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Chapter Author: Peter B.. Kenen

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EDUCATION AND HUMAN CAPITAL IN INTERNATIONAL ECONOMICS

SKILLS, HUMAN CAPITAL, AND COMPARATIVE ADVANTAGE •

PETER B. KENEN • COLUMBIA UNIVERSITY

This paper will deal with two important questions: (1) What have we already learned about the role of skills, human capital or, more broadly, knowledge, in determining national comparative advantage and, therefore, the structure of external trade? (2) What are the chief implications of the facts we have at hand, and what do we need to learn, whether by the speculative methods of the theorist or the patient efforts of the empiricist? My answers to these questions will be incomplete. I shall, indeed, spend more time posing a series of subsidiary questions under each main rubric than answering the two I have already asked. This exercise, however, may inspire new research on what may be the most exciting single issue facing specialists in foreign trade and those who are concerned with problems of development.

RESEARCH ON HUMAN CAPITAL AND FOREIGN TRADE

RESEARCH on this subject stems from two quite different papers by Kravis and Leontief.[1] The former, on wage rates in major trading industries, found that, in the U. S. case, the chief export industries pay somewhat

NOTE: I am grateful to Carol Gerstl and Constantin Voivodas for research assistance, and to the International Economics Workshop, Columbia University, for constructive criticism. Remaining blunders are my own.

[1] Irving Kravis, "Wages and Foreign Trade," *Review of Economics and Statistics*, February 1956; and Wassily W. Leontief, "Domestic Production and Foreign Trade: The American Capital Position Re-examined," reprinted in *Readings in International Economics*, R. E. Caves and H. G. Johnson (eds.), Homewood, Ill., 1968.

higher wage rates than import competitors. The latter found that U. S. trade is, on balance, labor using and, paradoxically, capital conserving. Kravis gave no explanation for his results, which seem superficially to contradict common views. Leontief, disturbed that the United States, a capital-rich country, could disobey the famous Heckscher-Ohlin theorem, offered a tentative rationalization. American labor, he suggested, is three times as efficient as foreign labor, the difference being due to "entrepreneurship and superior organization," rather than cooperation with abundant capital.[2]

Subsequent research inspired by these papers suggests that both phenomena—high wages and relative labor intensity in U. S. export industries—have a single cause: the substantial use of skill in U. S. export industries or, in current parlance, the intensive use of human capital.

A recent paper by Helen Waehrer reproduces Kravis' work for 1960 and tests it for significance.[3] She finds that twenty-two major export industries pay a yearly wage of $5,649, while an equal number of import competitors pay only $4,932. Further, there is a statistically significant relationship between an industry's trade balance, B, and its yearly wage, W.[4] Taking all major trading industries together:

$$B = -18.48 + 0.003\,W \qquad r = 0.43$$

Waehrer goes on to ask why this is so, and generates two more significant regressions that shed new light on Kravis' problem. Constructing an occupational index, I, to measure the fraction of each industry's labor force employed in jobs that call for skill,[5] she shows that:

$$B = 16.15 + 0.31\,I \qquad r = 0.50$$

while

$$W = 1923.4 + 67.89\,I \qquad r = 0.86$$

[2] Wassily W. Leontief, "Domestic Production and Foreign Trade," p. 525.

[3] Helen Waehrer, "Wage Rates, Labor Skills, and United States Foreign Trade," in *The Open Economy: Essays on International Trade and Finance*, P. B. Kenen and R. Lawrence (eds.), New York, 1968, especially pp. 23, 30 and 37. Waehrer's paper derived from her dissertation (Columbia, 1966).

[4] Waehrer's trade balance, B, is the difference between exports and imports, divided by industry shipments. It differs from the index B_i used later in this paper; B_i is divided by the sum of exports and imports.

[5] Waehrer's skill index, I, is the sum of professional, managerial, clerical, sales and service workers, and craftsmen and foremen, divided by total industry employment.

An industry's skill mix, *I*, gives a somewhat better statistical account of its trade balance than does its yearly wage, and its skill mix goes a long way to explain its wage rate. In Waehrer's view, Kravis' findings represent the role of skills in structuring our foreign trade, with wage rates (strongly linked to skills) serving as a proxy for skill intensity.

Leontief himself took the first important step toward a systematic explanation of his paradox. In a second article refining his results, he classified total employment in export and import-competing production according to occupation:[6]

	Per cent of Total Labor Force	
Occupation	Export Production	Import-Competing Production
Professional, technical, etc.	13.75	12.24
Clerical, sales and service	22.07	17.00
Craftsmen and foremen	15.15	11.79
Operatives	30.05	28.38
Laborers	18.98	30.59

Translating these numbers into a crude estimate of the human capital employed by the two sectors, one can say that American export production is the more intensive in this species of investment. I have, in fact, performed this particular translation, on the limiting assumption that unskilled laborers have no human capital and that all wage differences (the excess over laborer) are due to education and on-the-job training. For all trading sectors (and all supplying sectors), I obtained these estimates of the human capital used to manufacture 1947 trade:[7]

[6] Wassily W. Leontief, "Factor Proportions and the Structure of American Trade: Further Theoretical and Empirical Analysis," *Review of Economics and Statistics*, November 1956, p. 399.

[7] The results reported here are summarized in my "Nature, Capital and Trade," *Journal of Political Economy*, October 1965, pp. 456–58; for additional detail, see P. B. Kenen and E. B. Yudin, *Skills, Human Capital and U.S. Foreign Trade*, International Economics Workshop, Columbia University, New York, 1965. The particular figures cited in this table and the next derive from mean wage data (not medians), were deflated by consumer prices (not hourly earnings), and related to all sectors of the economy (Leontief's estimate A). Other computations, some less successful, can be found in Kenen and Yudin, pp. 21–23 (and a separate analysis of direct requirements is given on pp. 26–34).

1959 Wage Differences Capitalized at	Human Capital per Man Year (*thousands of 1959 dollars*) Export Production	Import-Competing Production
9.0 per cent	24.78	21.10
11.0 per cent	20.27	17.26
12.7 per cent	17.56	14.95

Next, I have converted these statistics into 1947 dollars in order to merge them with Leontief's statistics and generate a comprehensive capital-to-labor ratio for each trading sector:[8]

1959 Wage Differences Capitalized at	Total Capital per Man Year (*thousands of 1947 dollars*) Export Production	Import-Competing Production
9.0 per cent	30.61	29.83
11.0 per cent	27.16	26.89
12.7 per cent	25.08	25.12

In two of these three cases (and a handful of others), converting skills data into human capital suffices to reverse the well-known paradox.[9]

Four other studies, using a variety of models and techniques, forcefully emphasize the strategic role of skills. In an input-output study of West German trade in 1954, Roskamp was surprised to find that German exports were capital intensive, relative to those of the United States, even though labor seemed then the abundant factor in West Germany.[10] Re-

[8] This amalgamation invokes another limiting assumption concerning the long-run fungibility of all forms of capital. It counts upon society's ability to choose deliberately between investing in men and investing in things. The same supposition, involving strong assertions about the efficiency of capital markets, underlies much other work on human capital, especially comparisons of rates of return, and is the explicit basis for my own elaborate model in "Nature, Capital and Trade."

[9] One might still argue, however, that the paradox survives, for Leontief's computations continue to imply that U.S. trade conserves tangible capital, and all evidence suggests that the United States is well endowed with this form of capital. If, further, one rejects the limiting assumption set forth in the preceding note, this counterargument acquires great strength.

[10] Karl W. Roskamp, "Factor Proportions and Foreign Trade: The Case of West Germany," *Weltwirtschaftsliches Archiv*, No. 2, 1963.

cently, however, Roskamp and McMeekin have taken a new look at that same year's trade, using somewhat different methods and taking explicit account of human capital.[11] This reexamination had two results. First, it revealed that, neglecting human capital, German exports were, after all, more labor intensive than U. S. exports. Second, it found that West German exports were quite intensive in human capital. In the authors' own words, ". . . one has to conclude that human capital was the most abundant factor of production relative both to physical capital and to labor. Labor was the abundant factor relative to physical capital but not to human capital. Physical capital was the scarce factor of production. When factors actually moved [internationally] it was human capital which left the country and physical capital which flowed in. This corroborates our findings."[12]

A second major contribution to this new subject is the series of papers contributed by Keesing.[13] He has used U. S. "skill coefficients" to measure the skills content of many countries' trade and has come forth with several striking results. Devising a list of occupations different from those used in other studies, Keesing ranks fourteen countries' exports and imports according to the skills their trade flows would embody if all countries' industries used skilled labor as do their U. S. counterparts.[14] He then shows a powerful inverse correlation (a Spearman coefficient of −0.87) between the skill content of exports and the skill content of

[11] Karl W. Roskamp and Gorden C. McMeekin, "Factor Proportions, Human Capital and Foreign Trade: The Case of West Germany Reconsidered," *Quarterly Journal of Economics*, February 1968. The chief difference in method consists in using factor incomes, rather than physical factor data, to measure factor use in each industry; this was done because "revenue streams emanating from assets, capital or labor, determine how large those assets are" (p. 155).

[12] Roskamp and McMeekin, "Factor Proportions, Human Capital and Foreign Trade," p. 160.

[13] Donald B. Keesing, "Labor Skills and International Trade: Measuring Many Trade Flows with a Single Measuring Device," *Review of Economics and Statistics*, August 1965; "Labor Skills and Comparative Advantage," *American Economic Review*, May 1966; and "Labor Skills and the Structure of Trade in Manufactures," in *The Open Economy*, pp. 3–18. The summary furnished here draws mainly on the last-named work.

[14] Keesing ranks countries by means of an index which sums up scientists and engineers, technicians and draftsmen, and other professionals, gives them double weight, then adds machinists, electricians, and tool- and diemakers, and divides this weighted total of "skilled workers" by the corresponding industry total of semiskilled and unskilled workers.

imports; countries that "supply" large amounts of skill by way of their exports "absorb" very little skill by way of their imports. Keesing goes on to show that skill content of exports correlates impressively with income per capita (a Spearman coefficient of 0.93), this despite the fact that his study is confined to major industrial countries that do not display huge income differences. Finally, Keesing demonstrates remarkable consistency in the bilateral trade of the industrial countries; if a country exports skill-intensive goods to a trading partner, it is likely to import less skill-intensive goods from that same trading partner. Working separately with scientists and engineers, Keesing finds just two exceptions to a strong ordering of pairwise trade patterns; working with machinists, electricians, and tool- and diemakers, he finds only one exception.

Keesing's work is open to several objections,[15] and yields only roundabout results on the role of skills. It does not link the factor content of a nation's trade directly to that nation's factor endowment, but couples consistency in national rankings with the Heckscher-Ohlin theorem to *infer* differences in nations' skill supplies. Another cross-national analysis, however, gives us direct evidence that the stock of skills (or skill-generating power) shapes the production pattern within manufacturing and, therefore, affects a nation's foreign trade. Working with data for twenty-six countries, including less-developed countries, Yahr finds that certain industries pay high wages in all countries and, with Waehrer, treats these as the industries using large amounts of skill.[16] She then asks how large a part of each nation's output comes from these same industries. Finally, she employs a schooling index (Harbison-Myers) as a crude proxy for total skill supply (or the capacity to generate skill), and asks if countries with high scores on the schooling index do, in fact, specialize in skill-intensive products. Computing a separate cross-national regression for each industry, she seeks to "explain" that industry's share in each nation's total output by that nation's schooling score. Her results

[15] See, e.g., Johnson's comments on "Labor Skills and Comparative Advantage," and A. O. Krueger's comments following my paper.

