable to the faster growth of knowledge intensity in exports industries relative to import industries; of the 4.0 percentage point increase in the gap in the share of data workers, 70 percent was due to the technology effect; and of the 8.9 percentage point decline in the difference in the share of goods workers, 80 percent was ascribable to the technology effect.

D. Capital Intensity of Exports and Imports

Panel A of Table 7 shows the capital intensity of exports and import. This comparison forms the basis of the Leontief Paradox. Total net capital (in thousands of 1992 dollars) per worker of exports and import is given by: KE/LE and KM/LM, respectively. The results show a pronounced and continuous rise in the capital intensity of exports over the period from 1947 to 1996. In contrast, the capital intensity of imports rose steeply between 1947 and 1977 and then slipped from 1977 to 1997. The reason is the tremendous increase of oil imports during the 1970s (see Table 2), which is a very capital-intensive industry. Another important finding is that the capital intensity of both exports and imports was below the overall capital-labor ratio of the economy in 1947 but equal to or above overall capital intensity by 1996. Imports, in fact, exceeded the overall capital-labor ratio by 1958 and remained above average through 1996. This indicates a shifting of both exports and imports toward more capital intensive industries (primarily durable manufacturing).

Table 7. Capital and R&D Intensity of Exports And Imports: Direct Inputs Only, 1947-1996

Type of Capital	1947	1958	1967	1977	1987	1996	Ratio 1996/1947
A. Ratio of Total Net Capital ($1,000s of 1992 dollars) to Employment							
Exports	20.2	38.0	49.4	70.1	83.2	98.3	4.9
Imports	36.7	80.9	82.0	160.3	107.3	121.0	3.3
Ratio	0.55	0.47	0.60	0.44	0.78	0.81	
Total Economy	54.7	65.8	76.9	83.5	87.7	95.6	1.8
B. Ratio of Net Equipment ($1,000s of 1992 dollars) to Employment							
Exports	8.0	16.1	21.1	31.8	39.0	48.2	6.0
Imports	11.4	22.1	27.0	42.9	44.2	52.0	4.6
Ratio	0.70	0.73	0.78	0.74	0.88	0.93	
Total Economy	14.7	16.5	19.9	22.2	25.2	29.5	2.0
C. Ratio of OCA ($100s of 1992 dollars) to Employment [a]							
Exports	0.5	1.0	1.0	1.9	12.2	44.0	93.2
Imports	1.4	1.3	0.9	2.1	10.2	36.8	26.3
Ratio	0.34	0.78	1.05	0.93	1.19	1.20	
Total Economy	0.9	1.2	1.1	1.6	9.2	33.9	39.6
D. Ratio of R&D Expenditures to Net Sales (Percent) [b]							
Exports		1.96	2.18	1.79	3.49	2.87	1.47
Imports		0.70	1.07	1.60	3.23	2.92	4.19
Difference		1.26	1.11	0.19	0.26	-0.05	
Total Manufacturing		2.70	2.92	2.27	3.40	3.03	1.12

Note: The decompositions are based on direct labor requirements only. Exports and imports exclude wholesale and retail and transportation margins.
a. The government sector is not included.

b. R&D data are available only for manufacturing. The ratios are of 1996 to 1958.

The results show that, in fact, imports have been more capital intensive than exports (the "Leontief Paradox"). However, what is more telling is that the capital intensity of exports relative to imports, after falling between 1947 and 1977, climbed from 1977 to 1996. The capital intensity of exports rose by a factor of 4.9 between 1947 and 1996, compared to a 3.3-fold increase for imports. The capital intensity of exports relative to imports increased from a ratio of 0.55 in 1947 to 0.81 in 1996. These results thus indicate a gradual shifting of U.S. comparative advantage back toward capital intensive goods, particularly since 1977.

Panel B shows results for total net stocks of equipment per worker. Again, we find a continuous rise in the equipment intensity of both exports and imports between 1947 and 1996. In 1947, both exports and imports were less equipment intensive than the overall economy but by 1958 imports had exceeded and by 1967 exports had exceeded the economy-wide equipment per worker ratio. The results also show the equipment intensity of exports rising faster than that of imports over the years 1947 to 1996. Equipment per worker in export industries increased six-fold over this period, compared to a factor of 4.6 for imports. As a result, the equipment intensity of exports relative to imports grew from a ratio of 0.70 in 1947 to 0.93 in 1996, with most of the gain occurring after 1977. Thus, while imports have continued to remain more equipment intensive than exports, comparative advantage is clearly shifting back toward industries with a high equipment to worker ratio.

