Global Factor Trade in Ohlin's Time*

Antoni Estevadeordal, *Inter-American Development Bank*†
Alan M. Taylor, *University of California at Davis and NBER*††

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Abstract
An empirical tradition in international trade seeks to establish whether the predictions of factor abundance theory match present-day data. In the analysis of goods trade and factor endowments, mildly encouraging results have been found by Leamer et al. But ever since the appearance of Leontief's paradox, the measured factor content of trade has always been found to be far smaller than its predicted magnitude in the pure Heckscher-Ohlin-Vanek framework, the so-called "missing trade" mystery. Seeking a better fit with the data, recent work has contemplated considerable tinkering with the pure Heckscher-Ohlin theory. We wonder if this problem was there from the beginning. That is, we ask if the theory was so much at odds with reality at its time of conception. This seems like a fairer test of its creators' original enterprise. We apply contemporary tests to historical data on goods and factor trade from Ohlin's time, focusing on the major trading zone that inspired the factor abundance theory, the Old and New Worlds of the pre-1914 "Greater Atlantic" economy. Our analysis is set in a very different context than contemporary studies—an era with lower trade barriers, higher transport costs, a more skewed global distribution of the relevant factors (especially land), and comparably large productivity divergence. Thus, our work complements tests applied to today's data and informs our search for improved models of trade.

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† Antoni Estevadeordal is a Research Economist at the Inter-American Development Bank. Address: Inter-American Development Bank, 1300 New York Avenue NW, Washington DC 20577. Telephone: 202-623-2614. Fax: 202-623-3030. Email: <antonie@iadb.org>.
†† Alan M. Taylor is an Associate Professor of Economics at the University of California at Davis and a Faculty Research Fellow at the National Bureau of Economic Research. Address: Department of Economics, University of California, One Shields Avenue, Davis, CA 95616-8578. Telephone: 530-752-1572. Fax: 530-752-9382. Email: <amtaylor@ucdavis.edu>. WWW: <http://www.econ.ucdavis.edu/~amtaylor/>.

1. Factor Abundance Theory in Historical Context

Some years ago, scholars in the field of international trade, and perhaps especially the empiricists, might have viewed an invitation to the Ohlin centennial with a sense of unease. Most of us saw factor abundance trade theory as possibly unparalleled in the realm of economic science in its elegance of form and powerful statements on the sources of comparative advantage. At the same time the theory was viewed as having been confounded by empirical contradictions in a series of studies dating back to the paradox unearthed by Leontief.[1] Given such an environment, what kind of conference paper could one offer that would not mar the spirit of celebration?

Happily, at least for the legacy of Ohlin, perspectives do change. In recent years, new approaches and extensions to this landmark theory and its empirical testing have attested to its durability and relevance for explaining modern-day trade patterns.[2] In one tradition of empirical research, following Leamer (1984), scholars have constructed large datasets on national endowments and trade patterns so as to measure the link between factors and trade. This is predicted by the theory to be a linear relationship depending on technical coefficients, suggesting that, say, an increase in capital endowment should spill over into trade as an increase in the net export of capital-intensive goods. In another strand of work, following the notation and methodology of Vanek (1968), scholars have focused on the implicit factor trade alone and its relationship to factor abundance (Leamer 1980; Bowen, Leamer, and Sveikauskas 1987). This approach seeks to establish a pass thorough—in principle, a unit coefficient—relating increments in relative factor endowment directly to net exports of the same factor, as production shifts relative to a stable consumption pattern. Most of the very recent empirical contributions (for example, Trefler 1993, 1995; Davis and Weinstein 1999) have used the Vanek representation.

These recent works point to a compromise position where the Heckscher-Ohlin theory, augmented in various ways, might better account for the contemporary pattern of factor trade. To deal with the Leontief paradox one can allow for differences in cross-country productivties, as suggested by Leontief, and implemented empirically by Trefler (1993; 1995). Still, this modification alone doesn't get us very far towards narrowing the huge gap between measured and predicted factor trade. Trefler (1995) coined the term "missing trade" to depict the extent to which measured trade is still negligible compared to the prediction of the pure theory.[3] To get an even closer fit, other modifications have been suggested by Trefler (1995) and Davis and Weinstein (1999) such as home bias in consumption, an allowance for non-traded goods, and models without factor price

[1] Leontief (1953a) shocked everyone when he computed a U.S. input-output table for 1947 and discovered that the seemingly capital-abundant and labor-scarce United States was actually engaging in net labor export via trade, with a capital-labor ratio in imports 60% higher than exports.

[2] We need not review the whole literature here, but direct the reader to the excellent survey by Helpman (1998) on which we have drawn extensively in what follows.

[3] The same point has been forcefully repeated by Gabaix (1997)

equalization. However, before basking in fresh optimism over how the factor abundance theory has been thoroughly rehabilitated by these various devices, we should note that lurking here is a danger. After so much ornamentation has been added to the model, the skeptics might reasonably ask what is left of Heckscher and Ohlin's original design.

One wonders what Ohlin would make of all these developments and modifications to his theory given his original standpoint. Here was an economist working in the early twentieth century who was inspired to explain the international trade patterns previously witnessed in a largely free-trade regime—the trade of mostly commodity goods and manufactures in the Greater Atlantic economy during the first era of globalization before World War One.[4] And when Heckscher and Ohlin made their seminal contributions most observers still hoped that this regime would soon be restored for the long run in the 1920s, though that was not be.

Heckscher and Ohlin would not necessarily condone the use of their theory in today's very different global economic environment. Today we see numerous barriers to trade (especially in agricultural commodities and simple manufactures), trade in differentiated products and services, and significant intra-industry trade.[5] However, the duo still might be impressed by the substantial technical apparatus we have developed to evaluate their theory, even as they might regret that they never had easy access to the kinds of large datasets we now take for granted as we implement our sophisticated tests. Given all this, we can imagine one possible reaction from the fathers of factor abundance trade theory. Might they not call on us to take our considerably refined empirical skills back in time and at least give the theory—and its authors—some kind of a break by testing the model in the historical context for which it was first designed?

Imagining that we heard such a call at the time of Ohlin's centennial, and having a taste for economic history, we thought it would only be fair to him to do just that. Not only does this idea appeal for sentimental reasons, but also, we will argue, it helps resolve questions stimulated by the research on contemporary global factor trade. Testing the model in an earlier historical epoch might help us see the sources of difficulty in applying the model in the present. By bringing to the discussion new datasets from a different economic and political era, we can gain a new perspective. And in some ways, the pre-1914 period offers a better testing ground for the pure Heckscher-Ohlin trade model, as economic historians love to remind us. Indeed, a strand of the economic history literature has already found strong support in that era for several features of standard theory, including predictions of factor price convergence and the pattern of goods trade.[6]

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[4] For a study of the era, encompassing trade and factor flows, see O'Rourke and Williamson (1999).

[5] Still, in theories of differentiated products and intra-industry trade, the concepts of Heckscher-Ohlin trade theory endure in basic textbook formulations (Dixit and Norman 1980; Helpman and Krugman 1985).

[6] On factor price equalization see O'Rourke, Taylor, and Williamson (1996) and O'Rourke and Williamson (1994). On goods trade and factor endowments see Estevadeordal (1993). We review the latter in the next Section 2.

What are the features of the pre-1914 era that make it a better laboratory for testing pure trade theory compared to today? And are there other aspects that favor the present? We know, first, that there were much lower trade barriers then than now, and this could be why the theory fails in the present. Even though trade reforms and tariff reductions have progressed in postwar decades, tariff levels are still high by nineteenth century standards and quotas now apply to many goods.[7] Thus, the past epoch might more closely match the free-trade assumptions of the theory.

Second, in the last century, certain endowments were very skewed in their distribution, most famously the agricultural land that differentiated the endowments of the New World from the Old. Today, in contrast, many of the countries in the samples studied have very similar endowment patterns, and this leaves little data variation from which to get a strong of fit.[8] In the context of standard econometric tests of predicted-versus-measured factor content of trade such variation would strengthen the test enormously by offering a wide range in the independent variable. This could be another weak point in tests using modern data.

Third, we note that there were considerable divergences in productivity across countries circa 1913, just as there are today. Over the course of the twentieth century we have seen dramatic productivity convergence within a narrow club of countries—mostly the OECD and, thus, much of the Greater Atlantic economy. Yet it is equally true that outside this subset productivity convergence of the unconditional variety has been weak or nonexistent.[9] Thus, by doing our tests circa 1913, we are in no way making the problem simpler for ourselves by avoiding an essential ingredient in the "missing trade" puzzle: the possibility of international productivity differences.

Raw differences in factor productivity were postulated by Leontief (1953a) as a possible solution to his paradox for the United States, and his idea was supported in international samples by Trefler (1993; 1995) and Davis and Weinstein (1999). However, as Helpman (1998) notes, this way out just creates another disturbing puzzle: namely, where do these differences in productivity originate? In historical work, this same disturbing idea was brought to the fore by the controversial work of Clark (1985). He found no comfort in any economic explanation of international variations in the

[7] On trade barriers then and now see, for example, World Bank (1991). Tariff levels were in the single- or low-double-digit range before 1914, and much larger in the postwar period, especially in developing countries. Quotas were virtually nil before 1914, and considerable in the late postwar period.

[8] For example, Davis and Weinstein (1999) find inevitably that OECD countries are clustered together with similar capital-labor ratios, a feature arising from those countries' similar levels of development and industrial structures. Their Rest-of-the-World data point lies far away from the OECD group, but this gives a great deal of leverage to one point, so much so that it is thought prudent to exclude it from the tests as a sensitivity check. And in terms of data quality, the Rest-of-the-World point uses less consistent data, and the required measures have to be constructed by a more fragile procedure.

[9] The first studies of long-run convergence (Abramovitz 1986; Baumol 1986) used the 16-country data of Maddison (1982). Baumol was the first to note the postwar failure of unconditional convergence in wider samples that included less-developed countries. The origin of this failure was first identified by Dowrick and Nguyen (1989); they found conditional convergence controlling for investment and population growth, narrowing the problem to a determination of these factor accumulation processes.

productivity of cotton mills in various countries circa 1913. There seemed to be no compelling economic reason why one New England cotton textile operative performed as much work as 1.5 British, 2.3 German and nearly 6 Greek, Japanese, Indian or Chinese workers. After controlling for capital intensities, breakdowns, human capital, learning, and other effects, Clark was forced to admit the possibility of a purely cultural origin of the differences, quite possibly exogenous to the economic system. If Clark's idea holds in a wide range of sectors circa 1913, then, just as output would have been affected by these raw productivity differences, so too would the levels of trade and the factor content therein, with direct implications for our proposed tests.

Finally, we should note a couple of characteristic that work against the earlier period as a good testing ground. First, we must consider the higher transport costs of the past. Like measuring true tariffs from actual import data, measuring true transport costs from trade data is problematic. Comparing CIF and FOB prices then and now might not lead to a big difference in the measured transport cost premium *on goods actually shipped*: goods too expensive to ship never make it into the sample, creating a serious selection problem.[10] Data is scarce here, but it is a reasonable conjecture that many bulk goods shipped today move at a fraction of their cost a hundred years ago, and surely many exotic goods and services can now move more cheaply than they did in the past. The second problem for the earlier period—though it is by no means absent in the present—concerns factor mobility. It is well known that the theory predicts that trade and factor mobility are substitutes, and the late nineteenth century was a time of very fluid international factor markets. International labor mobility facilitated the migration of millions of people, especially in the great transatlantic waves from Europe to the New World (Easterlin 1961; Hatton and Williamson 1994, 1998; Taylor and Williamson 1997). The first era of global capital markets functioned very efficiently, reallocating vast sums of capital internationally (Obstfeld and Taylor 1998, 1999; Taylor 1996). The presence of endogenous factor movements could well interfere with empirical tests that treat factor endowments as exogenous independent variables. We will return to this issue in our conclusion.

All of these comparisons of past and present reaffirm the need to fall back on theory to judge the issue. For example, it might be tempting to look at trade volumes and argue that the late nineteenth century was as much of an integrated trading economy as today's, since, in many countries, trade-to-GDP ratios are no higher now than in the past. This misses the point. The factor abundance theory, for example, might counter this argument by pointing out that although the late nineteenth century trade (in goods or factors) was large, it was *not large enough* given the skewed distribution of world factor endowments. Our proper interest here is not in the size of trade *per se*, but how large that

[10] This caveat must be kept in mind, even though plenty of evidence attests to the fact that on a wide range of goods shipped before 1914 transport costs in the Atlantic were collapsing over a span of several decades, both on primary products and manufactures. O'Rourke and Willamson (1994). See also North (1958) and Harley (1988).

trade is relative to what theory would predict, whether for goods of factors.[11] But without tractable empirical tests and the right historical data we cannot attack this issue.