[16] Merle I. Yahr, "Human Capital and Factor Substitution in the CES Production Function," in *The Open Economy*, pp. 91–97, especially Table 6. Yahr's paper derives from her dissertation (Columbia, 1967). Her industries are composites of two-digit ISIC groups. Two out of thirteen could not be classified consistently according to relative wage (rubber products and nonmetallic mineral products); five others were classified as high wage and the remaining six as low wage.

are impressive. In four out of five high-wage industries, the regression coefficients are, as anticipated, positive and statistically significant (the coefficients of determination range as high as 0.47). In five out of six low-wage industries, the regression coefficients are, instead, negative and statistically significant (the coefficients of determination range as high as 0.43).[17] Clearly, countries with large amounts of skill specialize in industries needing much skill, while countries with limited amounts of skill specialize in industries needing little skill.

Finally, let me mention one more result, tangentially related to this general survey. In an early theoretical investigation of human capital and foreign trade, I argued that standard Heckscher-Ohlin models do allow for differences in incomes per capita, but seem to offer too few reasons for those same differences. If all factor prices were equalized by trade, there could be only two causes of differences in incomes: differences in labor-force-participation rates and differences in over-all capital-to-labor ratios. But models including investment in man introduce two more causes of differences in incomes: differences in stocks of human capital per worker and differences in the innate quality of labor (its "susceptibility to improvement by investment").[18] Recent work by Krueger, using an ingenious model, emphasizes the importance of these extra elements. A very large portion of most income differences can be attributed to measured differences in nations' stocks of human capital.[19] In sixteen of twenty-one countries studied, more than half the difference between U. S. income and that of the other country is due to a shortfall in human capital. In no fewer than eight cases, moreover, the shortfall accounts for more than three-fifths of the income difference.

[17] The sole exception among high-wage industries was chemicals production (including petroleum); the regression coefficient was negative but nonsignificant. The sole exception among low-wage industries was wood manufacture (including furniture); the regression coefficient was positive but nonsignificant. Yahr notes that the coefficients of determination are in general lowest for industries with close ties to natural-resource exploitation.

[18] See "Nature, Capital and Trade," p. 451, and "Toward a More General Theory of Capital and Trade," in *The Open Economy*, p. 118 and note 27.

[19] Anne O. Krueger, "Factor Endowments and *Per Capita* Income Differences Among Countries," *Economic Journal*, September 1968, especially pp. 651–53. Note Krueger's observation that her model understates accountable differences in income insofar as measured income is understated for poor countries and insofar as barriers to free trade prevent full factor-price equalization (pp. 651, 657).

Yet, some work on this subject leads to deep puzzlement. Bharadwaj and Bhagwati have made human-capital estimates for India very similar to those I have made for the United States.[20] Measuring the skills employed by Indian exports and import substitutes, converting these to human-capital equivalents, and adding their figures to tangible capital, they find, as expected, that India's external trade is labor using and human-*cum*-tangible capital saving, but, quite surprisingly, that the adjustment for human capital works to decrease, not increase, the relative labor intensity of India's exports. The two authors offer several explanations for this paradox and argue that more recent data might well resolve it.[21] But doubts and suppositions, however plausible, do not alter numbers, and these numbers do suggest that skills may not be all-important for comparative advantage.

Consider, moreover, the quite different recent work of Keesing and others, advancing a "dynamic" view of U. S. foreign trade. A pioneer in research on the role of skills, Keesing has now supplied a second, competing explanation for the behavior of U. S. exports. Spending on research and development, he argues, explains U. S. success in foreign markets better than any other variable tested, from which it is reasonable to conclude that "the world economic role of the United States involves the systematic export of new products."[22]

[20] Ranganath Bharadwaj and Jagdish Bhagwati, "Human Capital and the Pattern of Foreign Trade: The Indian Case," *Indian Economic Review*, October 1967.

[21] One, in particular, deserves complete quotation: "On the one hand, the weight of plantations, mining and textiles in Indian exports, for our period, is very considerable; and these sectors have a high percentage of 'skilled' workers. On the other hand, the over-all skill content, in labour, in import competing activities such as iron and steel and light engineering industries (many of which have a large base in the small-scale sector in India) turn out to be lower; the growth of more complex technology in these industries, involving perhaps greater over-all skill levels, must have come in the period *beyond* that covered by our wage rates and occupational data, which generally span the period 1955–1959" (pp. 139–40).

[22] Donald B. Keesing, "The Impact of Research and Development on United States Trade," in *The Open Economy*, pp. 175–89, and the several authors cited in Keesing's first footnote (especially Hoffmeyer, Lary, Hufbauer, and Vernon). See, too, William Gruber, D. Mehta and Raymond Vernon, "The R & D Factor in International Trade and International Investment of United States Industries," *Journal of Political Economy*, February 1967, and S. F. Kaliski's comment in the same journal, October 1967.

Keesing's chief evidence for this new view comprises a series of simple correlations (using sixteen or more sectors) between the U. S. share in major countries' exports during 1962 and the several constructs listed here:

Independent Variable[a]	Linear Correlation[b]
Company R & D as a percentage of sales	0.59
Federal R & D as a percentage of sales	0.84
Total R & D as a percentage of sales	0.90
Scientists and engineers in R & D as a percentage of the total labor force	0.91
Scientists and engineers outside R & D as a percentage of the total labor force	0.67
Semi- and unskilled workers as a percentage of the total labor force[c]	−0.59
Value added per establishment (standing for plant economies of scale)	0.44

[a] All data for 1960, save for value added per establishment (1958).

[b] All but last significant at the 0.05 level.

[c] Keesing gives simple correlations for two other skill groups ("other professionals" and "skilled manual workers") but does not aggregate his groups to test the role of all skilled labor outside R & D. Hence, I reproduce his correlation for all unskilled labor [as a proxy (with sign reversed) for skilled labor as a whole].

Clearly, expenditure on research and development and the corresponding professional employment in R & D have the highest correlations with export performance—higher than the correlations that relate to skills per se.

One observer has suggested that we need not choose between the skills hypothesis and the R & D approach, as the former is static and the latter is dynamic.[23] The R & D approach, however, is not dynamic in any conventional sense; it does not explain *changes* in the trade pattern. Instead it has to be viewed as treadmill dynamic, explaining the trade

[23] Edward J. Mitchell, "Explaining the International Pattern of Labor Productivity and Wages: A Production Model with Two Labor Inputs," *Review of Economics and Statistics*, November 1968, p. 467.

pattern at each point in time by ongoing innovation.[24] One is obliged to make a choice between the two approaches.

But Keesing's tests may not be the best basis for that choice. Note, first, that research input—employment or expenditure—is an imperfect proxy for research output, and it is the latter that must govern export shares.[25] Moreover, it is not clear that one year's R & D is, alone, decisive for export performance in another year, or that R & D undertaken in a single sector has its chief effects on the exports of that sector.[26] Note, finally, that Keesing reports high intercorrelations between several pairs of his "independent" variables, so that the sequential use of R & D and skills, in simple correlations with export performance, does not permit the perfect ranking of competing suppositions.[27]

This last point has led me to augment his analysis by running and reporting (in Appendix A) a series of multiple-regression relationships. These do not resolve the most important difficulties inherent in testing the R & D approach, but do help to clarify certain of the issues. Starting with Keesing's own dependent variable, X_i, the U. S. share in world exports of *i*th sector output is:

$$X_i = 19.16 - \underset{(2.850)}{14.988K_{1i}} + \underset{(5.515)}{4.037R_i} + \underset{(1.728)}{1.725S_{1i}} \qquad \bar{R}^2 = 0.88$$

where K_{1i} represents the (direct) capital-to-output ratio for 1947, derived from Leontief's original data; where R_i is Keesing's scientists and engineers working in R & D; where S_{1i} is Keesing's scientists and engineers outside R & D (but recomputed as a fraction of the total labor force

[24] If it were dynamic in conventional terms, the R & D approach might best be tested by correlation R & D input (or output) with the *change* in export share (or some "stock" of R & D with the share itself). One such test was performed in connection with this paper and was unsuccessful; there is no correlation between scientists and engineers in R & D (1960) and the change in export share (1962 to 1965). See Appendix A, Table 1. Note, however, one objection to this test (suggested orally by Richard Nelson): The R & D approach postulates prompt imitation of most innovations, so that old R & D grows obsolete very fast, and current or quite recent R & D represents the whole stock relevant to export shares.

[25] To make matters worse, available statistics on R & D are imperfect input measures; the classification of scientists and engineers (between R & D and other activities) is somewhat arbitrary, and one must also classify supporting personnel, not (as here) treat all of them as production workers.

[26] For more on this last point, see Keesing, "The Impact of Research and Development," pp. 176–77.

[27] For several of these correlations, see Appendix A, Table 3.

outside R & D); and where the several numbers in parentheses are "t" coefficients (not standard errors). In this and several other computations, the argument representing research and development is, indeed, more powerful than all others tried. The proxy for skills input, S_{1i}, and several broader aggregates serving the same purpose did not attain statistical significance (and did little to increase $\bar{R}^2$).

But when one employs a different measure of success in foreign trade, the ith industry's trade balance, B_i, one generates a very different series of results:

$$B_i = 23.94 - \underset{(2.168)}{87.782K_{1i}} + \underset{(0.471)}{2.656R_i} + \underset{(2.084)}{16.020S_{1i}} \qquad \bar{R}^2 = 0.46$$

Keesing's proxy for research and development, R_i, falls far short of significance (and actually reduces $\bar{R}^2$), while S_{1i} attains statistical significance. Further, a broader index of skill use (less closely correlated with R_i) gives a better explanation of the trade balance:

$$B_i = -\ 14.51 - \underset{(2.772)}{97.097K_{1i}} + \underset{(1.579)}{5.828R_i} + \underset{(3.252)}{2.671S_{5i}} \qquad \bar{R}^2 = 0.60$$

where S_{5i} includes scientists and engineers outside R & D, other professionals, and all skilled manual workers. Here, R_i comes closer to significance (and helps slightly to increase $\bar{R}^2$), but the index of skill use, S_{5i}, does the most to explain trade-balance performance.

One is led, in the end, to choose Keesing on skills over the more recent Keesing on R & D, for when one looks at imports along with exports (at B_i instead of X_i), skill use seems to be the more important variable.[28] Research and development may still play a vital role in sustaining U. S. exports (which is all that Keesing claims) and may be quite important in some other instances.[29] A cautious eclecticism is surely in order. Yet Keesing's work on skills, with that of many others, appears to open a more intriguing avenue for study, promising more general, comprehensive explanations of the structure of production and comparative advantage.

[28] Notice, however, that this B_i equation has a lower coefficient of determination than that obtained with X_i.

[29] See, e.g., Ozawa's work relating transferred knowledge—research output—to the rates of growth of Japanese exports. (Terutomo Ozawa, "Imitation, Innovation, and Japanese Exports," in *The Open Economy*, pp. 190–212.)