The results are even more dramatic for OCA per worker (see Panel C). The OCA intensity of exports has grown much faster than that of imports between 1947 and 1996. Moreover, while imports were more intensive in OCA than exports in 1947, the situation reversed since The OCA intensity of exports relative to imports climbed from a ratio of 0.34 in 1947 to 0.78 in 1958, 1.19 in 1987, and 1.20 in 1996. U.S. comparative advantage now lies in industries that intensively use office and computing equipment.

Appendix Table 3 shows the direct and indirect labor and capital content of exports and imports. The patterns are striking similar, though (as in earlier tables) the difference in the capital intensity of exports and imports is now more attenuated. The total (direct plus indirect) capital intensity and equipment intensity of imports remained greater than that of exports, though the differences narrowed sharply over the years from 1947 to 1996. Indeed, the equipment intensity of exports relative to imports was close to reaching parity by 1996. Moreover, the direct plus indirect OCA intensity of exports exceeded that of imports by 1967.

Table 8. Decomposition of the Change in Capital and R&D Intensity Into A Trade Effect And A Technology Effect, 1947-1996

	Decomposition			Percentage Decomposition		
Type of Capital	Trade Effect	Tech. Effect	Total Change	Trade Effect	Tech. Effect	Total Change
A. Total Net Capital ($1,000s of 1992 dollars) per Worker						
Exports	-0.9	79.0	78.1	-1	101	100
Imports	-68.6	152.9	84.3	-81	181	100
Ratio	0.23	0.04	0.26	86	14	100
B. Total Equipment ($1,000s of 1992 dollars) per Worker						
Exports	-3.1	43.4	40.2	-8	108	100
Imports	-21.5	62.1	40.6	-53	153	100
Ratio	0.26	-0.03	0.22	114	-14	100
C. Total OCA ($100s of 1992 dollars) per Worker						
Exports	7.3	36.2	43.5	17	83	100

Imports	15.8	19.6	35.4	45	55	100
Ratio	-1.15	2.01	0.86	-135	235	100
D. Ratio of R&D Expenditures to Net Sales (Percentage Points) [a]						
Exports	1.04	-0.13	0.91	114	-14	100
Imports	2.17	0.05	2.22	98	2	100
Difference	-1.13	-0.18	-1.31	86	14	100

Note: The decompositions are based on direct labor, capital, and R&D requirements only. Exports and imports exclude wholesale and retail trade and transportation margins.
a. R&D data are available only for manufacturing. The decomposition covers years 1958 to 1996 only.

The decompositions in Table 8 highlight some of the reasons for this remarkable turnaround in the capital intensity of exports relative to imports. The change in the capital-labor ratio generated by exports is given by:

$$(6) \quad [(K^1 L^{*1} e^2 / L^1 e^2 - K^1 L^{*1} e^1 / L^1 e^1 + (K^2 L^{*2} e^2 / L^2 e^2 - K^2 L^{*2} e^1 / L^2 e^1)] + [(K^2 L^{*2} e^1 / L^2 e^1 - K^1 L^{*1} e^1 / L^1 e^1) + (K^2 L^{*2} e^2 / L^2 e^2 - K^1 L^{*1} e^2 / L^1 e^2)]$$

where, as before, the first bracketed term is the trade effect and the second bracketed term is the technology effect, showing the average effect of changes in labor and capital coefficients on the capital-labor ratio. A similar decomposition can be used for imports.

As shown in Panel A, the ratio of total net capital per worker generated by exports increased by $78,100 (in 1992 dollars) between 1947 and 1977. Of this, $79,000 (or 101 percent) was accounted for by the rising capital intensity of export industries. Changes in export composition had almost no effect. Technical change in import industries had an even stronger effect on the increase in the capital-labor ratio generated by imports in this period, accounting for $152,900 (or 181 percent) of the total gain of $84,300. However, imports shifted away from capital intensive industries (mainly agriculture and primary metal products) toward low capital intensive ones (primarily industrial machinery, electrical equipment, and motor vehicles), accounting for a $68,600 decline in the capital-labor ratio of import industries. As a result, 86 percent of the growth in the capital intensity of exports relative to imports was due to changes in export and import composition (almost exclusively the latter), and only 14 percent due to changes of technology in the export and import industries.

Results are even stronger for the equipment per worker (Panel B). In this case, the ratio of the equipment intensity of exports to imports rose from 0.70 in 1947 to 0.93 in 1996. The change in the equipment to employment ratio generated by exports of $40,200 was exclusively due to the rising capital intensity of export industries. In contrast, the rising equipment intensity of imports, amounting to $40,600, was due both to the rising capital intensity of import industries and the negative effects of changing import composition. The growth of the ratio in equipment intensity between exports and import over this period emanated almost entirely from changes in import composition.