The rest of this paper is organized around the steps we took to mount such an attack. We focus on the two different types of tests used, those based on goods trade and factor trade, respectively. We describe the historical data and its manipulation for the test at hand. Results are presented in the usual form for each test and the implications are discussed. A brief conclusion muses over some broader interpretations and suggests directions for future research

2. Factor Endowments and Product Trade circa 1913

Tests

Consider the standard Heckscher-Ohlin theory, in a world of C countries, I industries, and F factors. Let the output in country c be $\mathbf{X}^c$ $(I \times 1)$. The factor content of $\mathbf{X}^c$ is $\mathbf{B}\mathbf{X}^c$, where $\mathbf{B}$ is a matrix $(F \times I)$ of factor content coefficients.[12] Full employment implies that $\mathbf{B}\mathbf{X}^c = \mathbf{V}^c$, where $\mathbf{V}^c$ is the factor endowment of country c. Consumption $\mathbf{C}^c$ $(I \times 1)$ in country c equals the country share of world expenditure (assumed equal to world output in this study) s^c times world consumption $\mathbf{C}^W$. The latter, by world market clearing, equals world output, $\mathbf{C}^W = \mathbf{X}^W = \Sigma_c \mathbf{X}^c$. Hence, $\mathbf{C}^c = s^c \mathbf{X}^W$, and the net goods trade $\mathbf{T}^c$ of country c equals $\mathbf{T}^c = \mathbf{X}^c - \mathbf{C}^c = \mathbf{X}^c - s^c \mathbf{X}^W$. If we denote world factor endowment by $\mathbf{V}^W = \mathbf{B}\mathbf{X}^W$, then

$$\mathbf{T}^c = \mathbf{B}^{-1} (\mathbf{V}^c - s^c\mathbf{V}^W). \qquad (1)$$

This equation says that trade in each industry is linearly related to factor endowments. We assume that $\mathbf{B}$ is invertible (that is , square, with $I = F$). Leamer (1984) argued that the equation need not be restricted to the square case and he proposed it be tested by regressions for each industry i. Evaluation centers on the fit and reasonableness of these equations, allowing for both statistical and quantitative significance.[13]

This methodology was used to study trade circa 1913 by Estevadeordal (1993). The challenge was to construct new datasets on net trades (the left-hand side) and endowments (the right-hand side) for the econometric study. A detailed explanation of the data, coding, and aggregation is found in the appendix to Estevadeordal (1997). We provide a brief overview here.

[11] Of course, switching from quantities to prices makes life no easier for the measurer of market-integration. Autarky prices can coincidentally equalize in two physically isolated economies, but prices can be far apart in two partially-integrated economies due to transaction costs barriers.

[12] In detail, B_{fi} is the direct and indirect use of factor f per unit output of industry i. Direct use refers to factors used as inputs in the given industry; indirect use refers to the factors embodied in the intermediate products used as inputs in the given industry.

[13] A potential weakness here is that we do not measure the matrix $\mathbf{B}^{-1}$, but rather estimate it. The specification is loose, and the estimated matrix has totally free parameters that may be unrelated to the true technological coefficients. This weakness is avoided in the factor-content approach we use in Section 3.

Data, Coding, and Aggregation

Data on net trade for the period circa 1913 was collected for $C = 18$ countries: Argentina, Australia, Austria-Hungary, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and United States. The sources used were official national reports of trade statistics, originating from such agencies as the Board of Trade (U.K.) or the Department of Commerce (U.S). The principal problem in ensuring consistency across countries was to set up a universal classification scheme for industries, since, prior to World War Two, no standards had been developed and each country used its own classification. The solution was to laboriously construct country-specific concordances that would map each country's sectors into selected sectors of the Standard International Trade Classification (SITC, Revised 1961) at the two-digit level. In this way the trade data $\mathbf{T}^c$ was rationalized into a database for $C = 18$ countries and $I = 55$ sectors expressed in U.S. dollars at market exchange rates. [14]

National product estimates were taken from Mitchell (1980, 1983) and Maddison (1995) and expressed in U.S. dollars at market exchange rates, providing the basis for expenditure shares s^c. [15]

Endowment data $\mathbf{V}^c$ for all countries were collected for $F = 5$ types of factor: capital stock, skilled and unskilled labor force, agricultural land, and mineral resources. In Estevadeordal (1993) a proxy for capital stock based on energy consumption of solid fuels was used. The data on energy consumption refers to apparent consumption of primary sources, including net imports of secondary as well as primary energy forms. Because of data availability only solid fuels had been considered (hard coal, brown coal, lignite and coke). In order to permit aggregation and comparison, data were expressed in thousands of hard-coal equivalents. However, in order to carry out the subsequent factor content analysis in Section 3 we made new capital stock estimates for 1913 using a perpetual-inventory method applied to pre-1913 annual investment rates and real outputs, as described in the appendix. The results gave capital-output ratios for the terminal year 1913, and multiplying by national products yielded capital stocks in U.S. dollars at market exchange rates. In this section of the paper we report results based on Estevadeordal (1993) which uses the original capital measure. The labor force figures originate in Maddison (1982) and Mitchell (1980, 1983), using interpolation between census years as necessary. Agricultural land is measured in hectares and the data is largely from a study by the League of Nations (1927). Mineral resources are estimated using as a proxy the U.S. dollar value of the annual production of petroleum plus twelve

[14] For all the data described in this section, figures were collected for the year closest to 1913. Exchange rates were taken from international compendia of exchange rates, where available, or from national sources.

[15] We do not calculate consumption or expenditure shares directly, but rather assume they are equal to income or output shares. That is we set $s^c = GDP^c/GDP^w$, and not, following the trade-balance correction of Trefler (1995) as $s^c = C^c/C^w$. This correction makes no material difference to our results.

other minerals and ores; quantities are drawn principally from Mitchell (1980, 1983) and prices from Potter and Christy (1962).[16]

Results

The Heckscher-Ohlin equation (1) expresses trade in terms of excess endowments ($\mathbf{V}^c - s^c\,\mathbf{V}^W$). For empirical purposes, following Leamer (1984), we can regress trade on endowment supplies alone.[17] We report results at two different levels of aggregation (six and forty-six commodity groups).

Table 1, Panel (a), reports the estimates for the following six commodity groups: agricultural products, raw materials, capital-intensive goods, labor-intensive goods, machinery and chemicals. The R^2 measures of fit are typically very high and most of the estimated coefficients are correctly signed and statistically significant. The coefficients still depend on the units of the explanatory variables. Since we are not only interested in the statistical significance of a coefficient but also in knowing how important each of the variables is in explaining the trade pattern, Panel (b) reports β values for each of the five explanatory variables for each trade aggregate considered.[18] If we select arbitrarily, as in Leamer (1984), 1.0 to define a significant β value, then capital is significant five times, land four times, and labor-skilled and minerals three times.

Generally speaking, using the estimates from Table 1, comparative advantage in agricultural products is associated with abundance of land and mineral resources and is negatively related to capital. Trade in raw materials owes comparative advantage to the availability of capital and unskilled labor; land and skilled labor contribute to

[16] The twelve ores are bauxite; copper; iron; lead; manganese; nickel; phosphate; potash; pyrites; sulphur; tin; and zinc. Some data was also drawn from Rothwell (various issues) and national sources of mineral production for various countries.

[17] The Heckscher-Ohlin model of trade can express trade in terms of endowment supplies or in terms of excess endowment supplies. In a 2 × 2 version the equations of the model are

$$T_1 = \beta_1 L\,(L - Y\,Lw/Yw) + \beta_1 K\,(K - Y\,Kw/Yw);$$
$$T_2 = \beta_2 L\,(L - Y\,Lw/Yw) + \beta_2 K\,(K - Y\,Kw/Yw);$$
$$Y = wLL + wKK;$$

where T_1 and T_2 are net exports of the two commodities, Y is GNP, L is labor, K is capital, w_L and w_K are factor returns, the w subscripts refers to the world, and the β are Rybczynski coefficients. This form of the model expresses net trade as a linear function of excess supplies of factors. However, excess factor endowments are a linear function of all factor supplies: that is, $L - Y\,L_w/Y_w = L - (w_L L + w_K K)\,Lw/Yw$. Thus, for almost all distributions of K and L these excess supplies are correlated, and a regression of trade on a subset of the excess supplies will yield biased and inconsistent estimates. This problem will be compounded if there are measurement errors. Because of this problem a reduced form of the model is preferred in empirical studies. This reduced form is found inserting the GNP equation into the net exports equations:

$$T_1 = \beta_1 LL + \beta_1 KK;$$
$$T_2 = \beta_2 LL + \beta_2 KK;$$
$$Y = wLL + wKK.$$

[18] A β value is equal to the estimated coefficient times the ratio of the standard deviation of the explanatory variable divided by the standard error of the dependent variable (Maddala 1977; Leamer 1978). These β values are directly proportional to the contribution that each variable makes to a prediction of net trade. These values indicate the amount of change in standard deviation units of the net trade variable induced by a change of one standard deviation in the factor endowment. A β value of 0.1 is small, since a change of one standard deviation in the resource would have a hardly perceptible effect on net exports, but a value of one can be regarded as large.

Table 1
Tests of Factor Endowments and Product Trade

(a) OLS estimates	Capital	Labor-skilled	Labor-unskilled	Agricultural land	Minerals	R^2	Adjusted R^2
Agricultural products	-7.6***	-26.3	-31.9	8.5**	4.5***	.81	.73
	(-5.22)	(-1.74)	(-0.55)	(2.38)	(4.50)		
Raw materials	2.7***	-20.6***	41.6*	-3.0***	0.4	.78	.69
	(5.22)	(-4.61)	(2.14)	(-4.91)	(1.67)		
Capital-intensive goods	2.1***	18.4***	13.3	-6.5***	-0.7*	.83	.77
	(5.98)	(4.21)	(0.66)	(-4.98)	(-2.08)		
Labor- intensive goods	-0.9***	17.8***	-9.8	-4.0***	0.8**	.65	.51
	(3.20)	(8.89)	(-1.24)	(-3.79)	(2.59)		
Machinery	1.1***	5.0*	-9.6	-3.1***	0.08	.91	.88
	(4.73)	(2.12)	(-1.05)	(-5.87)	(0.54)		
Chemicals	-0.1	6.7***	-6.3	-2.3***	0.38	.69	.56
	(-1.08)	(5.87)	(-1.62)	(-2.53)	(1.72)		

(b) β values	Capital	Labor-skilled	Labor-unskilled	Agricultural land	Minerals
Agricultural Products	-1.83	-0.51	-0.11	0.72	1.64
Raw Materials	2.36	-1.45	0.50	-0.92	0.53
Capital Intensive-Goods	1.30	0.92	0.11	-1.42	-0.65
Labor Intensive-Goods	-1.10	1.76	-0.17	-1.73	1.48
Machinery	1.22	0.45	-0.15	-1.22	0.13
Chemicals	-0.24	1.29	-0.21	-1.93	1.37

Notes: t-ratios in parentheses, (***) denotes significant at the 1% level. (**) denotes significant at the 5% level. (*) denotes significant at the 10% level. Commodity groups based on SITC Rev.1, 2 digit codes (see Appendix Table A3): Agricultural products (Groups 0, 1, 2 except 27 and 28, 4); raw materials (Groups 27, 28, 3 and 68); Capital-intensive goods (Groups 61, 62, 63, 64, 651-655, 67 and 69); labor-intensive goods (Groups 656, 66 and 8); machinery (Group 7) and chemicals (Group 5).
Source: Estevadeordal (1993).

comparative disadvantage. The sources of comparative advantage in manufacturing are, in general, as expected: capital is a source of comparative advantage for capital-intensive goods and machinery. Mineral resources are important for labor-intensive and chemicals groups. Skilled labor also contributes to comparative advantage in all manufacturing groups. The β values indicate, again, that the contribution is most important in labor-intensive and chemicals products, followed by capital-intensive goods and machinery. Net exports of all manufacturing groups are negatively associated with the supply of land.[19] We also performed some sensitivity analysis on these results.[20]

[19] Results such that agricultural land have a negative impact on the comparative advantage of all manufacturing groups should not be surprising. Although the model used here appears to require that all factors be used in all industries, this is not the case. The existence of industry-specific factors implies that particular elements of the factor requirements matrix **B** may be zero. For example in a model with two inputs, labor (L) and land (M), and two goods, agricultural (X_1) and industrial (X_2), if land is not used to produce the industrial commodity, the B_{M2} element of matrix **B** will be zero. It can be easily shown that even though both labor and land are used to produce the agricultural good, the output of agricultural goods depends only upon the endowment of land. And although land is not used to produce industrial goods, the level of output of industrial goods depends on both the endowment of labor and the endowment of land. This apparently paradoxical result stems from the fact that full employment requires that land must be fully utilized in the agricultural sector. This fact, together with the fixed input requirement B_{M1}, determines the level of agricultural output M/B_{M1}. Since the labor residual left over for industrial production is then dependent upon the endowment of land (that is, $L - X_1 B_{L1} = L - M B_{L1}/B_{M1}$), it becomes obvious that the level of industrial output is also dependent upon the endowment of land.