AN AGENDA FOR RESEARCH: POSITIVE ANALYSIS

THE several studies surveyed in the preceding section argue impressively that skills or human capital are an important determinant of trade flows. But this finding only serves to pose a series of questions that trade theorists and others have yet to examine. Statements that countries well endowed with skills will export skill-intensive products are no different from and no more illuminating than statements that countries well endowed with machines will tend to export machine-intensive goods. The fixed-endowment factor box used in every trade course helps us to describe national endowments and the two-way trade flows that endowments generate, but it is inadequate for a long-run analysis. It does not tell us how endowments come into being and why they should differ between countries.

To carry the analysis one vital step further, one must ask why some countries have acquired large supplies of skill and why others have acquired large stocks of machinery. "In the dynamic case," Valivanis argues, "the producible factors of production, given time, adjust precisely to the pattern of final demand. It makes no sense to speak of 'original endowments' unless one is speaking of the immediate short run."[30] This reminder gains new force when, as now, the labor force has to be regarded as a producible factor of production. One might, perhaps, adopt an intermediate view, supposing that financial capital and capital goods move across frontiers more readily than labor and that, in consequence, "the human resources of a country are subject to slower change than its man-made material resources."[31] This view, however, makes too much of a difference in degree to serve as the basis for general theorizing. Furthermore, it faces factual challenge. Many skills can be imported via foreign schooling and on-the-job training, and others can be borrowed by hiring foreigners.[32]

When, instead, stocks of skill and capital equipment are viewed as the end products of decisions to save and decisions to invest, an elemen-

[30] Stephan Valivanis, "Leontief's Scarce Factor Paradox," *Journal of Political Economy*, December 1954, p. 524.
[31] Keesing, "Labor Skills and the Structure of Trade in Manufactures," pp. 5–6.
[32] On imported skills, see A. D. Scott's important paper in this conference volume; on borrowed skills, see Elinor B. Yudin, "Americans Abroad: A Transfer of Capital," in *The Open Economy*, pp. 40–69.

tary answer starts to take shape. High-income countries, capable of saving, are likely to accumulate all forms of capital—labor skills, machinery, and disembodied knowledge. So, too, are those poorer countries, like Japan, which appear to generate unusually large savings. Note, again, Keesing's point that high-income countries are the ones that export skill-intensive products.[33]

But how are savings allocated—how much to training, to physical plant, and to the development of new techniques? I lay claim to the first, tentative reply. In two papers on this subject,[34] I have tried to convert conventional "point" theory, using the factor box, into "situation" theory, using a species of factor-transformation curve. That curve shows how savings should and will be allocated between the improvement of the nation's labor force and the production of tangible capital. Its shape and size depend upon the savings rate and the innate quality of labor and land. The point chosen on the curve depends upon the interest rate and prevailing factor prices (Valivanis' "pattern of final demand").

My approach is not without intriguing implications. It helps, for instance, to explain the ACMS finding that "the American advantage in efficiency tends to be least in capital-intensive industries,"[35] and shows

33 But note that skill abundance, as reflected in trades flows, does not strongly correlate with tangible-capital abundance; countries that export skill-intensive products seem also to conserve tangible capital. This point is implicit in Leontief's analysis, is made again by Keesing ("The Impact of Research and Development," p. 181), and is reaffirmed by my own multiple regressions (in which K_{1i} and K_{2i} have negative weights, while S_{1i} and S_{5i} have positive weights). It is, of course, possible that skill-intensive *processes* are not also tangible-capital intensive, and this would make for similar regression results, but there is little evidence to this effect. There is no correlation, positive or negative, between the two measures of capital intensity and the three measures of skill intensity in Appendix A, Table 3.

34 "Nature, Capital and Trade," pp. 442–49, and "Toward a More General Theory of Capital and Trade," pp. 101–07.

35 The finding in question is in K. J. Arrow, H. B. Chenery, B. S. Minhas and R. M. Solow, "Capital-Labor Substitution and Economic Efficiency," *Review of Economics and Statistics*, August 1961, p. 247. My note on the problem, attributing the bias to neglect of skills (labor augmentation), is "Efficiency Differences and Factor Intensities in the CES Production Function," *Journal of Political Economy*, December 1966, pp. 635–36. Recently, incidentally, Arrow, *et al.*, concede that "there is little to choose between neutrality [their first choice] and pure labor-augmentation." See their reply, furnished by a protégé, to Gupta's comprehensive treatment of the problem (Suraj B. Gupta, "Some Tests of the International Comparisons of Factor Efficiency with the CES Production Function," and Archen Minsol, "Reply," *Review of Economics and Statistics*, November 1968, pp. 470–80). Minsol's university, Lower Slobbovia, would seem to have acquired a brilliant economist!

why international capital movements can occur even when free trade has equalized all input prices.[36] Yet I do not recommend much more work along these lines. First, my own approach relies on the existence of diminishing returns to capital formation in man and land (the latter representing all tangible assets). This is far from realistic, if not with respect to man, surely with respect to land. Second, my approach leaves no room for direct use of simple, unskilled labor and, therefore, loses touch with much of the research summarized above, dealing with differences in the skill requirements of various activities and related trade flows. Third, my approach gives no place to the production of pure disembodied knowledge—research and development—although this species of investment seems to play a role in the explanation of U. S. exports.

Future work on human capital and foreign trade must surely answer the same questions studied in my model, but should now be focused less abstractly on two basic issues: (1) How does human capital enter the production function? (2) Why do certain countries seem to have an edge in the acquisition of human capital? Taken together, answers to these questions would lead us to modify factor-endowments theory and furnish an incisive analysis of foreign trade, especially of trade in manufactured products.

Trade theorists would be quite pleased if other economists were to reply to the first question; we do not care to poach on colleagues' preserves. But we cannot refine our own methods without knowing more about the links between skilled and unskilled labor and their relationship to physical capital. Are we now to use three-factor production functions, allowing for the joint employment of both types of labor? If so, should we treat the two as far from perfect substitutes? This view is endorsed by Mitchell and is the rationale for most of Keesing's computations on skill requirements.[37] Alternatively, should we use simple labor augmentation?

[36] "Nature, Capital and Trade," pp. 451–55, and "Toward a More General Theory of Capital and Trade," pp. 118–23.

[37] See Mitchell, "Explaining the International Pattern of Labor Productivity and Wages," especially pp. 466–68, and Keesing, "Labor Skills and the Structure of Trade in Manufactures," pp. 8–9. Others would appear to take a similar position, including Roskamp and McMeekin, Krueger, Waehrer, and Yahr, all cited previously. (Yahr's work on factor substitution, however, may fit more neatly into a labor-augmentation model; see pp. 70–85).

This view seems to have Griliches' support (see his paper in this volume) and was the explicit basis for my own theorizing.[38] If, finally, we are told that labor augmentation makes the most sense, how should we then interpret Keesing's computations, based as they are on fixed skill requirements?[39] Trade theorists are frequent lenders of technique. This time, we must be net borrowers of knowledge, and are likely to display strong preference for present over future goods or, at least, for quick service from the rest of the profession.

Meanwhile, we must deal with the second question—the reasons for differences in stocks of human capital. Here, then, are three conjectures, each of which may help explain the apparent concentration of human capital in a small handful of high-income countries:

I. SCHOOLING AND TRAINING MAY BE SUBJECT TO INCREASING RETURNS.

This conjecture is derived from two other suppositions. First, there are obvious economies of scale in formal education (measured in quantity and quality of output): large institutions can employ expensive, indivisible physical equipment and can gather staff in numbers that permit advanced, specialized instruction. Second, as countries accumulate skills, they may well encounter diminishing returns to the *use* of skills in manufacturing, so that the diversion of skilled workers to the supervision of on-the-job training makes for a smaller absolute sacrifice of current output than would be the case in countries with small stocks of skill.

II. THE OPPORTUNITY COST OF OBTAINING SKILL MAY DECREASE AS INCOME RISES.

This conjecture is derived from the further supposition that the marginal utility of current consumption does, in fact, decline and is, in

38 It is likewise consistent with my computations amending Leontief (and may also be consistent with Krueger's work on income, even though her model is cast in multifactor form).

39 One could, of course, treat Keesing's skill-mix computations as proxies for differences in degrees of augmentation or, more precisely, as measures of (augmented) labor intensities (which must differ systematically across sectors for the strong factor ordering required by factor-endowments analysis).

any case, quite high when income nears subsistence.[40] Put less controversially, personal savings and discretionary spending are, together, very small at prevailing income levels in many countries, so that too many youngsters and adults cannot pay the costs of training (whether tuition fees or foregone earnings).[41]

III. IMPERFECT CAPITAL MARKETS TEND TO DIVERT SAVINGS TOWARD TANGIBLE CAPITAL, AND IMPERFECTIONS ARE SEVERE IN ALL BUT A FEW MARKETS.

This conjecture does not call for much elaboration. Few observers would deny that capital markets are underdeveloped in a surprising number of countries (and even those that are developed have only recently begun explicitly to finance personal investments in formal education). Furthermore, imperfect capital markets tend to favor short-term lending against very visible, salable collateral. (In most countries, of course, formal education is financed by the state, not from private savings, but even here, differences in levels of development may correlate with biases against human capital. Less-developed countries are notorious for spending public funds on tangible symbols of economic sovereignty.)

Putting these conjectures into different form, the first suggests that the supply curve of training shifts out with rising income; the second suggests that the demand curve moves in the same direction; and the

[40] Note, however, Krueger's point (in her comment on this paper) that training to high skill levels may involve large opportunity costs to the individual and society, since those who receive this training are already skilled and forego high incomes to obtain more skill.

[41] This point applies to formal schooling and general training, since specific training is financed by employers. In fact, however, most of the skills employed in the poorer countries are probably low-level manual skills (and the markets for them are sufficiently competitive to treat them as general). Precisely because professional skills are in such short supply, production is patterned toward low-skill processes. On specific and general skills, see Gary S. Becker, *Human Capital*, New York, NBER, 1964, pp. 11–29. On manual and professional skills, see Keesing, "Labor Skills and the Structure of Trade in Manufactures," pp. 9–10, where he asserts that certain manual skills are "ubiquitously required in every manufacturing industry," and are, therefore, general in Becker's sense.

third conjecture reinforces the second. If one or more of them is true, human-capital formation is quite likely to proceed faster, absolutely and compared to other forms of investment, in high-income countries. If, further, this prediction is combined with the chief inference from Krueger's work—that human capital adds mightily to real income—one is brought to forecast the continuing concentration of human capital in the wealthy countries, with a corresponding concentration on those activities making intensive use of high-level skills.

Consider, finally, one more topic for investigation. Distinctions among types of skill may help to explain the sequence and migration of industrial development over long periods and the corresponding evolution of foreign trade. If a particular level or type of skill is used by a particular technology or subset of activities, a country pioneering in that technology may well acquire a comparative advantage in all the activities using that technology. In effect, a "leading" industry using that technology can furnish the "followers" with a low-cost input (or with the trained workers they will need as teachers). Put differently, the skills employed by a technology will be more or less specific to the leading industry—the first to be developed—and training costs will be borne by the first firms, but the same skills will be general for subsequent users of the same technology, and further training costs will be borne by workers. Yet a country that accumulates one level or type of skill may have no particular comparative advantage in other industries or upon the advent of a new technology. It is as likely to lag as lead in the development of those other industries or in the exploitation of the new technology.