The pattern is different for OCA per worker. The ratio of OCA intensity of exports relative to imports increased from 0.45 in 1947 to 1.07 in 1996. The evidence here indicates that the composition of exports shifted toward industries that were intensive in their use of computers and office machinery, accounting for 17 percent of the total growth of OCA per worker of $4,350 over the 1947-1996 period. The other 83 percent was due to the rising investment in OCA per worker in export industries. Imports likewise shifted toward computer intensive industries, particularly after 1977. Over the full 1947-1996 period, 45 percent of the overall gain of $3,540 in OCA per worker among import industries was attributable to changes in import composition and the other 55 percent to increases in capital intensity in import industries. Over the half century, imports shifted more strongly toward computer intensive industries than exports, while computer intensity rose much faster in export industries than import industries. As a result, the rise in the ratio of OCA intensity in exports relative to imports over this period was due entirely to the faster growth of OCA per worker in export industries than in import industries, while shifts in export and import composition had a negative effect on the ratio.

E. R&D Intensity of Exports and Imports

Panel D of Table 7 shows both R&D expenditures generated by exports and imports as a percent of net sales. Direct R&D expenditures as a percent of net sales of exports is given by: RE/**1**E, where **1** is a row vector of ones; direct R&D expenditures as a percent of net sales of imports is given by: RM/**1**M.

The results are surprising. The (direct) R&D intensity of U.S. exports in 1958 was almost three times as great as that of imports. The R&D intensity of both exports and imports increased between 1958 and 1987 and then fell off somewhat in 1996. However, over the 1958 to 1996, R&D intensity rose much faster for imports than exports -- a factor of 4.2 versus 1.5. As a result, by 1996, the R&D intensity of imports was slightly greater than that of exports. Interestingly, neither exports nor imports were as R&D intensive as overall manufacturing, except for exports in 1987.

The decomposition shown in Panel D of Table 8 indicate some of the reasons behind the falling R&D intensity of export industries relative to import industries. The decomposition of the change in the R&D expenditures as a ratio to net sales generated by exports is given by

(7) $(R^1 + R^2)(e^2 - e^1)/2 + (e^1 + e^2)(R^2 - R^1)/2$

The first term is the trade effect and the second term (the "technology effect") shows the average effect of changes in industry R&D coefficients on overall R&D intensity. A similar decomposition can be used for the R&D intensity of imports.

The effects of the changing composition of exports and imports explain almost the entirety of the decline in the ratio of R&D expenditures of exports relative to imports. Between 1958 and 1996, both exports and imports shifted toward more R&D intensive industries but the shift effect was twice as great for imports. Export growth was particularly strong in electrical and electronic equipment and scientific instruments, while imports gained share in motor vehicles, electrical and electronic equipment, chemicals, scientific instruments, and especially industrial machinery. Moreover, overall R&D expenditures in manufacturing, after declining from 2.70 percent of net sales in 1958 to 2.27 percent in 1977, increased to 3.03 percent in 1996. On net, the change in R&D coefficients (the technology effect) essentially washed out between the two periods, so that almost the entirety of the growth in R&D intensity of both exports and imports is explained by changes in trade composition. The fact that the trade effect was much stronger for imports than exports explains 86 percent of the elimination of the gap in R&D intensity between exports and imports.

F. Labor Costs and Labor Productivity of Exports and Imports

The final part of the analysis considers the average labor costs of both exports and imports. According to Ricardian trade theory, a country will export those products whose cost is relatively low and import those products whose cost is relatively high. Though the relevant comparison is with other trading countries, it might still be expected that a country will export the products of those industries that pay relatively low wages and import the products of industries with high wages.

The results, shown in Table 9, are a bit surprising. Average wages generated directly by exports is given by: WE/LE, where W is a row vector showing average employee compensation per full-time equivalent employee (FTEE) in 1992 dollars by industry. Average wages generated by imports is given by: WM/LM. The unit labor cost of industry i is defined here as the ratio of average employee compensation per FTEE (in 1992 dollars) in industry i to labor productivity (the ratio of GDP in 1992 dollars to FTEE) in industry i. The average unit labor cost generated by exports is given by: WE/**1**E; and the average unit labor cost generated by imports is given by: WM/**1**M.

Panel A looks at employee compensation per full-time equivalent employee (FTEE). In 1947 export industries were paying 6 percent more than import industries. By 1977, average wages in export industries were 5 percent below those in industries producing domestic substitutes for imports. Between 1977 and 1996, the situation reversed and average wages among exports rose relative to import industries. By 1996, export industries were paying 6 percent more than import substituting industries, exactly the same difference as in 1947.