[20] To test for the robustness of these estimates a sensitivity analysis was performed. Influential observations were identified using the extreme *t*-statistics of dummy variables that select a single country

Table 2, Panel (a), reports results from Estevadeordal (1997) where a more disaggregated Heckscher-Ohlin model was estimated with the goal of obtaining measures of trade protection by sector. Based on the reported F-statistics, thirty-seven out of the forty-six net trade regressions are significant. Moreover, most of the R^2 measures of fit are very high. For individual factor endowments, out of forty-six estimated equations, capital has significant coefficients (at the 10% confidence level) in twenty-six cases, skilled labor in fourteen, unskilled labor in only seven, land in twenty-nine, and mineral resources in twenty-seven. The β values are reproduced in Panel (b).

In general, capital and skilled labor are sources of comparative disadvantage for primary product trade. Capital is a source of comparative advantage in most capital-intensive goods; it is a source of disadvantage in labor-intensive commodities, where skilled labor contributes to comparative advantage. Agricultural land is consistently a source of advantage for primary products and creates comparative disadvantage in manufacturing. Interestingly, mineral resources are a source of comparative advantage in the processed agricultural products group and in almost all manufactures. Using the conventional 0.5 level to define a significant β value, capital is significant in thirty-six out of forty-six net trade equations.[21] Skilled labor is significant twenty-four times, unskilled labor only four times, agricultural land thirty-eight times, and mineral resources thirty-six times.

Summary

In this section we have shown how it is possible to implement a test circa 1913 of the Heckscher-Ohlin prediction that there exists a linear relationship between factor endowments and the net trade of goods. The results are very favorable to the hypothesis. For most goods the fit is acceptably good and many coefficients have statistical significance. Moreover, once we compare the signs of the coefficients for each type of good with what we expect—based on whether certain goods are intensive in certain types of factor—we also find a reassuring correspondence between the econometric results and our intuition. Finally, using the technique of β coefficients to see how much the variation in factor endowments explains the variation in net trade, we find that the quantitative significance of the model is also very high. In short, having appealed to the 1980s vintage of empirical trade tests of the form pioneered by Leamer (1984), we have found a good deal of correspondence between the empirical results of the past and present. In both cases the fit of the model is good, and it is quite a bit stronger in the historical data from Ohlin's time. Thus, viewed from a 1980s empirical perspective, the factor abundance theory seems to work very well in its own time. We now ask whether the same holds true from a 1990s perspective, where attention has shifted to tests based on factor content.

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and that are included in the equation one at a time. In general, however, the coefficients in Table 1 with high t-statistics are insensitive to the omission of those observations.

[21] In this highly disaggregated studies, 0.5 is usually used as a threshold for a β value to be considered significant (see Leamer 1984 and Saxonhouse 1986).

Table 2
Tests of Factor Endowments and Product Trade (Disaggregated Data)

(a) OLS estimates	Capital	Labor-skilled	Labor-unskilled	Agricultural land	Minerals	R^2	Adjusted R^2	$F(6,11)$
SITC Group 0: Food and Live Animals								
00	0.06*	-0.67**	-0.25	0.80**	-0.21**	0.66	0.48	2.52
01	-1.34**	0.60	-12.12*	1.88**	0.54**	0.79	0.69	7.30**
02	-1.03**	0.18	-8.37	1.79**	0.20*	0.75	0.62	5.62**
03	0.10**	-1.13**	-1.41**	0.33**	-0.10*	0.39	0.06	1.17
04	-1.16**	-8.52**	-17.8*	5.2**	0.18	0.90	0.85	17.53**
05	-0.42**	-0.74	7.21*	1.26	-0.20	0.68	0.50	3.90**
06	-0.64**	1.11	-4.02	-0.29	0.45**	0.58	0.35	2.55
07	-0.28**	-2.13**	1.50*	0.08**	0.06**	0.98	0.97	137.11**
08	-0.00	0.09	0.07	0.43**	-0.06**	0.70	0.54	4.36**
09	-0.28**	0.51*	-2.33*	0.16**	0.12**	0.73	0.59	5.08**
SITC Group 1: Beverages and Tobacco								
11	0.06*	-1.22**	6.45**	-0.24**	0.039*	0.70	0.54	4.41**
12	-0.06**	-0.43**	-0.16	0.07	0.06**	0.78	0.66	6.70**
SITC Group 2: Crude Materials, Inedible (Except fuels)								
21	0.20**	-0.40*	-0.56	0.88**	-0.22**	0.96	0.94	46.34**
22	0.13*	-5.80**	3.72	1.27**	-0.15	0.74	0.61	5.48**
23	-0.59**	1.44**	-3.28**	0.08	0.16**	0.96	0.94	49.54**
24	0.06	-3.83**	-3.0*	1.76**	-0.21**	0.72	0.57	4.83**
25	-0.16**	0.27	-2.80**	0.16**	0.06**	0.58	0.35	2.55
26	-1.27**	-17.24**	-4.11	5.64**	0.66*	0.79	0.68	7.25**
27	0.00	-1.04**	2.02**	0.07	0.01	0.22	0.10	0.53
28	-0.46**	-0.28	-4.29**	1.46**	-0.08	0.84	0.76	10.06**
29	-0.02	-2.27**	2.87	0.66**	-0.06**	0.62	0.41	3.04
SITC Group 3: Mineral Fuels, Lubricants and Related Materials								
32	2.02**	-8.33**	22.71**	-2.64**	-0.21**	0.89	0.83	15.04**
33	0.17**	-4.13**	2.15	0.88**	0.04	0.86	0.78	11.42**
SITC Group 4: Animal and Vegetable Oils and Fats								
41	-0.03	-0.44	-1.43	0.68**	-0.11**	0.70	0.53	4.31**
42	-0.20**	0.73**	-0.46	-0.11*	0.12**	0.80	0.69	7.35**
43	-0.03**	0.03	-0.21	0.02**	0.01**	0.74	0.60	5.40**
SITC Group 5: Chemicals								
51+52+53+55+59	0.04	0.82*	-0.17	-0.54**	0.03*	0.74	0.59	5.23**
54+56+57+58	0.03**	-0.04	0.45	-0.24**	0.05**	0.66	0.47	3.58**
SITC Group 6: Manufactured Goods Classified Chiefly by Material								
61	-0.42**	2.49**	-5.08**	-0.20*	0.25**	0.82	0.73	8.71**
62	-0.06**	1.04**	-0.61*	-0.19**	0.05**	0.80	0.69	7.35**
63	-0.90**	2.24**	-6.96*	0.23	0.41**	0.77	0.64	6.14**
64	-0.21**	1.08**	-2.18**	-0.39**	0.21**	0.70	0.54	4.42**
65	2.25**	10.86**	17.1	-3.74**	-1.23**	0.86	0.79	12.22**
66	-0.11	1.31	-8.69**	-0.80**	0.18**	0.69	0.52	4.12**
67	0.73**	0.80	10.93	-3.28**	0.37**	0.83	0.74	9.15**
68	-0.15**	-3.98**	1.60	0.94**	0.11	0.77	0.65	6.35**
69	0.21**	1.16*	2.61	-1.95**	0.38**	0.84	0.76	10.23**
SITC Group 7: Machinery and Transport Equipment								
71	0.84**	-2.82**	5.18**	-1.50**	0.17**	0.94	0.91	29.85**
72	0.08**	0.30	0.44	-0.75**	0.16**	0.87	0.80	12.49**
73	0.24**	2.21**	-0.12	-0.48**	-0.06**	0.94	0.91	31.32**
SITC Group 8: Miscellaneous Manufactured Articles								
81+83+85	0.11**	-0.08	1.19*	-0.40**	0.06**	0.88	0.82	14.65**
82	0.02**	-0.04	0.52**	-0.05**	-0.00	0.59	0.38	2.72
84	-0.04	4.29**	0.79	-1.17**	0.10*	0.80	0.69	7.39**
86	-0.15**	0.73**	-3.26**	0.10	0.06**	0.49	0.22	1.82
89	-0.41**	4.74**	-7.66*	-1.23**	0.24**	0.34	0.01	0.99
SITC Group 9: Commodities Not Classified According to Kind								
95	0.08**	0.16	0.35	-0.06**	-0.04**	0.83	0.73	8.96**

Table 2 (continued)
Tests of Factor Endowments and Product Trade (Disaggregated Data)

(b) β values	Capital	Labor-skilled	Labor-unskilled	Agricultural land	Minerals
SITC Group 0: Food and Live Animals					
00	0.46	-0.41	-0.03	2.14	-2.41
01	-2.26	0.08	-0.24	1.13	1.38
02	-2.29	0.03	-0.25	1.4	0.67
03	1.04	-0.95	-0.2	1.21	-1.57
04	-1.19	-0.68	-0.18	1.87	0.28
05	-0.79	-0.11	0.22	0.83	-0.57
06	-2.25	0.31	-0.2	-0.36	2.39
07	-0.86	-0.53	0.06	0.09	0.28
08	0	0.09	0.01	1.82	-1.09
09	-2.72	0.4	-0.3	0.55	1.76
SITC Group 1: Beverages and Tobacco					
11	0.7	-1.15	1.03	-0.98	0.68
12	-1.13	-0.65	-0.04	0.46	1.71
SITC Group 2: Crude Materials , Inedible (Except Fuels)					
21	0.62	-0.1	-0.02	0.96	-1.03
22	0.47	-1.68	0.19	1.63	-0.82
23	-2.32	0.46	-0.16	0.11	0.95
24	0.23	-1.19	-0.15	2.38	-1.22
25	-2.31	0.32	-0.56	0.82	1.31
26	-0.84	-0.86	-0.04	1.3	0.66
27	0	-1.01	0.34	0.3	0.18
28	-1.56	-0.08	-0.21	1.75	-0.41
29	-0.11	-1.04	0.23	1.32	-0.51
SITC Group 3: Mineral Fuels, Lubricants and Related Materials					
32	3.37	-1.08	0.45	-1.56	-0.53
33	0.57	-1.12	0.11	1.03	0. 2
SITC Group 4: Animal and Vegetable Oils and Fats					
41	-0.28	-0.33	-0.19	2.26	-1.57
42	-3.02	0.89	-0. 1	-0.59	2.74
43	-2.35	0.19	-0.23	0.55	1.18
SITC Group 5: Chemicals					
51+52+53+55+59	0.43	0.71	-0.03	-2.06	0.49
54+56+57+58	0.55	-0.06	0.11	-1.54	1.38
SITC Group 6: Manufactured Goods, Classified Chiefly by Material					
61	-2.81	1.34	-0.46	-0.47	2.52
62	-1.09	1.53	-0.15	-1.22	1.38
63	-3.04	0. 6	-0.35	0.27	2.09
64	-1.62	0.67	-0.24	-1.06	2.45
65	1.73	0.65	0.17	-1.01	-1.43
66	-0.52	0. 5	-0.52	-1.34	1.29
67	1.36	0.12	0.33	-2.16	1.04
68	-0. 6	-1.27	0.08	1.33	0.66
69	0.58	0.26	0. 1	-1.91	1.59
SITC Group 7: Machinery and Transport Equipment					
71	1.75	-0.48	0.16	-1.1	0.53
72	0.56	0.17	0.04	-1.87	1. 7
73	1. 1	0.82	-0.01	-0.78	-0.42
SITC Group 8: Miscellaneous Manufactured Articles					
81+83+85	1.2	-0.07	0.18	-1.54	0.99
82	1.26	-0.2	0.45	-1.11	0
84	-0.18	1.54	0.05	-1.85	0.68
86	-2.09	0.82	-0.62	0.49	1.26
89	-0.87	0.81	-0.23	-0.92	0.77
SITC Group 9: Commodities Not Classified According to Kind					
95	1.93	0.31	0.12	-0.51	-1.46

Notes: t-ratios not reported. (***) denotes significant at the 1% level. (**) denotes significant at the 5% level. (*) denotes significant at the 10% level. See Appendix Table A3 for a description of SITC Rev. 1 (2 digit) codes.
Source: Estevadeordal (1997)

3. Factor Endowments and Factor Trade circa 1913

Tests

The factor content test is based on the immediate precursor of Equation (1) that does not depend on any assumptions about the dimensions or invertibility of the matrix **B**, namely

$$\mathbf{BT}^c = \mathbf{V}^c - s^c\, \mathbf{V}^W. \qquad (2)$$

Here, the left-hand side vector is the measured factor content of trade (denoted MFCT_f) and the right-hand side is the predicted factor content of trade (denoted PFCT_f). In this methodology all parameters in Equation (2) are measured, none are estimated econometrically, and the test centers on whether the equation holds. Thus, the method is harder to implement since its data requirements are considerably larger, which might explain why cross-country tests of this type have only appeared relatively recently.