More concretely, could one show that the international migration of the industrial revolution from Britain to the Continent and the United States was related to differences between the skill requirements of the "leading" product groups in its successive phases, first textiles, then metals, then motorcars, chemicals and electrical equipment? As human-capital endowments may well change more slowly than physical endowments, inherited differences in skill supplies may have been more important in governing the pace and locus of development than inherited differences in stocks of machinery. Could one also show that the migration of disembodied knowledge and of small numbers of highly skilled workers, serving as temporary teachers, is strategic to the further spread of industrialization? The Japanese example may be a leading case in point.[42] Lastly, could one show that the well-documented tendency toward a more sophisticated specialization among industrial countries—the tendency toward larger two-way trade flows inside product groups—reflects the very specialized technologies and, therefore, specific skill requirements of the newer manufactures?[43] By doing so, one would attach a new operational significance to the Heckscher-Ohlin theorem, especially if one could show why one country has a comparative advantage in producing the techniques and the labor skills connected with its own differentiated exports.

AN AGENDA FOR RESEARCH: NORMATIVE ANALYSIS

MUCH of our research on human capital has been inspired by normative concerns, not mere curiosity. Are we investing enough in education? Are the several outputs of our schools well matched to the needs of our economy? Are we using the right input mix—teachers and professors, buildings and equipment—in the production of knowledge and skills? The bulk of the research called forth by these questions is, quite rightly, positive; one must have facts before one can give advice. Yet I should like to make a new plea for theoretical and normative investigations, and to ask that those investigations span a wider range of questions than the one to which research has already been addressed. There are, in particular, some problems in trade theory that acquire new dimensions when one takes account of skills.

42 See, again, Ozawa, "Imitation, Innovation, and Japanese Exports," and Yudin, "Americans Abroad." My comments here constitute a modified version of the familiar "late-comer" hypothesis, stressing the late-comer's exploitation of the leader's assets, not his mistakes. Incidentally, the importance of skilled labor to development was well known to the mercantilists centuries ago. Colbert's decrees, for example, offered large bounties to lure master craftsmen from Flanders to France.

43 For evidence on intraindustry trade and further thoughts on its causes, see Bela Balassa, "Tariff Reductions and Trade in Manufactures among the Industrial Countries," *American Economic Review*, June 1966, and his *Trade Liberalization among Industrial Countries*, New York, 1967, pp. 86–94.

The costs and benefits of training would seem to provide the most compelling case for infant-industry protection. The accumulation of human capital has two important aspects. First, it absorbs resources. Manpower and materials are consumed by education and by other forms of training, and there is an output loss (the counterpart of income lost by the students and trainees). Second, education is a time-consuming process. Most manual skills can, perhaps, be learned quite quickly, but professional and managerial skills are imparted very slowly; these involve continuous learning-by-doing over a large fraction of one's working life. Taken in tandem, these two aspects of the process justify temporary tariffs or subsidies for skill-using industries during the early stages of development. Protection may be most potent in fostering the acquisition of specific skills (as the training costs involved are borne by the firm, and the quite specific managerial skills which seem often to be scarcest take much time to acquire). But tariffs or subsidies may also be needed to promote investments in general training, as personal incomes are quite low and capital markets are imperfect in the less-developed countries, so that firms may be unable to shift any training costs onto their apprentices.[44]

In some cases, however, the gains from investment in human capital may justify permanent tariff protection for import-competing skill-using industries. Protection could increase the demand for skills, encouraging additional investment in training and raising real income. This possibility is explored in a two-sector model outlined in Appendix B. The model displays most of the properties of standard Heckscher-Ohlin constructs, but seeks to make explicit—if primitive—allowance for the costs and benefits of using skilled labor.

One sector of the two-sector economy produces and exports a primary commodity, using unskilled labor and embodied capital (permanent improvements in natural land). The second sector manufactures an import-competing consumer good, using skilled labor and imported machines. Skilled workers earn a higher wage and are trained by sacrificing current manufactured output (in a fixed amount per newly trained worker); skilled workers never die and machines do not depreciate.

[44] An analogous argument is made by Steffan Linder, (*An Essay on Trade and Transformation*, Stockholm, 1961, pp. 27–28).

Investments in skill are governed by rational calculations; future earnings due to skill are discounted at the market rate of interest and their present value equated to the cost of training. But because training costs are measured in consumer goods and these are subject to a tariff, investments in skill may be valued in two ways. The consumer goods absorbed by training have a social cost (their world price) and a private cost (their tariff-distorted domestic price). One's impulse is always to opt for social cost, all the more so in this instance, because the social cost is lower, making for additional investments in skill. But this impulse may be harmful. One has also to remember that the marginal product of skilled labor is distorted by the tariff on the skill-intensive good. We enter the unhappy world of the second best!

To round out the model, savings and tax revenues (from tariffs and income taxes) are used jointly to finance all forms of investment—further permanent improvements in the land, imports of additional machines, and the education of more skilled workers. Imports of consumer goods and machines are exactly equal to primary exports (a result which may depend on the exchange rate, though this rate does not appear directly in the model, because all prices are defined in foreign currency).

When set out most compactly (equations 2.1–2.14), the model still contains twenty-two variables, eight of them exogenous and fourteen endogenous. It is much too large for complete analysis. I have, therefore, extracted a subset of equations (the matrix 2.16) to analyze partially the role of the tariff, t, unit training costs, g, and growth in the labor force. This partial analysis has as its chief defect that it fixes net investment (by fixing the sum of savings and tax revenues) and the allocation of investment between the two sectors (by fixing the difference between total exports and consumer-destined imports). Note, however, that it does not fix the distribution of investment between machines and skills used in manufacturing. The partial analysis summarized below examines the effects of changes in t and g on the equilibrium position of the system and on the equilibrium growth rates of the skilled labor force and net national product.

Taking first the impact on the stock of skills (equation 2.18), an increase in the tariff on manufactures reduces, once and for all, the stock of skills, rather than increasing it, but has no direct effect on the rates of growth derived from population change and capital formation.[45] Furthermore, the mode of valuation of human capital (at social or private cost) makes no difference whatsoever at this juncture. Finally, an increase in unit training costs has no direct effect on the stock of skills, but does slow down the rates of growth attached to population change and capital formation.

Turning next to the effects on real income (valued at world prices), one encounters strange results (equation 2.19). If one asks what will happen when a tariff is imposed (not when an existing tariff is raised) and when human capital is valued at social cost, the answer is clear: real income will fall. If, instead, one asks about an increase in a tariff, the answer is not clear: real income will not fall so much and, indeed, may increase if the tariff rate and return to skill are quite high to start. Further, when human capital is valued at private cost, the argument grows more complex, since two new terms appear in the relevant coefficient, each with a different sign. One can say that valuation at private cost reduces the income loss consequent upon the introduction of a tariff (for one of the two terms drops out again), but one cannot evaluate the cost of change in a preexisting tariff.

To make matters worse, a tariff change has complex direct effects on the real growth rates attached to population change and to capital formation.[46] When human capital is valued at social cost, an increase in the tariff on manufactures will decrease the growth rate of real income caused by population change, will increase the growth rate caused by net investment in export production, and will decrease the growth rate caused by net investment in manufacturing (including net investment in human capital). Its over-all effect, of course, depends on the relationships among population growth and the two investment flows. When human capital is valued at private cost, the outcome is less certain. By way of illustration, consider the effects of an increase in the tariff, t, on the growth of real income due to population change: If $t > 1$, an increase

[45] This result is diametrically opposed to my initial supposition. But note the several *caveats* in footnotes 52 and 54.

[46] The word "direct" is meant to warn that the results reported here exclude effects of tariff change on several of the variables entering the argument of equation 2.19. This is a second sense in which Appendix B constitutes an incomplete, partial analysis.

in t will cause an even larger decrease in the growth rate. If $t = 1$, the two modes of valuation have identical (retarding) effects. But if $t < 1$, the outcome depends on the relationship between t and the wage differential due to skill, denoted by w:

a. When $(w - 1) < t(1 + w)$, an increase in t will be adverse to growth in real income.

b. When $(w - 1) = t(1 + w)$, an increase in t will have no effect on growth in real income.

c. When $(w - 1) > t(1 + w)$, an increase in t will actually promote growth in real income.[47]

One could perhaps refine all of these results, thereby explaining the source of their complexity. One could also generate additional results, pertaining to the consequence of higher training costs and to the effects of changes in t and g on other variables.[48] Most importantly, one should continue the search for a firm answer to the basic question: What is the precise interaction between tariff rates, wage differentials, and the real costs of training? This was the question with which I began, but I have not answered it in this account or in the appendixes.

APPENDIX A

THE data on skills and U. S. foreign trade used in the body of this paper are taken from Keesing,[49] Leontief,[50] and United Nations publications.

[47] Note the clearer implication of these findings for the imposition of a tariff (when $t = 0$ to start). If $w < 1$, the introduction of a tariff will reduce the growth rate due to population change; if $w = 1$, it will have no effect; and if $w > 1$, it will raise the growth rate.

[48] I have found that an increase in training costs (expenditure per worker) will raise real output, but have not tried to analyze its direct effect on the rates of growth of output linked to population change and the two investment flows. The task is not easy, and I doubt that much more effort should, in fact, be lavished on the partial model used in Appendix B.

[49] Donald B. Keesing, "The Impact of Research and Development on United States Trade," in *The Open Economy*, P. B. Kenen and R. Lawrence (eds.), New York, 1968.

[50] W. W. Leontief, "Factor Proportions and the Structure of American Trade: Further Theoretical and Empirical Analysis," *Review of Economics and Statistics*, November, 1956.

Precise definitions follow:

X_i U. S. exports of *i*th industry output, expressed as a percentage of Group-of-Ten *i*th industry exports, 1962.

G_i The over-all percentage change in X_i from 1962 through 1965.

B_i U. S. exports of *i*th industry output *less* U. S. imports of *i*th industry output expressed as a percentage of their sum, 1961.

R_i Scientists and engineers engaged in research and development, expressed as a percentage of total *i*th industry employment, 1960.

S_{1i} Scientists and engineers *not* engaged in research and development, expressed as a percentage of adjusted *i*th industry employment, 1960 (adjusted employment being total employment *less* scientists and engineers engaged in research and development).

S_{2i} Other professionals, expressed as a percentage of adjusted *i*th industry employment, 1960.

S_{3i} Skilled manual workers, expressed as a percentage of adjusted *i*th industry employment, 1960.

S_{4i} The sum of S_{1i} and S_{2i}.

S_{5i} The sum of S_{1i}, S_{2i}, and S_{3i}.

K_{1i} Direct capital requirements per dollar of *i*th industry output, 1947.

K_{2i} Direct *plus* indirect capital requirements per dollar of *i*th industry output, 1947.

The trade data used for X_i, G_i and B_i derive directly from Keesing's paper and from *Commodity Trade Statistics*. The skills data used for R_i and for S_{1i} through S_{5i} also come from Keesing's paper, but S_{1i}, S_{2i} and S_{3i} have been redefined to exclude from the labor-force denominator scientists and engineers engaged in research and development. The capital coefficients K_{1i} and K_{2i} are export-weighted averages of the coefficients given by Leontief. (As these weights and coefficients pertain to 1947, they are not well matched with the trade and skills data for 1960–62, but should not be wholly irrelevant.)

The eighteen industries studied here are those used by Keesing and account for the bulk of manufactured exports. The chief exclusions are atomic energy devices, communications equipment and electronic components, ordnance and guided missiles, petroleum, and food and kindred products.