Table 9. Labor Costs of U.S. Exports And Imports: Direct Labor Input Only, 1947-1996

Labor Cost	1947	1958	1967	1977	1987	1996	Ratio 1996/1947
A. Employee Compensation per FTEE ($1,000s of 1992 dollars)							
Exports	16.1	21.8	28.3	36.4	41.2	43.1	2.7
Imports	15.2	21.5	28.6	38.3	40.6	40.5	2.7
Ratio	1.06	1.01	0.99	0.95	1.01	1.06	
Total Economy	15.8	21.5	27.0	32.6	34.7	34.8	2.2
B. Employee Compensation plus Half Proprietors' Income per PEP ($1,000s of 1992 dollars)							
Exports	16.3	21.9	28.2	36.4	40.9	43.0	2.6
Imports	15.5	21.6	28.4	38.7	40.2	39.7	2.6
Ratio	1.05	1.02	0.99	0.94	1.02	1.08	
Total Economy	15.0	20.4	26.3	31.7	33.1	33.7	2.3

C. Output (GDP) per FTEE ($1,000s of 1992 dollars)							
Exports	21.4	28.7	38.0	45.3	59.9	75.0	3.5
Imports	25.8	33.0	39.8	53.5	55.9	69.5	2.7
Ratio	0.83	0.87	0.96	0.85	1.07	1.08	
Total Economy	30.1	38.1	46.3	53.1	57.5	61.1	2.0
D. Unit Labor Cost							
Exports	0.75	0.76	0.74	0.81	0.69	0.57	0.80
Imports	0.59	0.65	0.72	0.72	0.73	0.58	1.00
Difference	0.16	0.10	0.03	0.09	-0.04	-0.01	
Total Economy	0.53	0.56	0.58	0.61	0.60	0.57	1.10

Note: The decompositions are based on direct labor, capital, and R&D requirements only. Exports and Imports exclude wholesale and retail trade and transportation margins.
Key:
FTEE: Full-time equivalent employees
PEP: Persons engaged in production

It is also of note that in 1947, export industries paid higher than the average wage and import industries lower than the average wage. However, average compensation in both import and export industries grew faster than overall wages, so that by 1996 exporting and importing industries were both paying higher than the overall average wage.

Panel B shows another measure of labor costs, employee compensation plus half of proprietors' income per person engaged in production (PEP). Results are almost identical. By this measure, exporters paid 5 percent higher wages than import industries in 1947 and 8 percent higher wages in 1996. [5]1

Panel C shows average labor productivity in export and import industries. Between 1947 and 1996, labor productivity grew much faster in export than import industries: 2.6 versus 2.0 percent per year. In 1947, output per FTEE was 21 percent higher for imports than exports; but in 1996, it was 8 percent higher for exports. Labor productivity also grew faster among both exports and

[5] A third measure, wages and salaries per full-time equivalent employee also shows almost exactly the same pattern (results not shown).

imports than in the total economy over the 49-year stretch, because of the heavy concentration of manufactured goods in trade. In 1947, output per worker for both exports and imports was lower than the economy-wide average; but by 1996, the situation had completely reversed.

Changes in unit labor cost reflects both changes in worker compensation and labor productivity (Panel D). We find, as with other measures of wages, that in 1947 export industries had higher unit labor cost than domestic substitutes of imports. However, in this case, we see an almost continuous decline in the unit labor cost of export industries relative to import industries between 1947 and 1996. By 1996, unit labor costs of exports were slightly below those of import industries.

4. Conclusions

The composition of both exports and imports have changed considerably over the postwar period. In 1947, the most important U.S. exports in rank order (excluding wholesale and retail trade and transportation services) were food products, agricultural products, industrial machinery, primary metal products, motor vehicles, and textiles. Of this group, only industrial machinery could be considered high-tech and only motor vehicles medium-tech. By 1996, industrial machinery exports ranked first, followed by electrical and electronic equipment, motor vehicles, chemicals, and other transportation equipment such as aircraft. These are all high-tech or medium-tech industries.

In 1947 the leading import was, by far, processed foods and food products, followed by agricultural products, paper and paper products, primary metal products, and metal mining. These were all low-tech industries. In 1996, the three leading imports were motor vehicles, industrial machinery, and electric and electronic equipment, all medium- or high-tech. So, while U.S.

exports shifted over time away from low-tech industries and toward medium- and high-tech ones, the shift was even more pronounced for U.S. imports.