Testing Equation (2) can take a variety of forms, as outlined by Davis and Weinstein (1999, Table 3). Four tests have been deployed, usually one factor at a time and using the set of countries *c* of their sample:

- The *sign test* focuses on whether, the direction of MFCT_f matches that of PFCT_f. In Equation (2) this amounts to asking whether the sign of the left- and right-hand sides are equal. The results are displayed in terms of the fraction of correct predictions. In contemporary data using the *pure* Heckscher-Ohlin model, the successful prediction rate is very poor, typically no better than a coin flip (Bowen, Leamer, and Sveikauskas 1987; Trefler 1995; Davis and Weinstein 1999).
- The *variance ratio test* asks on whether the variance of MFCT is as large as PFCT. Of course, if the theory were a perfect fit, the ratio of the variances of the left- and right-hand sides of Equation (2) would be unity, but typically it is much less. In contemporary data using the *pure* Heckscher-Ohlin model, the "missing trade" problem pushes the variance ratio is less than 5 percent (0.03 in Trefler 1995; 0.0005 in Davis and Weinstein 1999).
- The *slope test* depends on a regression of MFCT on PFCT. One can calculate the slope coefficient and its significance level from a regression of the left-hand side of Equation (2) on the right-hand side. Again, if the theory were a perfect fit the slope would be unity In contemporary data using the *pure* Heckscher-Ohlin model, the "missing trade" problem pushes the slope to small, even negative, albeit insignificant, values (Gabaix 1997; Davis and Weinstein 1999).
- The *t-test* reports the *t*-statistic for the slope test where the null is a zero slope. This test can detect a positive and significant relationship of endowments to trade, although the relationship need not be one-for-one.

Data, Coding, and Aggregation

As in the previous tests, we will still need each country's trade and factor endowment data ($\mathbf{T}^c$ and $\mathbf{V}^c$), and for these we draw on the data described in the previous section for $C = 18$ countries, $I = 55$ sectors, and $F = 4$ factors.

We also need a factor use matrix **B**. In general, when there are intermediate goods, **B** depends on the direct factor use matrix $\mathbf{B}^d$ and the input-output matrix **A**. Using a Taylor expansion we see that, for any vector of outputs **Z**, the factor content of **Z** is given by

$$\mathbf{BZ} = \mathbf{B}^d\mathbf{Z} + \mathbf{B}^d\mathbf{AZ} + \mathbf{B}^d\mathbf{A}^2\mathbf{Z} + \mathbf{B}^d\mathbf{A}^3\mathbf{Z} + \ldots = \mathbf{B}^d(\mathbf{I} - \mathbf{A})^{-1}\mathbf{Z}.$$

Here, in the middle expression, the first term is direct use, the second term is direct use in intermediates, the third term is direct use in the intermediates used to make the intermediates, and so on. Thus, calculating $\mathbf{B} = \mathbf{B}^d(\mathbf{I} - \mathbf{A})^{-1}$ is straightforward if data on technology can be found to construct $\mathbf{B}^d$ and **A**. In the pure version of the theory and empirics it is assumed that **B** is constant across countries. The objective can then be easily met if we can construct **B** for just one country, and, like Trefler (1993, 1995) we pick the United States as the source of the **B** data.[22]

Construction of a historically useful direct factor use matrix $\mathbf{B}^d$ for the U.S. is possible using the study of Eysenbach (1976).[23] She used the BLS-Leontief 1947 input-output table as the basis of her 165-industry classification scheme. Her capital and labor coefficients came from the census of 1899, and her natural resource coefficients, via Vanek (1963), from the 1947 input-output table. Already, the composite nature of her sources alerts us to the fact that her estimated $\mathbf{B}^d$ is not built from a consistent database at one point in time, and this drawback should be kept in mind. However, with this matrix available, it was straightforward to construct a concordance mapping the 165 industries into the aggregated classification based on $I = 55$ industries codes of the SITC scheme.

For our purposes, another inconsistency problem with $\mathbf{B}^d$ arises in the factor classification. The categories (and the figures for the U.S.) do not exactly match the endowment data $\mathbf{V}^c$. Eysenbach measures six types of labor: male and all, with each broken down into three wage levels to proxy skill levels. As a first pass at the problem we looked at all labor aggregated, so as to correspond to our endowment data on labor force. For capital input, Eysenbach has a single stock measure expressed in U.S. dollars that we take as corresponding to our factor endowment definition of capital. She measures nonrenewable resource inputs in the same units (dollars) as our endowment measure of

[22] A less restrictive but very data-intensive formulation would examine allow **B** to vary across countries. See Davis and Weinstein (1999), who were fortunate to find this information easily to hand in a consistent form in the OECD input-output database. If **B** varies across countries then the relevant country-specific **B** must be used to calculate the factor-content of each countries exports and imports, radically changing Equation (2). Unfortunately, we have no consistent source of input-output tables circa 1913.

[23] Wright (1990) used Eysenbach's data in his study of resource abundance and U.S. industrial success from 1879 to 1940. The methodology in Wright's study followed in the Heckscher-Ohlin-Vanek tradition and examined the renewable and nonrenewable resource factor contents of exports and imports at the benchmark dates.

mineral resources. However, her renewable resources measure is not the same (neither in definition nor in units) as our endowment category of agricultural land. Thus, in the construction of **B** from $\mathbf{B}^d$ we will have four factors, but not an exact match to the structure of the endowment data.

The above discussion highlights the inconsistencies between the definitions of the endowment **V** on the right-hand side of Equation (2) and the factor use **B** on the left-hand side. This is a serious issue: if MFCT and PFCT, the two sides of Equation (2), are not commensurate then any tests that rely on consistent units will be rendered useless. Having taken care to make the units of labor (number of workers), capital (U.S. dollars), and nonrenewable resources (U.S. dollars) consistent, the problem should be avoided for these factors, notwithstanding the usual problems of measurement error, and all tests should be valid.

However, in the case of renewable resources we note that there is likely to be an insurmountable discrepancy between the measurement concepts of the two sides. This will invalidate some of our tests for this case: consistent units are needed for a meaningful benchmark of unity in the slope coefficient and variance ratio tests. However, even with the discrepancy in measurement, we can still deploy the sign test to see if the directions of factor trade accord with theory. We can also examine the significance of the slope coefficient to see if there is any statistically significant linear relationship between factor endowment and trade, albeit the slope is meaningless. Fortunately, then, the problem with units does not afflict all of the factor content tests. Unfortunately, it does rule out the more interesting tests that have the strongest bearing on questions of quantitative significance, though in this study this will only be a problem for the case of renewable resources.

Our final data collection task was to find a suitable input-output matrix **A**. Leontief's 1947 input-output table is well known, and was the source for Eysenbach's resource coefficients, but he also constructed an input-output table for 1919 that we can employ here (Leontief 1953b). However, the 1919 input-output table was built around a smaller classification scheme of only 41 industries, so yet another concordance problem had to be solved in order to usefully align this dataset with the 55-sector SITC classification scheme used in all the previous calculations. Considering the extent of the overlap and consistency between these two classifications, it was decided to settle finally on a 25-industry aggregation scheme for the present exercise.

Thus, two new sets of concordance mappings were constructed, one from the 165-industry classification to the new 25 industry classes, and one from the 41-industry classification to the 25 new classes. Our previously constructed vectors and matrices $\mathbf{T}^c$ and $\mathbf{B}^d$ were converted to this $I = 25$ classification by some simple arithmetic aggregation, and then $\mathbf{B} = \mathbf{B}^d (\mathbf{I} - \mathbf{A})^{-1}$ was calculated.

Results

Table 3, Panel 1, shows the results of applying the four basic tests (sign, *t*, variance ratio, and slope) to the raw data for 18 countries. We applied the tests to six individual factor types plus two sets of pooled factor types. A word on definitions and units is in order, although an appendix gives full details. Capital is measured in 1913 dollars, and uses Eysenbach's U.S. census measure of factor use on the left-had side and a perpetual-inventory estimate of 1913 capital stocks on the right. Labor is measured as the size of the workforce, and skilled and unskilled are based on Eysenbach's census data on the left, and on literacy rates across countries on the right. Nonrenewable resources are in dollar terms from Eysenbach's census data on the left, and from Estevadeordal's minerals measure on the right. Renewable resources are not commensurate on the left and right, being based on Eysenbach's dollar-value census data on the left and Estevadeordal's measure of agricultural land areas on the right.

In cases where the factors are pooled, we need to worry about the commensurability not only on each side of the equation, but also from one type of factor to the next. Units of, say, labor and capital, will never be commensurate in a physical sense, but econometric adjustments are needed to permit valid estimation, specifically to ensure homoskedasticity. Following Trefler (1995), we weight each observation by $\omega_{fc} = 1/(\sigma_f s_c^{1/2})$ where the σ_f are the standard deviations of the pure Heckscher-Ohlin-Vanek error $\text{MFCT}_{fc}–\text{PFCT}_{fc}$ for each factor f, and where s_c is an adjustment for country size. This is our preferred specification in what follows, although alternative weighting schemes do not dramatically change the results. In Table 3 we show unweighted results and results using the Gabaix (1997) weights $\omega_{fc} = 1/s_c$; we have also tried the Davis-Weinstein (1999) weights $\omega_{fc} = 1/V^W_f$ and found little difference.

The results are, at best, mixed, and perhaps a little disappointing. For capital and labor (total and disaggregated) all the tests offer almost no support for the theory. The sign test reveals a predictive power no better than a coin flip. The *t*-tests are insignificant and often of the wrong sign. The exceptions are the unweighted results, but these are clearly driven by country-size effects and should be ignored. The variance ratio and slope tests confirm that the fit is very poor, the slope is almost a horizontal line, and overall the model can explain maybe 1% of the overall variance of the dependent variable.

So far so bad, but our hopes pick up a little bit when resources are considered. For renewable resources, the non-commensurability problem confines us to the sign test and the *t*-test, but the results are more favorable. The sign test rises to 67% and the slope is always significant and positive. For non-renewable resources, we can run the full battery of tests, and we find the best fit of all. Consider the Trefler-weighted results. The sign test shows that we get the direction of trade right in almost 4 out of every 5 cases, the *t* ratio is a respectable 1.7, the variance ratio is 60% and the slope is 0.33.[24] Finally, what the

[24] The Gabaix-weighed results are weaker, we think, because the big resource exporters are big countries, like the United States. An additional weight of $1/(s_c^{1/2})$ severely downplays these observations.

Table 3
Tests of Measured versus Predicted Factor Content of Trade

Factors in the sample		sign	Trefler weights t	Trefler weights VR	Trefler weights slope	Gabaix weights t	Gabaix weights VR	Gabaix weights slope	Unweighted t	Unweighted VR	Unweighted slope
			Productivity correction: None								
K	Capital	0.50	1.40	0.01	0.03	0.00	0.00	0.00	2.20	0.01	0.04
L	Labor	0.44	-1.10	0.00	-0.02	-0.80	0.00	-0.01	-3.10	0.00	-0.03
Ls	Labor-Skilled	0.50	-0.60	0.01	-0.01	-0.50	0.01	-0.01	-2.80	0.00	-0.03
Lu	Labor-Unskilled	0.50	-1.00	0.00	-0.01	-0.80	0.00	-0.01	-2.40	0.00	-0.02
Rr	Resources-Renewable	0.67	2.60	—	—	1.40	—	—	4.80	—	—
Rn	Resources-Nonrenewable	0.78	1.70	0.60	0.33	0.50	0.26	0.08	2.00	0.69	0.37
K, L, Rn	Pooled	0.59	1.60	0.23	0.11	—	—	—	—	—	—
K, Lu, Ls, Rn	Pooled	0.56	2.00	0.26	0.12	—	—	—	—	—	—
			Productivity correction: GDP per capita								
K	Capital	0.72	2.40	0.01	0.06	1.40	0.01	0.04	6.50	0.01	0.10
L	Labor	0.44	0.20	0.18	0.02	1.00	0.26	0.15	-1.50	0.19	-0.15
Ls	Labor-Skilled	0.56	1.20	0.02	0.04	0.70	0.01	0.02	1.20	0.03	0.04
Lu	Labor-Unskilled	0.44	-1.10	0.01	-0.03	-0.70	0.01	-0.02	-2.20	0.01	-0.05
Rr	Resources-Renewable	0.83	3.00	—	—	2.00	—	—	3.20	—	—
Rn	Resources-Nonrenewable	0.78	2.60	1.00	0.61	1.80	0.90	0.49	3.30	0.63	0.50
K, L, Rn	Pooled	0.65	3.10	0.55	0.31	—	—	—	—	—	—
K, Lu, Ls, Rn	Pooled	0.62	3.70	0.59	0.32	—	—	—	—	—	—
			Productivity correction: Real Wage								
K	Capital	0.78	1.50	0.01	0.03	0.30	0.01	0.01	4.70	0.00	0.05
L	Labor	0.61	0.10	0.02	0.01	-1.10	0.03	-0.06	3.40	0.01	0.07
Ls	Labor-Skilled	0.56	0.70	0.01	0.02	-0.60	0.01	-0.01	4.70	0.00	0.05
Lu	Labor-Unskilled	0.39	-1.30	0.02	-0.05	-0.90	0.02	-0.03	-1.30	0.03	-0.05
Rr	Resources-Renewable	0.72	2.30	—	—	1.40	—	—	2.90	—	—
Rn	Resources-Nonrenewable	0.67	2.20	1.07	0.56	1.20	0.96	0.36	3.40	0.51	0.46
K, L, Rn	Pooled	0.61	2.50	0.52	0.24	—	—	—	—	—	—
K, Lu, Ls, Rn	Pooled	0.65	2.60	0.44	0.20	—	—	—	—	—	—