TABLE 1

Simple Correlations Between Trade Indexes and Input Indexes

Input Indexes	Trade Indexes X_i	B_i	G_i
R_i	0.9126[a]	0.5861[a]	0.0152
S_{1i}	0.6962[a]	0.5957[a]	0.1270
S_{2i}	0.7151[a]	0.5844[a]	0.1693
S_{3i}	0.0343	0.3145	0.2303
S_{4i}	0.7315[a]	0.6061[a]	0.1614
S_{5i}	0.4071	0.5843[a]	0.2821
K_{1i}	-0.3432	-0.3629	-0.3034
K_{2i}	-0.4813[a]	-0.4320	-0.0849

[a]Significantly different from zero at the 0.05 level.

TABLE 2

Simple Correlations Between Trade Indexes

	X_i	B_i	G_i
X_i	1.0000	–	–
B_i	0.6793[a]	1.0000	–
G_i	0.0918	0.3616	1.0000

[a]Significantly different from zero at the 0.05 level.

TABLE 3

Simple Correlations Between Trade Indexes

	R_i	S_{1i}	S_{4i}	S_{5i}	K_{1i}	K_{2i}
R_i	1.0000	–	–	–	–	–
S_{1i}	0.7092[a]	1.0000	–	–	–	–
S_{4i}	0.7536[a]	0.9295[a]	1.0000	–	–	–
S_{5i}	0.4108	0.6018[a]	0.5049[a]	1.0000	–	–
K_{1i}	-0.1528	0.1271	0.0084	0.2384	1.0000	–
K_{2i}	-0.3972	0.0044	-0.1968	0.1224	0.7552[a]	1.0000

[a]Significantly different from zero at the 0.05 level.

TABLE 4

Multiple Regression Equations Using K_{1i}

Trade Index		Regression Coefficients on Input Indexes[a]				$\bar{R}^2$
X_i	=	20.33 −	11.918 K_{1i}	+ 4.977 R_i		0.86
			(2.261)	(9.551)		
X_i	=	21.36 −	25.063 K_{1i}		+ 5.818 S_{1i}	0.63
			(2.954)		(5.062)	
X_i	=	18.97 −	19.957 K_{1i}		+ 1.769 S_{4i}	0.61
			(2.311)		(4.858)	
X_i	=	18.40 −	26.661 K_{1i}		+ 0.644 S_{5i}	0.29
			(2.214)		(2.459)	
X_i	=	19.16 −	14.988 K_{1i}	+ 4.037 R_i	+ 1.725 S_{1i}	0.88
			(2.850)	(5.515)	(1.728)	
X_i	=	18.92 −	13.125 K_{1i}	+ 4.248 R_i	+ 0.402 S_{4i}	0.86
			(1.482)	(5.337)	(1.200)	
X_i	=	17.38 −	14.184 K_{1i}	+ 4.644 R_i	+ 0.160 S_{5i}	0.86
			(2.582)	(8.022)	(1.234)	
B_i	=	34.73 −	59.267 K_{1i}	+ 11.387 R_i		0.34
			(1.406)	(2.731)		
B_i	=	25.38 −	94.411 K_{1i}		+ 18.713 S_{1i}	0.49
			(2.554)		(3.737)	
B_i	=	19.80 −	77.938 K_{1i}		+ 5.442 S_{4i}	0.44
			(2.021)		(3.346)	
B_i	=	− 13.22 −	112.754 K_{1i}		+ 3.278 S_{5i}	0.56
			(3.201)		(4.276)	
B_i	=	23.94 −	87.782 K_{1i}	+ 2.656 R_i	+ 16.020 S_{1i}	0.46
			(2.168)	(0.471)	(2.084)	
B_i	=	19.76 −	72.072 K_{1i}	+ 3.647 R_i	+ 4.268 S_{4i}	0.41
			(1.774)	(0.596)	(1.657)	
B_i	=	− 14.51 −	97.097 K_{1i}	+ 5.828 R_i	+ 2.671 S_{5i}	0.60
			(2.772)	(1.579)	(3.232)	

[a] Numbers in parentheses are "t" coefficients, not standard errors.

TABLE 5

Multiple Regression Equations Using K_{2i}

Trade Index		Regression Coefficients on Input Indexes[a]				$\bar{R}^2$
X_i	=	19.44 −	3.152 K_{2i} +	4.841 R_i		0.83
			(1.293)	(7.852)		
X_i	=	26.99 −	10.821 K_{2i}		+ 5.402 S_{1i}	0.69
			(3.541)		(5.106)	
X_i	=	22.77 −	7.840 K_{2i}		+ 1.596 S_{4i}	0.61
			(2.264)		(4.273)	
X_i	=	25.79 −	12.047 K_{2i}		+ 0.588 S_{5i}	0.38
			(2.800)		(2.457)	
X_i	=	19.67 −	4.848 K_{2i} +	3.774 R_i	+ 1.729 S_{1i}	0.84
			(1.851)	(4.017)	(1.465)	
X_i	=	18.40 −	3.529 K_{2i} +	4.212 R_i	+ 0.334 S_{4i}	0.83
			(1.417)	(4.483)	(0.892)	
X_i	=	17.58 −	3.899 K_{2i} +	4.537 R_i	+ 0.123 S_{5i}	0.83
			(1.489)	(6.290)	(0.836)	
B_i	=	37.54 −	19.586 K_{2i} +	10.315 R_i		0.31
			(1.076)	(2.241)		
B_i	=	38.74 −	35.999 K_{2i}		+17.142 S_{1i}	0.48
			(2.491)		(3.426)	
B_i	=	27.91 −	26.943 K_{2i}		+ 4.843 S_{4i}	0.40
			(1.695)		(2.825)	
B_i	=	5.53 −	42.344 K_{2i}		+ 2.982 S_{5i}	0.55
			(3.102)		(3.925)	
B_i	=	39.97 −	37.009 K_{2i} −	0.639 R_i	+17.763 S_{1i}	0.45
			(2.038)	(0.098)	(2.170)	
B_i	=	25.04 −	24.119 K_{2i} +	2.759 R_i	+ 4.016 S_{4i}	0.36
			(1.260)	(0.412)	(1.504)	
B_i	=	−1.56 −	35.309 K_{2i} +	3.917 R_i	+ 2.580 S_{5i}	0.54
			(2.234)	(0.900)	(2.914)	

[a]Numbers in parentheses are "*t*" coefficients, not standard errors.

Table 1 sets out simple correlations between X_i, G_i and B_i and the several measures of research input, skill use, and capital intensity. Table 2 sets out simple correlations between the three trade indexes themselves. Table 3 sets out simple correlations between R_i, S_{1i}, S_{4i}, S_{5i}, K_{1i} and K_{2i}. Table 4 supplies a comprehensive set of multiple regressions "explaining" X_i and B_i. Table 5 supplies a similar series using K_{2i} instead of K_{1i}.

APPENDIX B

THE model set out here describes a two-sector economy operating under pure competition, with constant returns to scale, and trading with the outside world. The first of its two sectors produces a primary commodity, A, using unskilled labor, L_a, and a stock of capital, K_a, which does not depreciate and can be augmented by sacrificing current production of A. By implication, K_a is measured in A, its rate of change is nonnegative, and K_a is exogenous (representing irretrievable investments in the past). In the first sector, then:

$$A = f_a(K_a/L_a, 1)L_a \tag{1.1}$$
$$p_a[(A/L_a) - (K_a/L_a)f_a'] = w_a \tag{1.2}$$
$$f_a' = r \tag{1.3}$$

where p_a is the world price of A and w_a the wage of unskilled labor (each of them expressed in foreign currency), and r is the rate of interest.

The second sector manufactures a consumer good, C, using skilled labor, L_c, and a stock of capital, K_c, consisting of imported machines that do not depreciate. By implication, used machines can be exported without discount, the rate of change of the stock can be negative, and K_c is not exogenous (being susceptible of instant adjustment). In the second sector, then:

$$C = f_c(K_c/L_c, 1)L_c \tag{1.4}$$
$$p_c(1 + t)[(C/L_c) - (K_c/L_c)f_c'] = w_s = (1 + w)w_a \tag{1.5}$$
$$p_c(1 + t)f_c' = p_k \cdot r \tag{1.6}$$

where p_c is the exogenous world price of C, p_k the exogenous world price of a machine, and w_s the wage of skilled labor (each of them expressed in foreign currency), where w is $(w_s - w_a)/w_a$, the wage differential due to skill, and t is the ad valorem tariff on C.

The skills used in this second sector are created by sacrificing current production of C at a fixed rate, g, per skilled worker. Skill, like other stocks, does not depreciate (workers do not die). By implication, L_c^*, the total stock of skills, has attributes similar to those of K_a; its rate of change is nonnegative, and L_c^* itself is exogenous.[51] Investments in skill are governed by rational cost-benefit calculations of the ordinary sort. In consequence:

$$g \cdot p_c(1 + nt) = \sum_{i=1}^{\infty} \frac{w \cdot w_a}{(1 + r)^i} = \frac{w \cdot w_a}{r} \tag{1.7}$$

where $n = 0$ if investments in skill are valued at social cost, and $n = 1$ if they are valued at private (tariff-distorted) cost. All skilled labor is employed in manufacturing—none of it is left to do the work of unskilled workers—and the whole labor force is fully employed. Formally:

$$L_c = L_c^* \tag{1.8}$$

$$L_a + L_c = L \tag{1.9}$$

where L is the whole labor force. Next, define gross (and net) national product, using the price of the exportable as numeraire and counting output sacrificed to capital formation.[52] At domestic prices:

$$Y_d = A + (p_c/p_a)(1 + t)C \tag{1.10}$$

and at world prices:

$$Y_w = A + (p_c/p_a)C \tag{1.11}$$

[51] One could, of course, reduce L_c^*/L (where L is the whole labor force) if L itself were growing, and this is how I shall interpret certain subsequent results. To put the same point in a general context; formulae that describe changes in the stock of skills or real income consequent on changes in tariffs or training costs must be viewed as pertaining to once-over movements between equilibria, accomplished by departing from the rates of growth associated with those equilibria. Formulae that describe changes in rates of growth must be viewed as pertaining to once-over changes in the equilibrium rates themselves.

[52] This sort of accounting will be valid provided the outputs in question (measured by $K_a \cdot \dot{K}_a$ and $gL_c^* \cdot \dot{L}_c^*$) are included in the definition of investment.