The main result is that U.S. comparative advantage lies in cognitive and interactive skill intensive products, and the comparative advantage in cognitive and interactive skills increased between 1950 and 1990. The finding of a higher skill content of exports than imports is consistent with the results of Lee and Schluter (1999), though Lee and Schluter did not find that the gap widened over time. With the exception of 1950, imports have been more motor skill intensive than exports and the difference has also widened over this period. Workers employed in export industries have had a higher mean schooling level than those in import industries, and the gap increased somewhat over time but much less than that for cognitive skills. The widening gap in cognitive, interactive, and motor skills between exports and imports is primarily due to changes in the composition of exports and imports. However, the technology effect explained about three-quarters of the slightly faster increase of mean schooling among exports than imports.

The results also show that exports are more intensive in their use of knowledge and data workers than imports and less intensive in their employment of goods producing workers, and the difference has widened dramatically over time The dominant factor explaining changes in the relative intensity of exports and imports with regard to information and goods producing workers is changes in the technology, rather than shifts in the composition of trade.

The results here provide new confirmation that imports are more capital intensive than exports. However, the capital intensity of exports relative to imports has been climbing since 1977. The results also show that imports are more equipment intensive than exports and that the equipment intensity of exports rose faster than that of imports over these years. The OCA intensity of exports has also grown much faster than that of imports and by 1987 exports were more OCA intensive than imports. These results thus indicate a gradual shifting of U.S. comparative advantage back toward capital intensive goods since 1977 and particularly toward industries with a high equipment and OCA intensity.

The decomposition analysis indicates that almost all the growth in the total capital and equipment intensity of exports relative to imports over the years 1947 to 1996 was due to changes in export and import composition (almost exclusively the latter). In contrast, the increase in the OCA intensity of exports relative to imports over this period was due entirely to the faster growth of OCA per worker in export industries than import industries, while shifts in export and import composition had a negative effect on the ratio.

While in 1958 the (direct) R&D intensity of U.S. exports was almost three times as great as that of imports, by 1996 the R&D intensity of imports was slightly greater than that of exports. The decompositions show that almost the entirety of the growth in R&D intensity in imports relative to exports is explained by changes in trade composition -- particularly, growing imports of motor vehicles, industrial machinery, electrical equipment, chemicals, and scientific instruments over these years.

There is no indication that average wages or employee compensation grew faster in import than export industries, as might be expected by the Ricardian theory of comparative advantage. However, labor productivity rose faster in export than import industries between 1947 and 1996: 2.6 versus 2.0 percent per year. As a result, the unit labor cost of export industries declined almost steadily relative to import industries between 1947 and 1996, as Ricardian theory would predict.

In sum, we find that the United States exports cognitive and interactive skills and imports motor skills. It also substitutes information for blue-collar workers. Moreover, the gap in skill and information content between exports and imports has been widening over time. These results implicitly suggest that the occupational structure of the American workforce has been shifting faster into cognitive skill intensive jobs, knowledge and data jobs and away from motor skill intensive and blue-collar jobs than those of other advanced industrial countries (for example, in contrast to Germany, as Engelbrecht, 1996, found).

American exports embody a higher level of schooling than do its imports, but while the gap has increased over time, it has risen much slower than that of cognitive skills. The likely reason is that other OECD countries have experienced a rapid catch-up in educational attainment. Evidence of this is provided in Wolff (forthcoming). Yet, a growth in educational attainment does not necessarily correlate with an increase in cognitive skills in the workplace, particularly if schooling is more and more performing a screening function rather than a skill augmentation role.

With regard to the gradual loss of comparative advantage in R&D intensive products, this also reflects a catch up in R&D by other OECD countries. Indeed, by 1995, Japan had overtaken the United States in R&D intensity. According to National Science Board (1998), Japan's R&D intensity (the ratio of R&D expenditures to GDP) has steadily grown since 1980 and by 1995 Japan had the highest R&D intensity in the G-7 (2.78 percent compared to 2.52 percent in the U.S., 2.28 percent in Germany, 2.34 percent in France, and 2.05 percent in the U.K.).

While the United States no longer has the edge in R&D and may lose it in education, it has taken the lead in another aspect of high-tech production, computer intensity and is gradually reclaiming its advantage in total capital and equipment intensity. This is likely a reflection of the gradual erosion in the human capital advantage of the United States vis-a-vis other OECD countries. For the moment, complementarities between OCA and both cognitive skills and knowledge worker jobs (see Wolff, 1996) may account for the lower capital intensity of exports than imports. However, the trends also suggest that the Leontief paradox may be overturned in the near future. However, this may create a new paradox, since the U.S. is no longer the most capital abundant country in the world (according to the OECD International Sectoral Database, in 1995 the U.S. ranked behind Germany, the Netherlands, and Belgium in overall capital intensity).