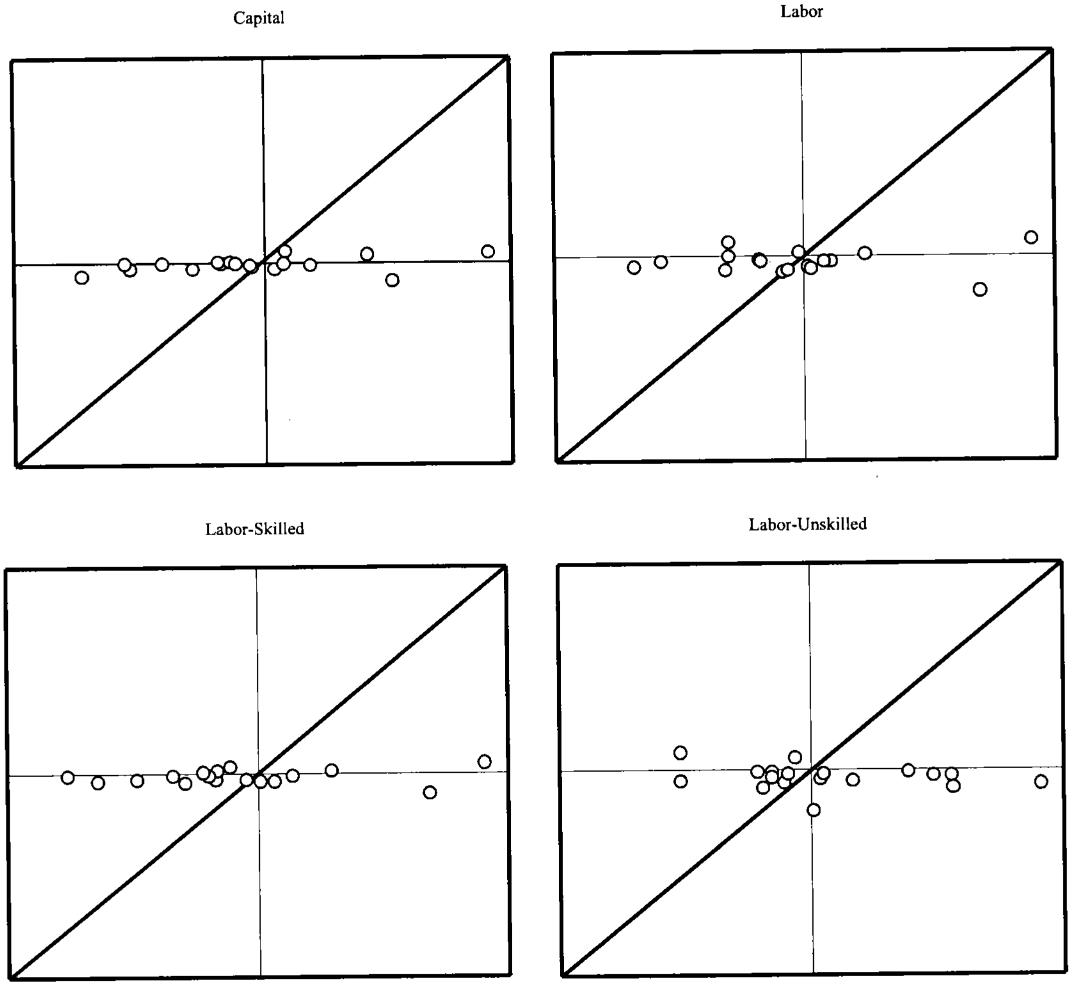
Notes: For description of tests, see text; sign = sign test; t = t test; VR = variance ratio test; slope = slope test.
Sources: See text. Minimal concordance (for more details see authors' appendix):

Capital: Perpetual inventory endowment (own, PFCT); total capital usage (Eysenbach-Leontief, MFCT).
Labor: workforce endowment (Estevadeordal, PFCT); total labor usage (Eysenbach, MFCT).
Labor-Skilled: literate workforce endowment (Estevadeordal, PFCT); skilled labor usage (Eysenbach, MFCT).
Labor-Unskilled: Labor minus Labor-Skilled (PFCT, MFCT).
Resources-Renewable: Agricultural land endowment (Estevadeordal, PFCT); usage (Eysenbach-Leontief, MFCT).
Resources-Nonrenewable: Mineral endowment (Estevadeordal, PFCT); usage (Eysenbach-Leontief, MFCT).

regressions are telling us we can also show graphically, and Figure 1 depicts the scatter plots for the eight cases in Panel 1, using no productivity correction and Trefler weights. The poor fit for labor and capital is immediately apparent given the diffuse cloud of dots seen in each case. For resources, the basis for a tighter fit is also clearly visible, and the pooling is a mélange of the two.

Such results, though disappointing, are not too surprising given the equally weak findings of the recent literature using the basic, unadorned specification of the Heckscher-Ohlin-Vanek hypothesis. Accordingly, various enhancements of the basic specification have been proposed. These looser specifications appeal to theory as a basis for adding additional parameters that allow for a better fit: for example, adjustments for factor productivity differences and home bias in consumption. We now apply each of these refinements to the historical data.

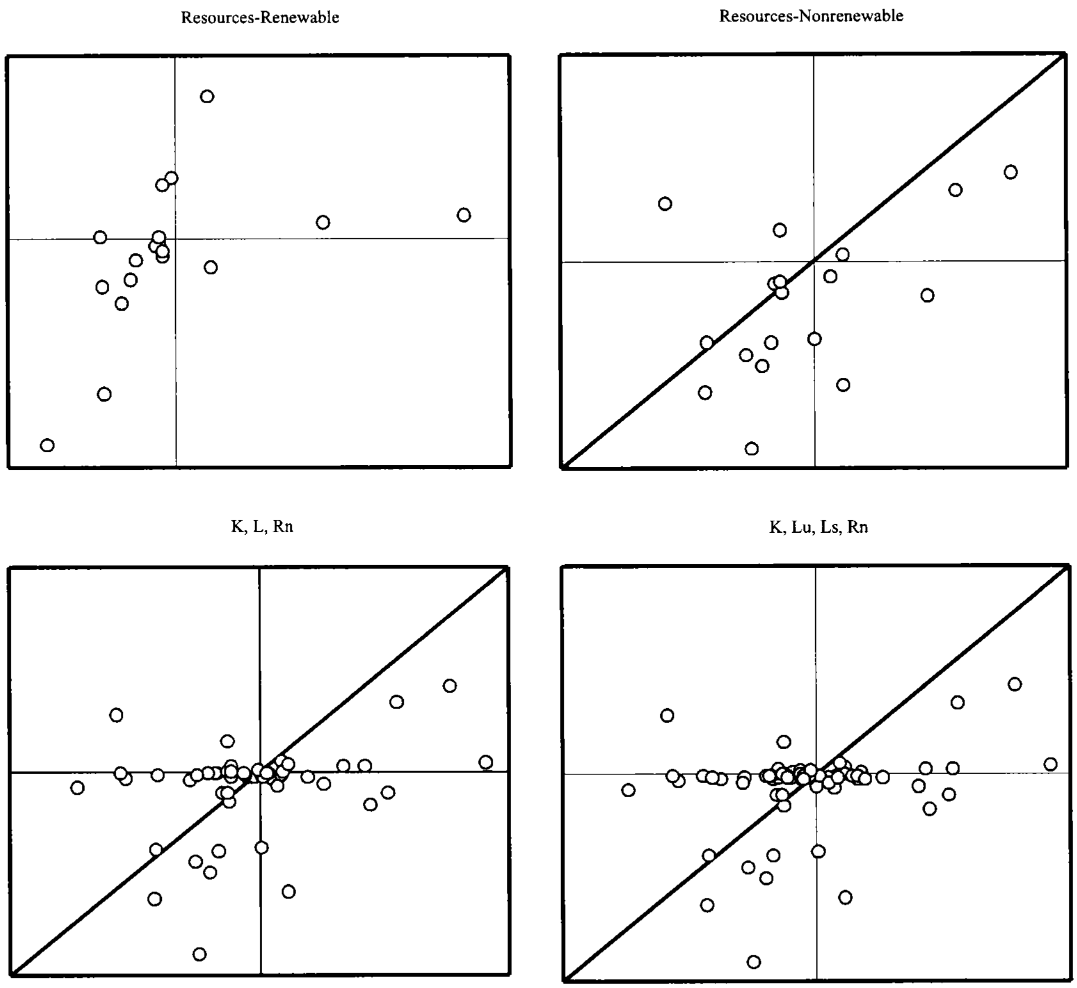
Figure 1
Measured versus Predicted Factor Content of Trade



Extensions: Factor Productivity Adjustment

Could the poor results be simply a manifestation of the Leontief problem? That is, could we be measuring factor endowments incorrectly in raw units instead of in effective units, controlling for productivity? Trefler (1993; 1995) showed that a way to correct for this problem is to rescale the endowment vector V_{fc} by some measure of relative productivity. If such a productivity correction δ_c is common to all factors in one country, then we would arrive at a productivity-corrected endowment vector of the form $\tilde{V}_{fc} = \delta_c V_{fc}$, and

Figure 1 (continued)
Measured versus Predicted Factor Content of Trade



Notes: MFCT on vertical axis, PFCT on horizontal. Trefler weights, no productivity correction. See text and Table 4. Units on each axis are non-commensurate for renewable resources, hence 45-degree line is omitted.

the analysis can then proceed as before. We use two proxies for δ_c, the relative GDP per capita (like Trefler) and the relative real wage.[25]

Table 3, Panels 2 and 3, show these results. By our reading, these productivity adjustments do help the model fit better, confirming the findings on contemporary data (Trefler 1993, 1995; Davis and Weinstein 1999). The sign tests starts to rise well above the coin-flip level for capital, and improves somewhat for both types of resources. The slope for non-renewable resources also rises, doubling to the level of about 0.6; and the

[25] In each case we set U.S. equal to 1, since we are using the U.S. factor-use coefficients on the left side. GDP per capita measures were taken from Maddison (1991) and real wages from Williamson (1995).

variance ratio rises to unity. However, the joy is short-lived, since the slope and variance ratio tests are still demoralizingly low for both capital and labor. The pooling of the results does not add a great deal to the analysis in any of the cases shown in the three panels of Table 3. With pooling the tests come out somewhere in between the good results for nonrenewable resources and the poor results for labor and capital, as expected.

Are we justified in using incomes and wages as productivity proxies? If these were imperfect measures of factor productivity, either due to measurement error, market failures, or deviations from pure Hicks-neutral technological shifts, then our results might be polluted. One way around this is to "let the data speak" by estimating the implied technology shift parameters, rather than imposing them. In this method, the parameters δ_c are chosen to maximize the fit of Heckscher-Ohlin-Vanek equation, subject to the normalization that $\delta_{US} = 1$.[26] Accordingly, we estimate the corresponding variant of equation (2):

$$\mathbf{BT}^c = \tilde{\mathbf{V}}^c - s^c \tilde{\mathbf{V}}^W = \delta^c \mathbf{V}^c - s^c \sum_{c'} \delta^{c'} \mathbf{V}^{c'}. \qquad (2')$$

Here, the implied slope and other tests are based on a regression of measured (left-hand side) versus predicted (fitted values on right-hand side).

Clearly, this method cannot be attempted on the data for a single factor type since it would exhaust all degrees of freedom.[27] Thus, we have to pool across factors to make the method workable. Consideration of the units and scaling problems then imply that we must use Trefler-weighted data only, and omit the non-commensurate data on renewable resources. The results appear in columns (1) and (2) of Table 4, first for capital, labor, and nonrenewable resources, and secondly with the labor types disaggregated into skilled and unskilled. Here the findings are somewhat encouraging. Column (1) uses up 17 out of 54 degrees of freedom (17 parameters, 54 observations), but to good effect. The sign test shows successful predictions in 3 out of 4 cases, the *t* ratio is very significant, the variance ratio of 0.87 is comfortingly close to 1 and the slope of 0.48 is not to be sneezed at. Column (2) looks very similar. But they key question is now: having so estimated the implied δ_c, do they make sense? One cross check is to see whether they correlate with other productivity-related measures like incomes and wages: they do, though not as much as one might wish. The GDP per capita correlation with δ_c is about 0.7, the wage correlation about 0.4. Another cross check involves simple inspection of the implied δ_c, and an appeal to introspection to determine whether they look reasonable. It might be questioned, for example, whether Britain really was 33% more productive than the U.S. in 1913 (column 1) or whether Norway really languished at a productivity level of 5%–15% of the U.S.