Further, define gross (and net) investment, including additions to K_a and to L_c^*:

$$I = K_a \cdot \dot{K}_a + (p_k/p_a)K_c \cdot \dot{K}_c + (p_c/p_a)(1 + t)gL_c^* \cdot \dot{L}_c^* \quad (1.12)$$

where dotted terms denote percentage rates of change. Tax revenues consist of tariff proceeds and of an income tax levied at a fixed rate, y. Savings are a fraction, s, of after-tax income. Continuing to use p_a as numeraire:

$$T = (p_c/p_a)t \cdot C_m + y \cdot Y_d \quad (1.13)$$

$$S = s(1 - y)Y_d \quad (1.14)$$

where C_m are imports of the manufactured good. Total imports are C_m *plus* the machinery used to manufacture C. Using the same numeraire:

$$M = (p_c/p_a)C_m + (p_k/p_a)K_c \cdot \dot{K}_c \quad (1.15)$$

Furthermore:

$$C_m = C_c + gL_c^* \cdot \dot{L}_c^* - C \quad (1.16)$$

where C_c is final domestic demand, a function of relative prices and total private spending:

$$C_c = C[(p_c/p_a)(1 + t), (1 - y)(1 - s)Y_d] \quad (1.17)$$

Export demand, in turn, depends on the relative price of the primary product:

$$X = A_f = A[(p_a/p_c), \phi] \quad (1.18, 1.19)$$

where ϕ impounds all exogenous elements affecting export demand. Finally, assume that foreign trade is always balanced and that all government spending is for capital formation. These assumptions give:

$$X = M \quad (1.20)$$

$$I = S + T \quad (1.21)$$

The system set out here can be rendered more compact and, in the end, determinate. Combine equations (1.1), (1.4), (1.9), (1.10), (1.11), (1.17) and (1.19) into five equations using the ten variables L_a, L_c^*, L, Y_d, Y_w, C_c, A_f, R_a [for K_a/L_a], R_c [for K_c/L_c^*], and q_c [for p_c/p_a], and the four parameters t, ϕ, y and s' [for $s(1 - y)$]:

$$L_a + L_c^* = L \tag{2.1}$$

$$Y_d = Y_w + q_c \cdot t \cdot f_c(R_c, 1)L_c^* \tag{2.2}$$

$$Y_w = f_a(R_a, 1)L_a + q_c \cdot f_c(R_c, 1)L_c^* \tag{2.3}$$

$$C_c = C[q_c(1 + t), (1 - y - s')Y_d] \tag{2.4}$$

$$A_f = A(1/q_c, \phi) \tag{2.5}$$

Then combine the rest of the original equations into five more, using the six additional variables w, $\dot{R}_a$, $\dot{R}_c$, $\dot{L}_a$, $\dot{L}_c^*$ and q_k [for p_k/p_c], and the remaining parameters, g and n:

$$\left(\frac{1 + w}{1 + t}\right)\left[\frac{f_a(R_a, 1) - R_a \cdot f_a'}{f_c(R_c, 1) - R_c \cdot f_c'}\right] = q_c \tag{2.6}$$

$$(1 + t)(f_c'/f_a') = q_k \tag{2.7}$$

$$g\left(\frac{1 + nt}{1 + t}\right)f_a' = \left(\frac{w}{1 + w}\right)[f_c(R_c, 1) - R_c \cdot f_c'] \tag{2.8}$$

$$K_a \cdot \dot{L}_a + q_c(g + q_k \cdot R_c)\dot{L}_c^* \cdot L_c^* + K_a \cdot \dot{R}_a + q_c(q_k \cdot K_c)\dot{R}_c = J_1 \tag{2.9}$$

$$q_c(g + q_k \cdot R_c)L_c^* \cdot \dot{L}_c^* + q_c(q_k \cdot K_c)\dot{R}_c = J_2 \tag{2.10}$$

where $J_1 = q_c(C_c - C)t + (y + s')Y_d$, net revenues plus savings; where $J_2 = A_f - q_c(C_c - C)$, the difference between total exports and imports of consumer goods; and where, by additional assumption, $A_f > q_c(C_c - C) > 0$.[53] Finally, differentiate (2.1), (2.6), (2.7) and (2.8) to form four more equations using the six additional variables L, w, q_k, q_c, g and t, and determining the sector allocation of investment and of any increase in the total labor force:

[53] The variable C appears in J_1 and J_2, but does not count among the endogenous variables entering this compact version. Here and hereafter, C and A are used in place of the more cumbersome functions $f_c(R_c, 1)L_c^*$ and $f_a(R_a, 1)L_a$, whenever convenience will not be misleading. Notice, in passing, that $J_1 - J_2 = K_a \cdot L_a + K_a \cdot R_a = K_a \cdot K_a$, investment in primary production, and this is nonnegative. Notice, further, that subsequent procedures in which J_1 and J_2 are held constant imply an arbitrary allocation of fixed tax revenues and savings between primary production, on the one hand, and skills *plus* machines, on the other. It is of course possible to fix these two terms, despite changing incomes, exports, imports, prices, and tariffs; one could change the tax rate, y, to stabilize J_1, and one could impose export taxes or export subsidies to manipulate A_f and stabilize J_2 (while altering y again to offset the fiscal consequences for J_1). But a constant allocation of tax revenues and savings may not be optimal (and may, indeed, be inconsistent with some equilibria). This is the major defect of the method I adopt below.

$$L_a \cdot \dot{L}_a + L_c^* \cdot \dot{L}_c^* = L \cdot \dot{L} \tag{2.11}$$

$$[A_{kk}(p_a/w_a)r \cdot R_a]\dot{R}_a - \left[C_{kk}(p_a/w_a)\left(\frac{1}{1+w}\right)(q_c \cdot q_k)r \cdot R_c\right]\dot{R}_c + \left(\frac{w}{1+w}\right)\dot{w} - \left(\frac{t}{1+t}\right)\dot{t} - \dot{q}_c = 0 \tag{2.12}$$

$$A_{kk} \cdot \dot{R}_a - C_{kk} \cdot \dot{R}_c + \left(\frac{t}{1+t}\right)\dot{t} - \dot{q}_k = 0 \tag{2.13}$$

$$\dot{g} - A_{kk} \cdot \dot{R}_a - \left[C_{kk}(p_a/w_a)\left(\frac{1}{1+w}\right)(q_c \cdot q_k)r \cdot R_c\right]\dot{R}_c - \left(\frac{1}{1+w}\right)\dot{w} - \left(\frac{t}{1+t}\right)(1-n)\dot{t} = 0 \tag{2.14}$$

where $A_{kk} = -f_a''(R_a/f_a')$ and $C_{kk} = -f_c''(R_c/f_c')$, and each may be deemed positive.

This second version of the model has twenty-two variables, but eight of these should be regarded as exogenous: the size and rate of change of the total labor force (L and $\dot{L}$); the size and rate of change of the import price ratio ($\dot{q}_k$ and q_k); the stocks L_c^* and K_a, representing investments brought forward from the past; and changes in the tariff and in unit training costs ($\dot{t}$ and $\dot{g}$). There are, then, fourteen endogenous variables and the same number of equations.

I seek now to ascertain the principal effects of changes in the tariff and in unit training costs. To do so totally, however, would be quite difficult, requiring the simultaneous solution of fourteen equations. Hence, I shall develop partial answers, neglecting all changes in J_1 and J_2,[54] and concentrating on two questions:

1. What are the effects of changes in g or t on the equilibrium *position* of the system, especially upon the stock of skills and upon national income at world prices?

2. What are the effects of changes in g or t on the equilibrium *rates of growth* of L_c^* and Y_w when and if the system has attained the equilibrium position implied by a new g or t? To answer these two questions,

[54] For *caveats* concerning this procedure, see notes 51 and 53.

one has first to use equation (2.3) to define the rate of change of national income:

$$Y_w \cdot \dot{Y}_w = A \cdot \dot{L}_a + (q_c \cdot C)\dot{L}_c^* + f_a'(R_a \cdot L_a)\dot{R}_a + f_c'(q_c \cdot R_c \cdot L_c^*)\dot{R}_c + (q_c \cdot C)\dot{q}_c \quad (2.15)$$

Notice, however, that equations (2.9) through (2.14) contain the same five variables that affect $\dot{Y}_w$ and that there is only one other endogenous variable, $\dot{w}$, in that subset of equations. In consequence, one can attach (2.15) to that six-equation subset, then use this central portion of the whole system to answer the questions just posed. First, set $(p_a/w_a) = q_c = q_k = 1$, by an appropriate choice of the relevant physical units. Then remove $\dot{q}_c$ from (2.15), using the arguments of (2.12). Finally, add (2.13) to (2.14) to simplify the latter, and subtract (2.10) from (2.8) for similar purposes. After these manipulations:

$$\begin{bmatrix} L_a & L_c & 0 & 0 & 0 & 0 \\ 0 & 0 & A_{kk} & -C_{kk} & 0 & 0 \\ 0 & 0 & 0 & U_1 & 1 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & g + R_c & 0 & R_c & 0 & 0 \\ A & C & U_2 & U_3 & -w \cdot C & -1 \end{bmatrix} \begin{bmatrix} \dot{L}_a \\ \dot{L}_c^* \\ \dot{R}_a \\ \dot{R}_c \\ \dfrac{-\dot{w}}{1+w} \\ Y_w \cdot \dot{Y}_w \end{bmatrix} = \begin{bmatrix} L \cdot \dot{L} \\ \dot{q}_k - \left(\dfrac{t}{1+t}\right)\dot{t} \\ \dot{q}_k - \dot{g} - n\left(\dfrac{t}{1+t}\right)\dot{t} \\ (J_1 - J_2)/K_a \\ J_2/L_c^* \\ C\left(\dfrac{t}{1+t}\right)\dot{t} \end{bmatrix} \quad (2.16)$$

where $U_1 = -\left(\dfrac{r \cdot R_c}{1+w} + 1\right)C_{kk}$, $U_2 = r(L_a + C \cdot A_{kk})R_a$, and $U_3 = r\left(\dfrac{1}{1+w}\right)\left[\left(\dfrac{1+w}{1+t}\right)L_c^* - C \cdot C_{kk}\right]R_c$.

This system has a simple, nonsingular determinant:

$$/D/ = -[L_a(g + R_c)C_{kk} + L_c^* \cdot R_c \cdot A_{kk}] < 0 \quad (2.17)$$

It also supplies straightforward solutions for changes in the stock of skills and national income. Solving first for $\dot{L}_c{}^*$:

$$\dot{L}_c{}^* = (R_c/Q)\left\{L_a\left[\dot{q}_k - \left(\frac{t}{1+t}\right)\dot{t}\right] + (L \cdot A_{kk})\dot{L} + \dot{H}\right\} \tag{2.18}$$

where $Q = -\ /D/ > 0$, while $\dot{H} = (1/K_c)[(K_a \cdot C_{kk})J_2 - (K_c \cdot A_{kk})(J_1 - J_2)]/R_a \gtrless 0$.[55]

An increase in the tariff, t, reduces the equilibrium level of $L_c{}^*$ (slowing or halting investment in human capital until the economy has achieved the requisite reduction in $L_c{}^*/L$). Further, the mode of valuation of human capital, whether at social or private cost, has no effect on the influence of changes in the tariff; the term $n\left(\frac{t}{1+t}\right)\dot{t}$ in (2.16) does not appear in (2.18). Finally, an increase in $\dot{q}_k$—in the price of the machinery used to manufacture C relative to that of C itself—augments the equilibrium value of $L_c{}^*$.

Consider, next, two continuing effects—population growth, denoted by $\dot{L}$, and gross investment, denoted by $(J_1 - J_2)$ and J_2. Clearly, population growth raises $L_c{}^*$. Notice, moreover, that the tariff rate does not appear in Q or in any other part of the coefficient attaching to $\dot{L}$. Once, then, the economy has attained the equilibrium implied by a new tariff rate, that rate has no direct effect on the allocation of subsequent additions to the total labor force.[56] But changes in training costs do have a direct effect; as g appears in Q, an increase in unit training costs will shunt a larger share of additional labor into primary production. The joint effects of investment, denoted by $\dot{H}$, cannot reduce the stock of skill, but the separate effects of $(J_1 - J_2)$, investment in primary production, and of J_2, investment in manufacturing, have unambiguously opposite signs. The former tends to reduce $L_c{}^*$; the latter tends to raise it. In each case, moreover, the tariff rate does not affect the impact of investment, but higher training costs, increasing Q, diminish the influence of both forms of investment.