The results on productivity and labor costs are consistent with my earlier studies (Dollar and Wolff, 1993, and Wolff, 1995, 1997, and 1999), which found on the basis of cross national evidence that changes in industry net exports were positively related to industry productivity growth and negatively related to changes in unit labor cost. They also provide support to the technology gap model of trade. On the other hand, these results, together with the findings on capital and R&D intensity, are hard to reconcile with the standard (and static) HOV model. However, they do appear potentially consistent with the Trefler variant of the HOV model, which allows for factor price and unit labor costs differences across countries.

References

Amable, B., and Bart Verspagen (1995), "The Role of Technology in Market Share Dynamics", **Applied Economics**, 27, 197-204.

Balassa, Bela (1965), "Trade Liberalization and 'Revealed' Comparative Advantage," **The Manchester School**, 33, May, 99-123.

Baumol, William J., Sue Anne Batey Blackman, and Edward N. Wolff (1989), **Productivity and American Leadership: The Long View**, Cambridge, MA: MIT Press.

Bowen, Harry P., Edward E. Leamer, and Leo Sveikauskas (1987), "Multicountry, Multifactor Tests of the Factor Abundance Theory," **American Economic Review**, 77(5), December, pp. 791-809.

Caves, Richard E. (1960), **Trade and Economic Structure: Models and Methods**, Cambridge, MA: Harvard University Press.

Deardorff, A.V. (1982), "The General Validity of the Heckscher-Ohlin Theorem," **American Economic Review**, Vol. 72, pp. 683-694.

Dollar, David, and Edward N. Wolff (1993), **Competitiveness, Convergence, and International Specialization**, Cambridge, MA: MIT Press.

Dosi, Giovanni, Keith P., and Luc Soete (1990), **The Economics of Technical Change and International Trade**, London: Harvester Wheatsheaf.

Engelbrecht, Hans-Jurgen (1996), "The Composition of the Human Capital Stock and the Factor Content of Trade: Evidence from West(ern) Germany," **Economic System Research**, 8(3), pp. 271-297.

Fagerberg, Jan .E. (1988), "International Competitiveness," **Economic Journal**, 98, June, pp. 355-374.

Heckscher, Eli ([1919] 1949), "The Effect of Foreign Trade on the Distribution of Income," reprinted in H.S. Ellis and L.A. Metzler editors, **Readings in the Theory of International Trade**, Homewood, Illinois: Richard D. Irwin, Inc., pp. 272-300.

Keesing, Donald B. (1965), "labor Skills and International Trade: Evaluating Many Trade Flows with a Single

Measuring Device," **Review of Economics and Statistics**, 47(3), August, pp. 287-294.

Lawson, Anne M. (1997), "Benchmark Input-Output Accounts for the U.S. Economy, 1992," **Survey of Current Business**, Vol. 77, No. 11, November, pp. 36-83.

Leamer, E. (1984), **Sources of International Comparative Advantage**, Cambridge, MA: MIT Press.

Lee, Chinkook, and Gerald Schluter (1999), "Effect of Trade on the Demand for Skilled and Unskilled Workers," **Economic System Research**, 11(1), 49-65.

Leontief, Wassily (1956), "Factor Proportions and the Structure of American Trade: Further Theoretical and Empirical Analysis," **Review of Economics and Statistics**, 38(4), November, pp. 386-407.

------- (1964), "International Comparisons of Factor Cost and Factor Use," **American Economic Review**, 54, pp. 335-345.

MacDougall, G.D.A. (1951), "British and American Exports: A Study Suggested by the Theory of Comparative Costs, Part I," **Economic Journal**, 61, December, pp. 697-724.

---------, (1952), "British and American Exports: A Study Suggested by the Theory of Comparative Costs, Part II," **Economic Journal**, 62, September, pp. 487-521.

National Science Board (1998), **Science & Engineering Indicators - 1998**, Arlington, VA: National Science Foundation, (NSB 98-1).

Ohlin, Bertil (1933), **Interregional and International Trade**, Cambridge, MA: Harvard University Press.

Posner, M. (1961) "International Trade and Technical Change," **Oxford Economic Papers**, 13(3), October, 323-341.

Trefler, Daniel (1993), "International Factor Price Differences: Leontief Was Right!" **Journal of Political Economy**, 101, pp. 961-987.

------- (1995), "The Case of Missing Trade and other Mysteries," **American Economic Review**, 85, pp. 1029-1046.

Vanek, J. (1968), "The Factor Proportions Theory: the N-Factor Case," **Kyklos**, 21(4), pp. 749-756.

Verspagen, Bart, and Wakelin, K., (1997), "Trade and Technology from a Schumperterian Perspective" **International Review of Applied Economics**, 11(2), May, pp. 181-194.