[26] Obviously, in a less interesting exercise, if we can scale each factor and each country independently, with a free choice of δ_{fc}, then we can obtain a perfect fit in the HOV model by using all degrees of freedom. (Trefler 1993; 1995).

[27] Actually, there would be one degree of freedom, because the U.S coefficient is not free,

Table 4
Productivity and Home Bias Parameters

	(1)	(2)	(3)	(4)	(5)	(6)
Factors	(K,L,Rn)	(K,Ls,Lu,Rn)	(K,L,Rn)	(K,Ls,Lu,Rn)	(K,L,Rn)	(K,Ls,Lu,Rn)
Productivity correction	Implied Hicks-Neutral	Implied Hicks-Neutral	None	None	Imposed GDP per capita	Imposed GDP per capita
Home Bias	No	No	Yes	Yes	Yes	Yes
sign	0.74	0.71	0.63	0.65	0.61	0.62
t	4.1	4.9	7.6	7.8	10.0	11.4
VR	0.87	0.87	1.86	2.21	1.43	1.47
slope	0.48	0.48	1.00	1.00	1.00	1.00
Coefficient	δ	δ	$1-\alpha^*$	$1-\alpha^*$	$1-\alpha^*$	$1-\alpha^*$
Argentina	0.80 (0.464)	0.96 (0.257)	0.29 (0.475)	0.24 (0.409)	0.39 (0.352)	0.34 (0.291)
Australia	0.70 (0.236)	0.76 (0.168)	0.40 (0.356)	0.40 (0.310)	0.58 (0.217)	0.58 (0.180)
Austria	0.30 (0.154)	0.37 (0.111)	0.95 (0.465)	0.95 (0.405)	1.01 (0.274)	1.01 (0.227)
Belgium	0.53 (0.223)	0.61 (0.146)	0.53 (1.139)	0.61 (0.828)	0.94 (0.496)	0.94 (0.410)
Canada	0.48 (0.303)	0.61 (0.180)	1.43 (0.373)	1.32 (0.241)	-4.22 (2.017)	-3.88 (1.559)
Denmark	0.74 (0.570)	0.65 (0.273)	-1.18 (1.141)	-1.08 (0.978)	-0.91 (0.849)	-0.86 (0.700)
Finland	0.33 (0.518)	0.57 (0.319)	0.65 (0.833)	0.64 (0.742)	0.71 (0.600)	0.69 (0.526)
France	0.69 (0.155)	0.61 (0.075)	0.21 (0.338)	0.24 (0.286)	-0.27 (0.374)	-0.01 (0.276)
Germany	0.58 (0.106)	0.63 (0.068)	0.90 (0.962)	0.90 (0.891)	0.92 (0.305)	0.89 (0.264)
Italy	0.48 (0.154)	0.59 (0.091)	0.67 (0.272)	0.69 (0.220)	0.71 (0.213)	0.61 (0.195)
Netherlands	0.71 (0.355)	0.75 (0.203)	-1.74 (0.701)	-1.09 (0.532)	-2.02 (0.587)	-2.13 (0.494)
Norway	0.05 (0.230)	0.15 (0.161)	1.36 (0.445)	1.36 (0.380)	1.38 (0.421)	1.38 (0.349)
Portugal	0.15 (0.164)	0.29 (0.149)	0.71 (0.896)	0.76 (0.635)	0.86 (0.557)	0.74 (0.538)
Spain	0.43 (0.178)	0.70 (0.136)	1.04 (0.333)	1.01 (0.228)	0.98 (0.248)	0.97 (0.198)
Sweden	0.75 (0.468)	0.58 (0.187)	1.10 (1.000)	1.04 (0.628)	1.02 (0.599)	1.01 (0.489)
Switzerland	0.48 (0.304)	0.55 (0.187)	-0.20 (0.709)	-0.11 (0.596)	0.16 (0.476)	0.23 (0.379)
United Kingdom	1.33 (0.237)	1.00 (0.104)	1.12 (0.211)	1.10 (0.172)	1.20 (0.217)	1.21 (0.182)
United States	1.00	1.00	0.75 (0.166)	0.79 (0.127)	0.54 (0.217)	0.52 (0.181)
Correlation with:						
GDP per capita	0.73	0.67	—	—	—	—
Real wage	0.38	0.37	—	—	—	—

Notes: Trefler weights. Standard errors in parantheses.

All in all, productivity adjustment appears to be a useful and necessary step, given that we should allow for imprecision in the historical income and wage data and the possible divergence between these measures and the factor productivity parameters. Hence—as was the case with tests on contemporary data—our historical study provides more support to the idea that an allowance for the Leontief hypothesis will play an important part in making the Heckscher-Ohlin-Vanek theory fit the data.

Extensions: Home Bias in Consumption

A second extension to the basic model, also due to Trefler (1995), allows for home bias in consumption. For simplicity, we abstract from the (empirically less-relevant) adjustments he included to allow for trade imbalances. This extension to the theory amounts to changing the basic model to allow for consumption preferences such that country c consumption is no longer just a simple fraction of world output, $\mathbf{C}^c = s^c\mathbf{X}^W$. Instead it is equal to a weighted combination of home-produced goods and the country-share of world-produced goods, $\mathbf{C}^c = (1 - \alpha_c^*)\, \mathbf{X}^c + \alpha_c^*\, s^c\, \mathbf{X}^W$. In the case $(1 - \alpha_c^*) = 0$, we have no home bias and we revert to the standard theory. In the case $(1 - \alpha_c^*) = 1$ we have complete home bias. A range of values of $(1 - \alpha_c^*)$ between zero and one is assumed to correspond to a varying degree of home bias.

It is straightforward to estimate the model with this adjustment, since in this case the estimating equation (2) becomes:

$$\mathbf{BT}^c = \alpha_c^*(\mathbf{V}^c - s^c\,\mathbf{V}^W). \tag{2''}$$

Already, we can intuitively see what is going to happen. Suppose the home bias were constant across countries, with $\alpha_c^* = \alpha^*$. Clearly, a regression based on (2″) will then set α^* equal to the slope from (2) and the fit will improve dramatically. A corollary of the OLS algebra is that the implied slope of measured (left-hand side) versus predicted (fitted values on right-hand side) will be unity by construction! This eliminates the slope test as a meaningful criterion. However, the other tests are still good—for example, the variance ratio is not necessarily equal to unity in these regressions, nor is the R^2.

The result of applying these tests is shown in columns (3) through (6) of Table 4. Again, if we want to allow for country-specific parameters we can only gain sufficient degrees of freedom by pooling, and we repeat both types of pooling (with and without labor disaggregation). The results show promise of a better fit, though it does not seem to matter whether an (imposed) productivity correction is included or not (columns 5 and 6 versus 3 and 4).[28] This is worrying. But of greater concern are the implied home bias parameters themselves, with $(1 - \alpha_c^*)$ shown for each country. Judging whether these are reasonable parameters is again a matter for our introspection, but the range of these estimates seems implausibly large, and beyond the bounds of what theory permits. It is not clear what is implied by a value of $(1 - \alpha_c^*)$ that is outside the interval [0,1]. We cannot dismiss this is a case of imprecision—the standard errors are fairly small.

Thus, we react to the home-bias extension rather pessimistically. Like Trefler (1995), we find some strange implied values for the $(1 - \alpha_c^*)$ coefficients that make little sense in theory. Given that the results here are not markedly better as judged by fit, we have reason to suspect that the productivity-correction specifications are the best we have to offer in the way of reconciling theory and data for now.

Summary

In this section we have shown how it is possible to implement a test circa 1913 of the Heckscher-Ohlin-Vanek prediction that there exists a linear relationship between factor endowments and the net factor content of trade. The results are very *unfavorable* to the hypothesis. For labor and capital the fit of the model is close to nonexistent. For resources, there is evidence that the model fits—though we are hampered by a units problem that prevents us from fully testing the predictions for renewable resources. For

[28] Though feasible, there would be few degrees of freedom left if we estimated *both* a productivity correction (17 paramaters) and a home bias correction (18 parameters).

all factors the fit of the model is much improved by a Leontief-style productivity correction, whether by direct proxy such as incomes or wages, or indirect via an estimated technology coefficient. If home bias is allowed the model fits very well, by construction, but the implied home bias parameters appear, in most cases, quite implausible. In short, having appealed to the 1990s vintage of empirical trade tests of the form pioneered by Trefler (1993; 1995) we have found a good deal of correspondence between the empirical results of the past and present. Missing trade is everywhere, though it is less absent in the case of resources than in the cases of labor and capital (Gabaix 1997). The fit of the model in the latter cases is poor, and productivity and home bias corrections do not solve the problem in an entirely satisfactory way. Thus, the simple factor-content approach seems to work as well in its own time as it does today—that is, not very well at all. Our study brings us to a point that corresponds to the year 1995 in the contemporary empirical literature—the year Trefler announced the mystery of the "missing trade." In the conclusion we ponder where we can go from here

4. Conclusion: Give Heckscher and Ohlin a Break!

This work has looked very broadly at the applicability of modern tests of the Heckscher-Ohlin trade theory to the historical data for 1913, an earlier period of relatively well-integrated goods markets, and a time in history that inspired the creators of the factor-abundance model. The results of this exercise have been mixed. The relationship between factor endowments and goods trade appears strong, even stronger than that found in contemporary data. But the factor content tests perform as poorly as they do on recent data, although a Leontief-style productivity correction can go some way towards correcting the problem. Even then, the best fit in 1913 seems to be for resource endowments, rather than for capital and labor.

Though we are disappointed to find such weak evidence, is this cause to dismiss the Heckscher-Ohlin model? We think not. First, on empirical grounds, we are not fully satisfied with the methodology adopted here and, compared to the most recent advances in the field that have attained a close match between theory and data, we have many gaps in our data. The Davis and Weinstein (1999) analysis goes further than any previous work in achieving a satisfactory fit. They extend the model in new ways, allowing for factor productivities and home bias, but adding the possibility of differing technologies across countries and deviations from factor-price equalization. They are fortunate to have a wealth of OECD data that allows them to investigate different factor-use matrices **B** for each country. They can also directly test for home bias and productivity differences using production and consumption data, and then test for the fit of the trade model. In contrast, we have only one factor-use matrix **B** for the U.S. in 1913, and even that was a struggle to construct, needed much manipulation, and had to draw on data from a variety of sources at different points in time. It is clearly a strong assumption to impose the U.S. technology matrix on all countries in 1913, and it is likely to be rejected as an assumption, just as Davis and Weinstein reject the constancy of **B** across countries today. In terms of production and consumption data, we have nothing like the OECD data to work with, so our productivity and home bias parameters fall out from the factor-content regressions themselves. It might then be no surprise that some of these parameters look odd since we have had to estimate them indirectly.

Could one do better in a historical setting? This would be a major archival and data-gathering exercise, though we think it would be very profitable for all of us if someone did it. As historians are painfully aware, there are no CD-ROMs with OECD data for 1913. Only in the postwar period was even (single-sector) national accounting beginning to be standardized. It may be a vain hope, then, to imagine we might build full set of input-output tables and production-consumption accounts for even just these 18 countries at a 25-sector level circa 1913. However, it is clear to us that such basic work expanding the range of our data would be necessary to advance beyond the circa 1995 econometric vintage that we have been confined to work with here.

Notwithstanding these methodological constraints, what can we say about the interpretation of our results when they are taken at face value? The fact that we can only get really strong support for the case of natural resource trade need not be a fatal weakness—at least not in 1913. Gabaix (1997) protested that the good fit of the Heckscher-Ohlin-Vanek model on natural resources today was cold comfort, since such endowments constitute such a paltry share of world output in the modern, service-oriented, knowledge-based economy. In this world most of factor rewards accrue to capital and labor (mostly skilled, i.e. human capital). Such objections are clearly less relevant in 1913, when much of the basis of world trade, and still significant portions of world output, were based on primary-producing activities.

The role of resources, and the good fit of the model there, also brings us back to the point made in the introduction: the Heckscher-Ohlin theory supposes that factors are not mobile and endowments are exogenous. Only then would estimation be valid. In a paper entitled "Give Heckscher and Ohlin a Chance!" Wood (1994a) raised this concern in connection with contemporary tests of the theory that ignore the fact of considerable international capital mobility that can equate rates of return across countries; instead, he argues, we must restrict attention only to the factors that are basically immobile. Land being problematic to measure, his research agenda has focused on skilled and unskilled labor as the key contrast in his "North-South" view of the global economy (1994b).

Note that these shortcomings are econometric problems, not a failure of the theory itself: indeed, the theory very usefully predicts that trade and factor migration can be substitutes. This brings us back to the nature of the world economy in 1913: it was not just a world of relatively free trade, it was also a world with a high degree of factor mobility. If we think just capital mobility is a problem today for factor content tests, then in 1913 we will have an even bigger problem for both labor and capital were highly mobile then. These are the factors for which the fit of the Heckscher-Ohlin-Vanek model is weakest in our data—a coincidence? We think not. The fit of our model is strongest for the immobile factors that have long been considered the key source of comparative advantage in the late-nineteenth and early-twentieth centuries. The same thrust of argument can be found in the study of the United States by Wright (1990), but the recent analysis of Estevadeordal (1999) generalizes the point to a much broader sample of countries using Wood's approach applied to same 18-country dataset we have used here.