[55] The sign attached to $\dot{H}$ derives from the fact that $(J_1 - J_2)$ and J_2 are continuing processes, not single acts like $\dot{t}$ or $\dot{g}$, and have continuing effects on $L_c{}^*$, regardless of the size of $\dot{L}$. But $\dot{L}_c{}^*$ is nonnegative, so $\dot{H}$ must be nonnegative.

[56] The tariff, however, will influence the equilibrium values of R_c, L_a and $L_c{}^*$ (appearing in R_c/Q) and will then have an indirect effect on the allocation of additional labor.

Now solve (2.16) for $\dot{Y}_w$, the rate of change of real income valued at world prices:

$$\begin{aligned}\dot{Y}_w = \left(\frac{1}{Y_w}\right)\Big\{&[C(r \cdot R_c) - (K_c/C_{kk})V - (1/Q)(K_c \cdot L_a)W]\dot{q}_k \\ &+ [w \cdot C]\dot{g} \\ &- [(L_a/A_{kk})(Z - 1) + C(1 + r \cdot R_c - n \cdot w)]\left(\frac{t}{1+t}\right)\dot{t} \\ &+ [L \cdot Z]\dot{L} \\ &+ [r - (Z - 1)/R_a](J_1 - J_2) \\ &+ \left[r\left(\frac{1}{1+t}\right) - V - (1/Q)(L_a \cdot C_{kk})W\right]J_2\Big\} \qquad (2.19)\end{aligned}$$

where $V = (C/Q)[w + r(R_c - R_a)]C_{kk} \cdot A_{kk}$, and $V > 0$ if $R_c > R_a$ (the familiar strong factor-intensity assumption); where $W = \left(\frac{t}{1+t}\right)\left[1 - \left(\frac{n \cdot w}{1+t}\right)\right]$, and $W > 0$ if $n\left(\frac{w}{1+t}\right) < 1$; and where $Z = [1 + (g + R_c)V - (1/Q)(K_c \cdot A_{kk})W] = \left[(L_a/Q)(g + R_c)C_{kk} + (K_c/Q)\left(1 + \frac{n \cdot w \cdot t}{1+t}\right)\left(\frac{1}{1+t}\right)A_{kk} + (g + R_c)V\right]$, so that $[1 + (g + R_c)V] \gtrless Z > 0$.

The first three arguments of (2.19) pertain to the effects of once-over changes ($\dot{q}_k$, $\dot{g}$ and $\dot{t}$) on the equilibrium level of income. Unfortunately, two of them are ambiguous, even after one invokes strong factor ordering (to set $V > 0$). One can say that an increase in expenditure on training ($\dot{g} > 0$) causes a permanent increase in income (and that the influence of changes in training costs is not directly dependent on the tariff rate or the mode of valuation of human capital). But one cannot know the impact of changes in q_k or t.

If human capital is valued at social cost ($n = 0$), the second portion of the tariff coefficient has to be positive. If, further, $t = 0$ to start, Z will exceed unity (as W is zero). The *introduction* of a tariff will reduce Y_w. If $t > 0$ to start, however, Z could be less than unity, diminishing the adverse impact of a higher tariff. If human capital is valued at private cost ($n = 1$), the argument grows more complex. With or without a tariff to start, this mode of valuation activates the final term in the tariff coefficient, working to reduce, if not to reverse, the impact of the tariff change. When $t = 0$ to start, then, the introduction of a tariff could increase real income (and is the more likely to do so, the larger the wage difference earned by skill). When $t > 0$, however, W reappears, reducing Z, and the net effect of a higher tariff is again in doubt.[57]

The last three terms of (2.19) relate to the effects of population growth and the two forms of investment. Once more, however, two of them have uncertain signs. An increase of the labor force ($\dot{L} > 0$) raises real income, but the fixed pattern of investment denoted by $(J_1 - J_2)$ and J_2 could work to reduce it.[58]

Consider, next, the impact of the tariff rate on the rates of change of income associated with $\dot{L}$ and with investment.[59] Neglecting indirect effects (those on L_a, L_c^*, K_a, K_c, w, and r):

$$(\delta Z/\delta t) = -(1/Q)(K_c \cdot A_{kk})(\delta W/\delta t) \tag{2.20}$$

where:

$$(\delta W/\delta t) = \left(\frac{1}{1+t}\right)^2\left[1 - n\left(\frac{1-t}{1+t}\right)w\right] \tag{2.21}$$

If, then, human capital is valued at social cost ($n = 0$), an increase in the tariff rate will lower the $\dot{Y}_w$ induced by $\dot{L}$ (but cannot turn it negative). If human capital is valued at private cost ($n = 1$), an increase in the tariff may have different consequences:

a. If $t > 1$, an increase in t will be even more adverse to growth in income due to growth in population;

b. If $t = 1$, an increase in t will have the same effect as when $n = 0$;

c. If $t < 1$, there are three possibilities:

(i) With $(w - 1) < t(1 + w)$, an increase in t will be adverse to growth in income;

[57] Notice, however, that W declines as w rises, so that, with high returns to skill, the whole coefficient could be positive.

[58] The uncertain signs of the coefficients multiplying $(J_1 - J_2)$ and J_2 themselves may well derive from the fact that fixed rates of investment will not always maximize growth in real income.

[59] Changes in training costs are equally significant for the population and investment coefficients, but their effects are more difficult to analyze (and the partial analysis used thus far is even less appropriate).

(ii) With $(w - 1) = t(1 + w)$, an increase in t will not affect growth in income; and

(iii) With $(w - 1) > t(1 + w)$, an increase in t will actually promote growth in income due to growth in population.

Turning, finally, to investment, when $n = 0$, the argument multiplying $(J_1 - J_2)$ rises with a higher tariff. Investment in primary production will make a larger contribution to $\dot{Y}_w$. This is because the higher tariff raises W, reducing Z (see equation 2.21). When $n = 1$, however, one must go through all the cases listed above, turning them around. In case c(i), for instance, an increase in t will reduce the contribution of $(J_1 - J_2)$; the positive derivative of $-Z$ will be reduced, so that the whole coefficient multiplying net investment will not rise as much. Again, when $n = 0$, the argument attached to J_2 alone is decreased by a higher tariff, for $r\left(\frac{1}{1 + t}\right)$ will fall and W will rise. Investment in manufacturing, including human capital, will make a smaller contribution to $\dot{Y}_w$. When $n = 1$, of course, one must again apply the serial analysis developed from (2.21), but without reversing the substance of the argument. In case c(i), for instance, an increase in the tariff will reduce the adverse impact (or enhance the contribution) of capital formation in manufacturing.

COMMENTS

ANNE O. KRUEGER
UNIVERSITY OF MINNESOTA

As Kenen's paper amply demonstrates, the role that human capital plays in determining comparative advantage is not yet well understood, even in a static sense. The solution of the question of the determinants of individual countries' paths of accumulation of various productive factors will be even more difficult. Kenen has done a masterful job of surveying the results to date and outlining the approaches with which future work is likely to have the highest payoff.

No matter how well-founded the reasons given, the ultimate test of such speculations about future research is the outcome. By and large, my own hunches are in accord with Kenen's. I shall, nonetheless, confine my remarks to those areas where there are differences in emphasis between us.

I. THE PRESENT STATE OF KNOWLEDGE

Kenen is, in my judgment, somewhat too charitable in accepting the work on research and development to date. While the question of the relative importance of R & D and human capital in explaining comparative advantage is still open, Kenen seems to accept two aspects of the work that are surely questionable. First, there are serious questions about the meaning of the variables used by Keesing and others to represent the role of R & D. Second, there is good reason to question the appropriateness of a skill index to measure a human capital stock.

The R & D variable used in most regression analysis is either the number of scientists and engineers engaged in R & D as a percentage of total employment in the industry, or current expenditures on R & D as a percentage of sales (which undoubtedly contains a high percentage of scientists' and engineers' salaries). Both are flow variables. If one were to consider the stock of "disembodied knowledge," one would surely wish something like cumulated expenditures on R & D or the present value of past investments. Even then, there is a question whether R & D is a factor of production or a produced good. Scientists and engineers, after all, represent a certain very highly skilled group of employees. To the extent that a production process requires specific design and engineering skills carried on in an R & D department, the production process requires a large human capital input. It may be that R & D activities, essential to production, are human-capital-intensive activities, and as such, are carried on most successfully in countries with a large stock of human capital relative to other factors. The collinearity which Kenen notes suggests that human capital inputs to an industry and its R & D performance are not independent.

As Kenen shows, a broader skill index reverses the results in terms of relative importance of scientists and engineers in R & D and in other skill categories. This raises the second question. That is, to what extent can the importance of human capital in determining comparative advantage be tested using a skill index of the type constructed by Keesing and others? The skill indexes are all derived by taking certain skill groups as a percentage of total employment in the industry. In one sense, this implies that there is perfect substitution among all groups included in the numerator and no substitution between those groups and other groups excluded from the numerator. Surely, by standards of some developing countries, some American industries must have more than one skilled worker per worker.

Measurement of physical capital stock, despite all the conceptual problems, is usually in some sort of homogeneous unit. Investing in humans constitutes the same sort of capital accumulation, yet the fraction of workers with skills (above some minimal level) is regarded as an adequate proxy for the human capital content of the labor force. A similar procedure with machines would be to take machines of more than twenty-five horsepower, for example, as a fraction of all machines. It can also be argued that investing in human capital results in an addition to capital stock, not the substitution of one kind of labor for another.

A skill index, such as that used by Keesing and others, is therefore highly suspect as a test of the role of human capital in determining comparative advantage. In view of the suspicions which must attach to both indexes, it is doubtful how much weight can be given to regression results of the type reported by Keesing and others.

II. AGENDA FOR RESEARCH: POSITIVE ANALYSIS

I fully agree with Kenen's conclusion that use of a multifactor model, incorporating not only the static aspects of the Heckscher-Ohlin theory, but also an explanation of how factors are accumulated, will stimulate productive research.

I would, however, add several queries to his list. First, what is the role of population growth (and rates of change in it) in determining the relative allocation of investable resources between skills and machines? This question has two parts because: (a) insofar as population growth comes from increasing life expectancy, it surely must raise the rate of return (or the present value) of investment in man relative to investment in machines; and (b) one can envisage families with limited resources to invest in future generations: they can either invest intensively in a few children (for education, health, nutrition, and the like) or extensively in many children, allocating fewer resources to each one. Given the systematic patterns observed in the birth rate-death rate pattern as a function of income levels, it is difficult to believe that economic incentives are unimportant in determining the choice. One can imagine growth models incorporating mechanisms of this kind which might go far to explain the systematic factor-endowment differences observed among countries at different income levels.

My second question is, in a sense, an expression of doubt about two of Kenen's empirical assumptions. He believes that the real costs of training vary inversely with the skills on hand. This is questionable because increasing the skills of an already skilled person requires a higher foregone income. In rich countries, increasing skill levels involves the additional training of already skilled persons, whereas in poor countries, increasing skill levels may well involve training unskilled persons. The a priori reasons for believing that the real costs of the latter are higher are not clear. Kenen's second assumption is that learning-by-doing is less costly for high-income countries. This is questionable for much the same reasons expressed in the first assumption. High-income countries have more human capital invested in the learners, which would tend to make foregone income during on-the-job training higher.