Wolff, Edward N. (1995), "Technological Change, Capital Accumulation, and Changing Trade Patterns Over the Long Term", **Structural Change and Economic Dynamics**, 6(1), March, pp. 43-70.

----- (1996), "Technology and the Demand for Skills", **OECD Science, Technology and Industry Review**, 18, pp. 96-123.

----- (1997) "Productivity Growth and Shifting Comparative Advantage on the Industry Level", in Jan Fagerberg, Par Hansson, Lars Lundberg, and Arne Melchior eds., **Technology and International Trade**, Edward Elgar Publishing Ltd, pp. 1-19.

----- (1999), "Specialization and Productivity Performance In Low-, Medium-, and High-Tech Manufacturing Industries" in Alan Heston and Robert E. Lipsey eds., **International and Interarea Comparisons of Prices, Income,**

and Output, Studies of Income and Wealth Vol. 61, Chicago University Press (NBER), pp. 419-452.

----- (forthcoming), "Human Capital Investment and Economic Growth: Exploring the Cross-Country Evidence", **Structural Change and Economic Dynamics**.

Data Appendix

1. NIPA employee compensation: Figures are from the National Income and Product Accounts (NIPA), available on the Internet. Employee compensation includes wages and salaries and employee benefits. Proprietors' income is net income to self-employed persons, including partners in businesses and owners of unincorporated businesses.

2. NIPA employment data: Full-time equivalent employees (FTEE) equals the number of employees on full-time schedules plus the number of employees on part-time schedules converted to a full-time basis. The number of full-time equivalent employees in each industry is the product of the total number of employees and the ratio of average weekly hours per employee for all employees to average weekly hours per employee on full-time schedules. Persons engaged in production (PEP) equals the number of full-time and part-time employees plus the number of self-employed persons. Unpaid family workers are not included.

3. Capital stock figures are based on chain-type quantity indexes for net stock of fixed capital in 1992$, year-end estimates. Source: U.S. Bureau of Economic Analysis, CD-ROM NCN-0229, "Fixed Reproducible Tangible Wealth of the United States, 1925-97."

4. Research and development expenditures performed by industry, including company, federal, and other sources of funds. Company-financed R&D performed outside the company is excluded. Industry series run from 1957 to 1997. Source: National Science Foundation, Internet. For technical details, see National Science Foundation, **Research and Development in Industry**, (Arlington, VA: National Science Foundation), NSF96-304, 1996.

5. The original input-output data are 85-sector U.S. input-output tables for years 1947, 1958, 1963, 1967, 1972, 1977, 1982, 1987, 1992, and 1996 (see, for example, Lawson, 1997, for details on the sectoring). The 1947, 1958, and 1963 tables are available only in single-table format. The 1967, 1972, 1977, 1982, 1987, 1992, and 1996 data are available in separate make and use tables. These tables have been aggregated to 45 sectors for conformity with the other data sources.

The 1950, 1960, 1970, 1980, and 1990 input-output tables are estimated from the benchmark U.S. input-output tables. The 1950 table is interpolated from the 1947 and 1958 input-output tables; the 1960 table is interpolated from the 1958 and 1963 input-output tables; the 1970 table is interpolated from the 1967 and 1972 input-output tables; the 1980 table is interpolated from the 1977 and 1982 input-output tables; and the 1990 table is interpolated from the 1987 and 1992 input-output tables.

6. Imports and exports. Sources for the industry level data are U.S. input-output data for years 1947, 1958, 1963, 1967, 1972, 1977, 1982, 1987, 1992, and 1996. The data are interpolated for years 1950, 1960, 1970, 1980, and 1990.

Appendix Table 1. Average Skill Content of U.S. Exports and Imports: Direct Plus Indirect Labor Input, 1950-1990

Skill Type	1950	1960	1970	1980	1990	Percent Change 1950-1990
A. Substantive Complexity (SC)						
Exports	3.44	3.59	3.76	3.92	4.15	20.5
Imports	3.39	3.42	3.59	3.73	3.84	13.3
Difference	0.05	0.16	0.18	0.19	0.30	
Total Economy	3.75	3.81	4.07	4.23	4.38	16.9
B. Interactive Skills (IS)						
Exports	1.45	1.55	1.63	1.74	1.94	34.3
Imports	1.45	1.46	1.51	1.61	1.74	20.2
Difference	0.00	0.09	0.12	0.13	0.20	
Total Economy	2.19	2.21	2.27	2.31	2.37	8.0
C. Motor Skills (MS)						
Exports	5.37	5.37	5.39	5.38	5.25	-2.3
Imports	5.28	5.34	5.43	5.42	5.32	0.9
Difference	0.09	0.04	-0.03	-0.04	-0.08	
Total Economy	5.11	5.13	5.17	5.10	5.01	-1.9
D. Mean Educational Attainment						

Exports	9.26	10.14	11.00	12.14	12.82	38.5
Imports	9.00	9.97	10.91	12.00	12.57	39.7
Difference	0.26	0.17	0.10	0.13	0.25	
Total Economy	9.40	10.30	11.50	12.50	13.00	38.3

Note: Exports and imports exclude wholesale and retail trade and transportation margins. The average direct plus indirect skill content of exports and imports is given by $SL^*(I-A)^{-1}E/L(I-A)^{-1}E$ and $SL^* (I-A)^{-1}M/L(I-A)^{-1}M$, respectively.