In summing up, we urge caution before interpreting poor static regression results as providing evidence against the theory for this historical period. A large literature in economic history has sought to model endogenous capital and labor flows in the Greater Atlantic economy of that era (Taylor and Williamson 1994; Hatton and Williamson 1994, 1998; O'Rourke and Williamson 1999; Edelstein 1982). Until an econometric strategy can be found that adapts the factor-content tests to cope with this simultaneity problem we should, perhaps, give Heckscher and Ohlin a break.

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DATA APPENDIX

Endowment Data (Table A1)

a. Capital (1): Variable used in tests of Section 2. It is calculated as apparent energy consumption (production plus net imports) of solid fuels (Hard Coal, Brown Coal, Lignite, and Coke). Data are in thousands of hard-coal equivalents. See Estevadeordal (1993) for a detailed description.

b. Capital (2): Variable used in tests of Section 3. The capital stock estimates are constructed using a perpetual inventory method applied to pre-1913 annual investment rates and real outputs. Our approach here was to use a 3% constant depreciation rate, calculating the contribution of real investment in each year as the investment share times real GDP times the depreciation factor. Alternative depreciation methods were tried, such as 30- and 50-year straight line and 5% constant rates, but although these altered the levels in 1913, they did not markedly change their cross-country variation, as expected. Summing up the weighted investments from each year and dividing by the terminal year real GDP gave an estimate of the 1913 capital-output ratio, which was then multiplied by country GDP to obtain capital stock estimates in 1913 dollar terms. This procedure was possible for 14 countries in our sample, but 4 countries lacked pre-1914 investment time series. These were Austria-Hungary, Belgium, Portugal, and Switzerland. For these 4 countries, extrapolations were made on the basis of Estevadeordal's 1913 proxy for capital stock (the correlation between Estevadeordal's data and the resulting capital stock estimates for the 14 countries for which we had investment data was .9575). All investment data were taken from the database of Obstfeld and Taylor (1999). Data are 1913 dollars.

c. Total Labor: Data for all countries except Argentina, Spain, and Portugal is total labor force (in thousands) estimated at mid-year and is taken from A. Maddison (1982), *Phases of Capitalist Development* (Oxford, UK: Oxford University Press). Data for Argentina, Portugal, and Spain refers to the economically active population as reported in B.R. Mitchell (1980), European Historical Statistics 1750-1975, 2nd edn (London: Macmillan) and (1983), *International Historical Statistics: The Americas and Australasia* (London: Macmillan). Linear interpolation between census years was used when needed.

d. Skilled Labor: Computed as Labor times literacy rate. Data are in thousands of workers.

e. Unskilled Labor: Computed as Labor minus Skilled Labor. Data are in thousands of workers.

f. Agricultural Land: Agricultural land for all countries except Portugal are available in League of Nations (1927), Population and Natural Resources, (Geneva). For Portugal data on agricultural land is taken from P. Lains (1989), Foreign Trade and Economic Growth in the European Periphery. Portugal, 1850-1913 (Florence: European University Institute, *mimeo*). Data are in thousands of hectares.

g. Mineral Resources: Computed as the value of petroleum production plus ore production of a composite of 12 minerals: Bauxite, Copper, Iron Ore, Lead, Manganese, Nickel, Phosphate, Potash, Pyrites, Sulfur, Tin, and Zinc. Data are in thousands of 1913 dollars. See Estevadeordal (1993) for detailed sources.

h. GDP Data: Real GDP per capita data in 1990 U.S. dollars comes from Maddison (1995), Monitoring the World Economy, 1820-1992 (Paris: OECD). These figures are then normalized to the U.S. and multiplied by U.S. real GNP per capita in 1913 U.S. dollars, as given by U.S. Department of Commerce, Bureau of the Census (1975), *Historical Statistics of the United States: Colonial Times to 1970* (Washington, DC: Bureau of the Census), to get real GDP per capita in 1913 U.S. dollars for all countries. To calculate country GDP, the resulting figures are then multiplied by the 1913 population data found in Maddison. Data are in 1913 dollars.

Trade Data (Table A2)

Net export data was constructed from national trade records and originally aggregated in fifty-six commodity groups. Commodities were classified according to the Standard International Trade Classification (Revised, 1961) at the two-digit level (See Table A3). All data is for 1913 except for a few countries for which the closest year to 1913 was used. Data are in 1913 dollars. See Estevadeordal (1993) for detailed sources.

Technology Data (Tables A4-A5)

We make use of Leontief's 1919 U.S. input-output table as found in W.W. Leontief (1953), *The Structure of the American Economy, 1919-1939* (Oxford, UK: Oxford University Press). Data are in millions of dollars. (Table A4).

Data on factor coefficients come from M.L. Eysenbach (1976), *American Manufactured Exports, 1879-1914: A Study of Growth and Comparative Advantage* (New York: Arno Press). Eysenbach industry data follows the classification scheme as outlined in U.S. Department of Labor, Bureau of Labor Statistics (1953), *Industry Classification Manual for the 1947 Interindustry Relations Study* (Washington, DC: BLS). Direct use renewable- and nonrenewable-resource coefficients can be found on pages 297-301. Labor and capital coefficients can be found on pages 302-6. We convert labor and capital coefficients into per dollar terms. Skilled labor coefficients can be found on pages 307-11. Unskilled labor coefficients are given by column (3), the share of males, women, and children as a fraction of all employees. We calculate skilled labor coefficients as one minus the unskilled labor coefficient for each industry. (Table A5)

Concordance (Tables A6 and A7)

Due to the range of data sources, the first task was to create a concordance mapping relating the 165 BLS industry codes used by Eysenbach, the SITC Rev. 1 codes used to report the net trade data, and the 41 industries that comprise Leontief's U.S. 1919 input-output table. Each BLS industry was first assigned to a related SITC Rev. 1 category. Each SITC Rev. 1 category was subsequently assigned to one of the Leontief industries. In some cases BLS industries proved difficult to classify according to the SITC Rev. 1 system. This is due to the fact that the BLS codes identify particular industries while the SITC Rev. 1 codes identify products. Likewise, it proved difficult in some cases to classify SITC Rev. 1 products according to the Leontief industries. Generally speaking, this problem was resolved by going directly from the BLS industrial classification system to the Leontief industry classification.

It also proved useful to "collapse" the 41 industries given by Leontief's input-output table into 25 industries, as occasionally a product classified according to the SITC Rev. 1 system belonged to multiple Leontief industries. For example, SITC Rev. 1 product 32 is "Coal, coke, and briquettes." Leontief separates "Coal" and "Coke" into two separate industries. It thus seemed logical to combine "Coal" and "Coke" from the input-output table to better accommodate the trade data. In addition, some of the original input-output industries appeared rather indistinguishable from one another, so it was decided to combine such related categories for the sake of simplicity. An example is the case of "Lumber & timber products" and "Other wood products." Finally, it should be noted that two industries, "Electric utilities" and "Construction" were removed entirely from the original input-output table.

Calculating Factor Content of Trade

Before calculating the factor content of trade, it was first necessary to compute direct use factor content coefficients for each of our 25 industries. All relevant Eysenbach coefficients were first grouped on the basis of our 25-industry classification scheme and averaged. Eysenbach's labor and capital coefficients are reported as "Labor per unit of Value Added" and "Labor per unit of Capital," so in order to make use of her numbers, it was then necessary to calculate the value added as a fraction of total output for each of the 25 industries. This was done by first converting the collapsed input-output table from absolute numbers into fractions of industry gross total output. To obtain value added as a share of output for a given industry, we simply subtracted the sum of the contributions of each input industry to the output industry from one. We were then in a position to calculate the direct use factor content coefficients for each of our 25 industries according to the following formulas:

Labor: (labor / value added) × (value added / output) = (labor / output)

Capital: [1 / (labor / capital)] × (labor / value added) × (value added / output) = (capital / output)

In addition, by multiplying the solutions to each industry's *Labor* equation by the share of unskilled labor in total labor, as given by Eysenbach, and by one minus this share, we were able to obtain the direct use factor content coefficients for unskilled and skilled labor, respectively. Eysenbach's raw material coefficients are reported in per-output terms, so no further calculations were needed to obtain direct use coefficients for renewable and nonrenewable resources.

To complete the construction of our technology matrix, **B**, we had to account for the indirect usage of each factor in each industry. To do so, the following formula was employed:

$$\mathbf{B} = \mathbf{B}^0 (\mathbf{I} - \mathbf{A})^{-1}$$

where $\mathbf{B}^0$ is the (6 × 25) matrix of direct use coefficients, **I** is the identity matrix, and **A** is the (25 × 25) input-output table expressed in terms of input industry shares of gross total output. Multiplying **B** by our vectors of trade data yields the factor content of trade for each of our 18 countries.

Appendix Table A1

Factor Endowments and GDP in 1913

Countries	Capital (1)	Capital (2)	Total Labor	Skilled Labor	Unskilled Labor	Agricultural Land	Mineral Resources	GDP
Argentina	3801	3433222006	3162	2052	1110	18780	580	2228525624
Australia	8145	4932800511	2076	2030	46	7260	95787	2035353163
Austria	40257	11793779639	3186	2644	542	18420	43583	1810164212
Belgium	28312	9634472145	3484	3017	467	2010	25149	2428086689
Canada	25725	6990369775	3107	2921	186	35730	34715	2536980164
Denmark	3590	2264699287	1358	1315	43	2950	0	861089294.1
Finland	586	927410885.1	1338	740	598	2840	0	475895505.9
France	64266	31519795903	21225	18699	2526	36800	88969	11036922774
Germany	189259	44300847086	17638	17373	265	34810	327139	12000803764
Italy	10853	18691927041	16632	10445	6187	20770	29056	6947871078
Netherlands	10479	5415075831	2365	2330	35	2180	0	1867261089
Norway	2516	1269658875	999	984	15	990	51783	426933950.4
Portugal	1417	4772640831	2545	791	1754	5037	2952	623142844.9
Spain	7169	5772694763	7675	3669	4006	40680	121084	3515841163
Sweden	5739	2320033742	2631	2592	39	5010	35622	1338900699
Switzerland	3387	5128759354	1923	1894	29	702	0	1246679882
United Kingdom	216315	26863944809	18964	18300	664	18200	69682	16448253048
United States	498102	97713161627	42509	39236	3273	193620	790512	39725642000

Source: All data come from Estevadeordal (1993) with the exception of Capital (2) and GDP, which are calculated as described in the appendix.

AppendixTable A2
Aggregated Net Trade Data

industry	Argentina	Australia	Austria	Belgium	Canada	Denmark	Finland	France	Germany
1	262729078	24713358	-35245400	-50189375	-7715612	-16332940	-7347680	-113819988	-449456340
2	29783816	46378436	-4604200	-94890796	111106412	-27276340	-18439690	-123061754	-184988310
3	-2786537	-6760430	58675200	6102272	-20349974	945100	-3735590	8767140	61264410
4	-13982211	-9724345	5843200	-10878459	-7461685	-965640	-2202670	-5175114	-922760
5	-7199793	-5066915	-9476200	-3144875	-7187749	-1935180	-1325060	-7704661	-3662520
6	44155620	36650028	3039200	-1038004	1087594	47221200	-936320	75703	-19234900
7	-2516019	17751641	8759000	-8955112	16545352	64432680	6639930	-4150317	-88429940
8	-9930061	-13410690	-29060400	-19748011	-1279668	-5218200	-4473930	-59241682	-95651020
9	103773	51660546	-8844600	-404434	42850417	-420940	0	-1329598	-99568840
10	-30771219	-26619309	-4253000	30944458	-114208547	-7189260	319200	9094757	167501640
11	-50931051	-57602499	-18118400	-5411796	-43253975	-7093320	-5782080	-32309826	367096330
12	-25449768	-19619499	-994200	21297067	-18923271	-2548000	-693310	36507793	29545110
13	-3761695	-4737494	-18996600	2948531	-21060619	-2634580	-6931580	-42193281	-67737070
14	-41554782	-8788333	15534800	2781045	-21054578	-1426100	-4872550	-8287471	32670810
15	-10921625	-7075358	10526800	-11558376	-13230032	-19053580	-1442290	-34886820	-29753720
16	1394286	5306824	-32594400	-13528352	-37134578	-2635880	139080	-102117972	99590230
17	-8008836	-7673949	-15072000	-8892821	-25172602	-9396660	-4211540	3877913	4392080
18	-21474811	-12583177	50784400	-24191654	17208108	-12013820	42423770	-7405877	-76829660
19	-7072163	-9779652	4965200	3851134	3294813	-1723800	13024120	8459327	53550900
20	24874641	56245732	-93602000	-1049362	-76075062	-23457460	-12121620	-52277768	-278086330
21	-9855328	-22136838	10812000	-857960	-28041440	-77480	0	52875132	77806240
22	-2331430	372169	-7654000	3200187	-9547428	-3258580	-800470	21944554	47137810
23	-1055082	-4057488	0	0	-4612682	0	0	0	35384120
24	-1172967	-4642102	-6143600	-4152152	-11007837	-1720680	-2401790	10621380	-2765980
25	-20448524	-45082090	-11641400	-2558650	-39122047	-2709460	-2029010	148921589	99059620