Kenen makes these assumptions in attempting to explain why different countries have different human- to physical-capital ratios. His research, reported in his paper, provides the most fruitful starting point for analysis of the question, and raises additional questions. Focus upon the role of the interest rate and population growth (which capital theory suggests may be interrelated) in determining the allocational pattern between skills and machines, rather than on training costs, appears promising. Investment in man generally takes longer, and depreciates over a longer period of time than does investment in physical capital. One would, therefore, expect that at a higher interest rate, it would pay to invest relatively more in machines than at a lower interest rate. Similarly, a higher rate of population growth due to increasing life expectancy would increase the present value of investment in man, whereas a higher birth rate would reduce it.

Kenen's discussion of migration suggests one other line for research, both positive and normative. Trade will, in general, tend to lower the wage of relatively scarce factors of production and raise the wage of abundant factors. If the amount invested in skills (and machines) is an increasing function of the return to investment, trade may reduce investment in human and physical capital in capital-scarce countries by lowering the return on it. Offsetting this is the higher real income a country can attain through trade, which tends to increase the country's saving and therefore its investable resources. If skills are acquired partly in response to the incentive to do so, and trade reduces those incentives, there may be a justification for infant-industry intervention somewhat different from that suggested by Kenen. A subsidy or tariff for capital- (physical and human) using industries will tend to raise the rate of human and physical capital accumulation by increasing incentives and returns on it, and lower the rate of accumulation by lowering real income and therefore saving. An infant industry subsidy or tariff would then be set at a level where the increase in investment in human and physical capital generated by the higher incentives exactly offsets the reduction in investment occasioned by lower present real income as a consequence of reduced trade.

III. NORMATIVE ANALYSIS

Kenen's plea for more theoretical normative analysis is well taken. His own heroic attempt illustrates the difficulties of model formulation, either positive or normative. His model is a worth-while starting point, although one might question the focus upon training costs, for the reasons I have outlined.

Even if one believes that training costs are the appropriate focal point for analysis, there remain significant problems, which Kenen pointed out in his earlier discussions. Perhaps the most important is the question of how skills are incorporated in the production function. Kenen's production function (equation 1.4) has constant returns to scale. In form, the production function for manufacturers (1.4) is no different from that in agriculture (equation 1.1), even though it is assumed that manufacturing requires skilled workers and agriculture only unskilled workers. (Is this a good assumption?)

If investing in skills adds to resources, a satisfactory treatment would require a production function of the form:

$$C = f_c[K_c/L_c, S_c/L_c, 1] \cdot L_c \tag{1.4'}$$

where S_c/L_c represents skills per worker, just as K_c/L_c represents capital per worker. In Kenen's treatment, the difference between skilled and unskilled workers on the demand side is only that skilled workers must receive a higher wage, and therefore must have a higher value of marginal product.

At a more technical level, Kenen has amply demonstrated the difficulties inherent in attempting to develop a dynamic model of human and physical capital accumulation. He set out to analyze the effects of changes in training costs and tariffs on the growth paths of real income and human capital accumulation. Yet he succeeds only at the cost of holding constant: (1) imports of machinery to produce consumer goods (J_2); and (2) total investment (J_1).[1] In a model where all growth occurs through factor accumulation, it is reasonable to question whether a model in which there is one degree of freedom in the factor accumulation path —the allocation of fixed investable resources between the primary sector's physical capital and the manufacturing sector's human capital—will answer the questions he poses. One can only conclude, with Kenen, that additional research is badly needed.

ROBERT E. BALDWIN
UNIVERSITY OF WISCONSIN

International trade theory is presently in the interesting but somewhat confusing state in which there are almost too many promising hypotheses with which to supplement the traditional, simple factor-proportion approach to explaining the structure of trade. For example, as Peter Kenen

[1] Kenen asserts (footnote 54) that ($J_1 - J_2$) equals investment in primary production. Since, however, J_1 is total government revenue plus government saving (equals investment, by equation 1.21) and J_2 is the difference between export earnings and consumer good imports (1.15), J_2 must equal the net addition to manufacturing physical capital stock.

points out, both relative differences in labor skills and in research expenditures have tested out as highly significant variables in recent investigations of trade patterns. Moreover, there are a number of other variables that seem to be important determinants of a country's trade pattern. It has been suggested, for example, that the existence of natural resource scarcities in conjunction with a complementary relationship between these natural resources and physical capital explains Leontief's paradoxical results. There are also those who claim their analyses show that factor-intensity reversals within relevant factor-price ratios are so pervasive that they make the entire factor-supply approach irrelevant. Tariffs and other market perfections are another set of factors that apparently play an important role in accounting for actual trade patterns.

What is very much needed in the trade field are careful empirical efforts to determine the relative importance of these various factors. As Kenen notes, there are several players in the drama, and we should stop the common practice of trying to show that some one player is really the star, if only one is willing to ignore certain other players or concentrate on some particular scene. It is in this spirit of eclecticism that he considers the relative importance of labor skills and research activities. From this analysis he concludes that skills may be a more significant determinant of the U. S. trade pattern than production function differences related to relative research expenditures.

Although there seems to be no doubt that relative supplies of skilled labor play a major determining role in the composition of U. S. trade, I should like to underline a few of the well-known difficulties of measuring skill data in human capital terms and also to caution against underestimating the importance of research. One method of approaching the skill problem is to assume that wage differences are a consequence of differences in skill levels, which, in turn, are the result of differences in investment in education and on-the-job training. Kenen has performed the exercise of capitalizing such wage differences among skill groups employed in U. S. export and import industries and has shown that exports are considerably more intensive in human capital terms than imports. Moreover, he is able to reverse the Leontief paradox by capitalizing these wage differences at rates less than 12.7 per cent and then combining them with Leontief's measure of tangible capital.

A drawback of computing human capital by capitalizing income differentials is, of course, that this procedure assumes all income differences to be the result of differences in education, on-the-job training, and other forms of human investment.[1] However, there is growing evidence that market imperfections associated with various economic and social factors as well as differences in ability are also important explanatory factors accounting for wage differences. Nevertheless, other measures of skills and human capital do indicate that in 1962 U. S. export industries employed a higher proportion of skilled workers than U. S. import-competing industries.[2] For example, the average years of education of workers employed in export industries was greater than in import-competing industries. Similarly, as is consistent with Leontief's findings, export industries employed relatively more professional and managerial employees as well as craftsmen and foremen than did import-competing industries. The opposite relationship held with respect to operatives and nonfarm laborers.[3]

As an indicator of the relative importance of research efforts, a class of research workers was constructed from the detailed occupational statistics of the 1960 sample census and the number of such individuals employed directly and indirectly in export- versus import-competing industries was then calculated. A representative bundle of exports turned out to require about 50 per cent more workers of this type than a representative bundle of import substitutes. Similarly, using the R & D sector in the 1958 input-output table, it was found that the R & D expenditures associated with export industries were also about 50 per cent higher than with import-competing industries. In running multiple regressions between an industry's net trade balance and such variables as years of education, earnings, capital/labor ratios, and various skill groups, the research-worker measure invariably turned out to be highly significant. The proportion of skilled workers and of farmers and farm laborers employed in each industry are two other variables that were significantly correlated in a positive manner with the trade-balance variable.

[1] By not including the human capital represented by unskilled laborers, Kenen's procedure tends to overstate the ratio of human capital in export compared to import-competing production, since in 1959 there were more unskilled laborers involved in a million dollar's worth of import-competing production than export activities.

[2] In making these calculations, I used the 1958 input-output table, capital and labor coefficients estimated for that year, and the 1960 1/1000 sample census of population.

[3] However, there are slightly more farm plus nonfarm laborers engaged in producing a representative export- than import-competing bundle of commodities.

It would seem, therefore, that as far as the U. S. trade structure of the early sixties is concerned both research and skills are important explanatory variables. Furthermore, using a single gross measure of human capital such as years of education, cost of education, or earnings does not appear to capture all the labor force qualities that influence the pattern of trade. This suggests that other factors are also important in accounting for the qualitative composition of a country's labor supply. We need a better empirical and analytical understanding of what these other variables may be and how they are interrelated with the notion of human capital. Moreover, we need to explore further the relations between the nature of technological progress and such factors as natural resource conditions and the nature of the labor skills available in a country.

Kenen and those who have been working with him in the trade workshop at Columbia have in recent years made substantial analytical and empirical contributions to questions of this sort. As he points out, the models that have been developed are still quite simple and restrictive but they are important first steps in moving trade theory away from the simple factor-proportion approach that has dominated it for too long. Consequently, I strongly second his point that—partly as a result of research in the human investment field—international trade theory is at a stage where a whole series of promising lines of inquiry have opened up and are much in need of research. Hopefully, those with special competence in the human investment field will not only help to influence the nature of this research but also will actually participate in it themselves.

D. J. DALY
YORK UNIVERSITY

This paper continues the valuable work on the contribution of skills and human capital to the composition of commodity trade of the United States. It emphasizes the role of the high levels of human skills and education in the U. S. labor force, and the differences in education and skill requirements in broad commodity groups.

It is worth emphasizing that a new range of empirical data relevant to this question is available in a recent Brookings study.[1] In this study the contribution of a wide range of factor inputs and other topics are estimated and assessed for the United States and eight European countries. A Canadian study, using the same framework, has also been prepared.[2] These countries provide data in a comprehensive framework for a group of countries that dominate world trade, especially in manufactured products.

Although this framework and these data were developed initially to deal with differences in the levels of real output and growth experience between countries, they can be easily applied to international trade. For example, the data on factor supplies per employed person and output in relation to total factor inputs can be used to test the relevance and relative importance of the theories of Ricardo and Heckscher-Ohlin to international trade and comparative advantage in the main industrial countries.

Kenen's data on human capital use the percentages having various skills or the percentage engaged in R & D, and Anne Krueger's comments raise questions about these measures. Denison measures the whole education distribution and provides a measure with the desired characteristics.

This point can be illustrated for Canadian data, which have been assembled and published along the same lines as developed in the Brookings study. Although the levels of education in Canada are lower than in the United States, the supplies of other factors of production per employed persons are higher (e.g., construction, inventories, and natural resources). In total, the supplies of the total levels of all measured factor inputs are almost identical in the two countries, when weighted by their importance in national income. On the other hand, the levels of output per employed person and output in relation to total factor inputs is about 20 per cent lower than in the United States for the economy as a whole, and the differences are much larger for total manufacturing. The Canadian data are much more consistent with the Ricardian assumption

[1] Denison, E. F. and Poullier, J. P., *Why Growth Rates Differ: Postwar Experience in Nine Western Countries*, Washington, 1967.

[2] Walters, Dorothy, *Canadian Income Levels and Growth: An International Perspective*, Staff Study No. 23, Economic Council of Canada, Ottawa, 1969.

of different production functions in different countries (or quite different observable positions on a similar production function), than the Heckscher-Ohlin theory which emphasizes the role of different factor prices and factor supplies and similarities in production conditions.

I hope that future work on trade and comparative advantage can incorporate more analysis and use of the new material on international comparisons of real incomes, factor supplies, and output in relation to input.