Appendix Table 2. Employment of Information and Goods Workers as a Percent of Total Employment Generated by Exports and Imports: Direct Plus Indirect Labor Input, 1950-1990

Class of Worker	1950	1960	1970	1980	1990	Percentage Point Change 1950-1990
A. Knowledge Workers						
Exports	5.2	6.5	9.0	10.7	13.9	8.7
Imports	4.4	5.7	8.2	9.8	11.5	7.0
Difference	0.8	0.7	0.8	0.9	2.4	1.6
Total Economy	7.5	8.0	9.6	11.0	12.9	5.4
B. Data Workers						
Exports	18.9	21.0	25.7	30.4	32.4	13.5
Imports	16.5	19.3	24.7	28.8	28.5	12.0
Difference	2.4	1.6	1.0	1.6	3.9	1.5
Total Economy	29.2	34.2	39.6	41.5	41.9	12.7
C. Goods Workers						
Exports	71.4	65.4	57.8	50.6	44.9	-26.6
Imports	75.4	69.4	61.2	54.9	53.3	-22.2
Difference	-4.0	-4.0	-3.4	-4.3	-8.4	-4.4
Total Economy	51.7	43.5	36.0	31.4	29.0	-22.7

Note: Exports and imports exclude wholesale and retail trade and transportation margins. The total (direct plus indirect) employment by occupation generated by exports and imports is given by: $n(I - A)^{-1}E$ and $n(I-A)^{-1}M$, respectively.

Appendix Table 3. Capital and R&D Intensity of U.S. Exports And Imports:
Direct plus Indirect Capital, Labor, and R&D Input, 1947-96

Type of Capital	1947	1958	1967	1977	1987	1996	Ratio 1996/1947
A. Ratio of Total Net Capital ($1,000s of 1992 dollars) to Employment							
Exports	29.4	51.0	63.5	87.2	93.7	103.8	3.53
Imports	34.6	71.0	81.7	129.2	102.1	114.1	3.29
Ratio	0.85	0.72	0.78	0.67	0.92	0.91	
Total Economy	54.7	65.8	76.9	83.5	87.7	95.6	1.75
B. Ratio of Net Equipment ($1,000s of 1992 dollars) to Employment							
Exports	9.4	17.5	23.1	34.7	38.9	46.2	4.91
Imports	10.5	20.3	26.4	39.0	40.7	47.5	4.51
Ratio	0.89	0.86	0.87	0.89	0.96	0.97	
Total Economy	14.7	16.5	19.9	22.2	25.2	29.5	2.01
C. Ratio of OCA ($100s of 1992 dollars) to Employment [a]							
Exports	0.5	0.9	0.9	1.7	10.8	40.5	78.26
Imports	0.9	1.1	0.8	1.7	9.0	34.6	37.98
Ratio	0.57	0.87	1.01	1.01	1.20	1.17	
Total Economy	0.9	1.2	1.1	1.6	9.2	33.9	39.64
D. Ratio of R&D Expenditures to Net Sales (Percent) [b]							
Exports	1.77	1.91	1.51	2.61	2.15	1.21	
Imports	0.89	1.18	1.37	2.55	2.17	2.44	
Difference	0.88	0.73	0.14	0.07	-0.03		

Total Manufacturing	2.70	2.92	2.27	3.40	3.03	1.12

Note: Exports and imports exclude wholesale and retail trade and transportation margins. The total direct plus indirect employment and capital generated by exports is given by $L(I-A)^{-1}E$ and $K(I-A)^{-1}E$, . respectively. The total employment and capital generated by imports is given by $L(I-A)^{-1}M$ and $K(I-A)^{-1}M$, respectively. .

a. The government sector is not included.

b. R&D data are available only for manufacturing. The total (direct plus indirect) R&D intensity of exports and imports is given by: $R(I - A)^{-1}E/\mathbf{1}(I - a)^{-1}E$ and $R(I-A)^{-1}M/\mathbf{1}(I-A)^{-1}M$, respectively. The ratios are 1996 to 1958.