industry	Italy	Netherlands	Norway	Portugal	Spain	Sweden	Switzerland	United Kingdom	United States
1	59440453	-45142041	-645325	-662978	29399006	-12417245	-16371917	-305123912	-230173551
2	-74820263	-98790313	-15976750	-4288024	-19994046	-14480834	-30403622	-387522214	194716287
3	601132	19603896	-3914600	-1875528	245014	-873841	-5952892	-115871498	4543660
4	16177567	-505826	-2380000	8435380	28767670	-2430773	-6940337	877803	-16326757
5	-6473583	-1140492	-1088675	-483210	0	-3071769	-1794590	-22628597	12667153
6	7814	13329802	4512100	62191	381488	1721462	-5829881	-268394176	127302854
7	21798344	24226459	2755575	51881	-3125106	12294954	8810831	-203740619	-3259296
8	-22389974	24621517	25181225	-1447071	-2089516	-13693790	-1311993	-137604237	-150977884
9	-2033406	-2773496	6737700	1058932	27972461	17590060	-11569575	-82836163	-33849493
10	-21716980	-85477893	-8583825	-3590762	-10669193	12054407	-8891995	144940033	66954708
11	-23374892	-19178107	-13599825	-2530138	-22704268	6402305	3393865	212117222	259669692
12	-1035003	-2728239	-6701650	-1338856	-15926407	-2833996	-524158	78327619	53081824
13	-20487763	-11157714	1689500	-1203797	18472634	-6556729	-2985329	-97521358	47678995
14	-69543598	-24744369	-604675	-1275552	-3531411	4281636	-3892699	-9181254	-59993216
15	-10842442	-6491365	-2679500	-692416	-3073517	-7619373	-2395216	-40202182	139622325
16	0	-33056118	-10418175	-3600640	-12245756	-27119399	-18012908	260607586	63623548
17	-23785048	-22609783	-5028550	-1984111	-6253757	-14916308	-4825764	-29565533	-15594989
18	-20557320	-33283782	16718550	2423431	1079650	50602041	-6548819	-177089886	48717279
19	-5399686	30798803	7172500	-732444	-519098	35837194	-1640590	-43023597	23287590
20	11900701	-16959667	-14361725	-9723827	-18916657	-31575793	26319929	50143716	230353846
21	9713860	-10354121	-1563200	-229295	-387951	-3393982	-5252617	57623518	-13028488
22	-13623499	3787985	-2040825	-1970879	-1022017	-4475349	-4109474	-46069529	28355886
23	-32411	-2338175	0	58645	2711274	353385	-192104	24540653	19818804
24	-1623512	113807	-662800	-336748	-2342751	-3148295	-1116946	-96943878	-89838545
25	-19258467	197033280	-3433600	-1496908	1850857	516767	11961131	50822128	-83861946

Source: Estevadeordal (1993).

Table A3
Description of Standard International Trade Classification codes (2 Digit, Rev.1)

SITC Group 0: Food and Live Animals
00 Live Animals
01 Meat and meat preparations
02 Dairy products and eggs
03 Fish and fish preparations
04 Cereals and cereal preparations
05 Fruit and vegetables
06 Sugar, sugar preparations and honey
07 Coffee, tea, cocoa, spices and manufactures thereof
08 Feeding stuff for animals (not including unmilled cereals)
09 Miscellaneous food preparations

SITC Group 1: Beverages and Tobacco
11 Beverages
12 Tobacco and tobacco manufactures

SITC Group 2: Crude Materials, Inedible, Except Fuels
21 Hides, skins and furskins, undressed
22 Oil-seeds, oil nuts and oil kernels
23 Crude rubber
24 Wood, lumber and cork
25 Pulp and waste paper
26 Textile fibres
27 Crude fertilizers and crude minerals (excluding coal and petroleum)
28 Metalliferous ores and metal scrap
29 Crude animal and vegetable materials, n.e.s.

SITC Group 3: Mineral Fuels, Lubricants and Related Materials
32 Coal, coke and briquettes
33 Petroleum and petroleum products
34 Gas, natural and manufactured

SITC Group 4: Animal and Vegetable Oils and Fats
41 Animal oils and fats
42 Fixed vegetable oils and fats
43 Animal and vegetable oils and fats, processed, and waxes

SITC Group 5: Chemicals
51 Chemical elements and compounds
52 Mineral tar and crude chemicals from coal, petroleum and natural gas
53 Dyeing, tanning and couloring materials
54 Medicinal and pharmaceutical products
55 Essential oils and perfume materials
56 Fertilizers, manufactured
57 Explosives and pyrotechnic products
58 Plastic materials, regenerated cellulose and artificial resins
59 Chemical materials and products, n.e.s.

SITC Group 6: Manufactured Goods Classified Chiefly by Material
61 Leather, leather manufactures, n.e.s., and dressed furskins
62 Rubber manufactures, n.e.s.
62 Wood and cork manufactures (excluding furniture)
64 Paper, paperboard and manufactures thereof
65 Textile yam, fabrics, made-up articles and related products
66 Non-metallic mineral manufactures, n.e.s.
67 Iron and Steel
68 Non-ferrous metals
69 Manufactures of metal, n.e.s.

SITC Group 7: Machinery and Transport Equipment
71 Machinery, other than electric
72 Electric machinery, apparatus and appliances
73 Transport equipment

SITC Group 8: Miscellaneous Manufactured Articles
81 Sanitary, plumbing, heating and lighting fixtures and fittings
82 Furniture
83 Travel goods, handbags and similar articles
84 Clothing
85 Footwear
86 Professional, scientific and controlling instruments; photographic and optical goods; watches and clocks
89 Miscellaneous manufactured articles

SITC Group 9: Commodities not Classified According to Kind
95 Firearms of war and ammunition thereof

Appendix Table A4
Aggregated Input-Output Table

industry	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	9102	1792	163	57	202	3033	797	261	0	0	0	0	0	0	0	0	308	0	4	1117	0	30	0	0	0
2	686	354	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	27	50	11	6	0	0	30	140	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0
4	0	0	0	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	19	92	0	0	0	354	17	0	0	0	0	0	0	0	0	0	79	0	0	20	0	247	0	0	0
7	0	27	0	0	0	0	0	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	22	0	0	0	0	0	67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	7	274	0	0	267	0	0	0	0	0	0	0	0	0	0	0	0
10	46	0	0	0	0	0	0	0	43	1157	1315	189	0	13	76	89	0	0	0	0	0	0	0	2	0
11	522	28	1	11	0	0	51	101	15	17	503	1812	0	7	76	30	11	50	24	110	7	19	14	17	47
12	744	82	26	11	0	77	0	0	99	121	165	1002	17	187	131	763	9	337	0	0	0	0	0	0	0
13	0	0	0	0	5	0	0	13	0	24	287	47	622	0	0	0	41	0	0	0	0	0	0	0	0
14	7	0	1	21	0	0	0	19	0	26	22	29	3	20	3	0	54	0	9	0	0	1	0	0	0
15	2	6	6	2	0	5	1	4	5	50	40	85	18	36	1029	1	23	4	5	5	0	0	0	1	10
16	0	14	15	10	1	15	5	9	19	342	105	449	29	80	84	228	49	15	37	41	2	6	2	8	24
17	356	0	0	0	0	159	0	0	13	3	0	10	0	1	13	23	194	0	6	58	0	47	0	2	25
18	258	0	0	0	13	0	0	0	15	0	110	139	0	0	35	36	48	975	0	0	0	0	25	0	14
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	287	0	0	0	0	0	233
20	47	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	61	0	1205	1255	1	6	189	1
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	145	0	0	0	0
22	75	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	8	17	0	6	4	120	482	0	3
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	233	0	0
24	0	0	0	0	0	0	0	0	0	0	1	153	0	0	0	0	0	0	0	0	0	0	0	19	0
25	21	0	0	0	0	0	0	0	0	0	10	30	0	0	0	0	0	14	0	3	20	0	0	0	184
Output	22147	3810	1201	615	1013	4576	1148	2028	648	3652	10459	8930	1812	806	3004	2471	3272	3432	1244	6163	3371	1309	1379	1138	3445

Source: Leontief (1953b) and authors' calculations.

AppendixTable A5
Aggregated Eysenbach Coefficients

our classification	Labor per dollar of value added	Labor per dollar of Capital	Unskilled Labor as a share of Total Labor	Skilled Labor as a share of Total Labor	Direct Use Renewable Resources	Direct Use Nonrenewable Resources
1		0.00067	0.000	1.000	1.000	0.001
2	0.00069	0.00058	0.310	0.690	0.495	0.001
3	0.00078	0.00009	0.550	0.450	0.153	0.008
4	0.00024	0.00029	0.459	0.541	0.128	0.004
5	0.00086	0.00094	0.366	0.635	0.653	0.002
6	0.00077	0.00055	0.317	0.683	0.878	0.000
7	0.00070	0.00055	0.275	0.725	0.771	0.002
8	0.00121	0.00082	0.550	0.450	0.211	0.002
9		0.00019	0.000	1.000	0.005	1.000
10	0.00095	0.00049	0.412	0.588	0.000	0.054
11	0.00106	0.00058	0.377	0.623	0.000	0.002
12	0.00097	0.00051	0.370	0.630	0.000	0.001
13	0.00072	0.00034	0.403	0.597	0.000	0.152
14	0.00119	0.00063	0.369	0.631	0.000	0.335
15	0.00094	0.00039	0.405	0.595	0.000	0.512
16	0.00113	0.00066	0.309	0.691	0.007	0.705
17	0.00081	0.00033	0.463	0.537	0.066	0.024
18	0.00128	0.00082	0.265	0.735	0.153	0.001
19	0.00113	0.00069	0.350	0.650	0.099	0.014
20	0.00129	0.00072	0.364	0.636	0.234	0.002
21	0.00128	0.00130	0.747	0.253	0.004	0.001
22	0.00111	0.00056	0.324	0.676	0.002	0.002
23	0.00161	0.00143	0.688	0.312	0.000	0.001
24	0.00091	0.00041	0.553	0.447	0.000	0.004
25	0.00112	0.00080	0.321	0.679	0.001	0.005

Source: Eysenbach (1976) and authors' calculations.

Appendix Table A6
Concordance Mapping

Our classification	Input-Output classification	SITC Rev. 1 classification	1947 BLS classification
1	1	00,05,08,21,22,29	1,7-10
2	2,4	04	4,24,25
3	5	06	27
4	6	11	28
5	7	12	6,29
6	8	01	2,21
7	9	02	3,22
8	3,10	03,07,09	23,26
9	11,16	28	11-15
10	12,13	67	78-81,92
11	14	69,71,72	94-96,98-102,104-144
12	15,41	73	145-152
13	17,18	68	82-91,93
14	19	27,66	18-20,70-77
15	20,21,24	33,34	17,62,64
16	22,23	32	16,63
17	26	41-43,51-59	48-50,52-61
18	27,28	24,63,82	36-43,162
19	29,30	25,64	44-46
20	32,34	26,65,83	5,30-33,35
21	33	84	34
22	35,37	61	67,68
23	36	85	69
24	38	23,62	51,65,66
25	31,39	81,86,89,9	47,97,103,153-161,163-165

Notes and sources: Authors' mapping to reconcile the Eysenbach-BLS, Leontief-IO and SITC classification.

Appendix Table A7
Industry Classification Descriptions

our classification	Leontief's 1919 U.S. Input-Output table categories
1	Agriculture
2	Flour & grist mill products; Bread & bakery products
3	Sugar, glucose & starch
4	Liquors & beverages
5	Tobacco manufactures
6	Slaughtering & meat packing
7	Butter, cheese, etc.
8	Other food industries; Canning & preserving
9	Iron mining; Non-Iron metal mining
10	Blast furnaces; Steel works & rolling mills
11	Other iron, steel & electric manufactures
12	Automobiles; Transportation
13	Smelting & refining; Brass, bronze, copper, etc. manufactures
14	Non-metal minerals
15	Petroleum & natural gas; Refined petroleum; Manufactured gas
16	Coal; Coke
17	Chemicals
18	Lumber & timber products; Other wood products
19	Paper & wood pulp; Other paper products
20	Yarn & cloth; Other textile producs
21	Clothing
22	Leather tanning; Other leather products
23	Leather shoes
24	Rubber manufactures
25	Industries, nes; Printing & publishing

Note: For Leontief-category numeric equivalents see Leontief (1953b).