The Origins of American Industrial Success, 1879–1940

By Gavin Wright*

The United States became the world's preeminent manufacturing nation at the turn of the twentieth century. This study considers the bases for this success by examining the factor content of trade in manufactured goods. Surprisingly, the most distinctive characteristic of U.S. manufacturing exports was intensity in nonreproducible natural resources; furthermore, this relative intensity was increasing between 1880 and 1920. The study then asks whether resource abundance reflected geological endowment or greater exploitation of geological potential. It was mainly the latter. (JEL 042)

Recent thinking about American economic performance has been marked by alarm over the country's loss of its "competitive edge." Most of this discussion is not rooted in an understanding of the historical origins of the economic leadership now thought to be in jeopardy. Modern economists tend to assume that the American advantage has been technological and dates from the remote recesses of history, about as far back as anyone really cares to go. In a volume on U.S. competitiveness, Harvey Brooks writes: "Both our firms and our government, *long accustomed to being the technological leaders in almost every field*, have until recently measured their performance against domestic rather than foreign competitors" (Bruce R. Scott and George C. Lodge, 1985, p. 331; emphasis added). For one country to maintain a technologically based advantage over others for long historical periods is anomalous, and surely calls for explanation. Indeed, it is difficult to see how policies can respond appropriately to "what we have lost" without knowledge of what it was that we had and how we got it. It would be an understatement, however, to say that the subject has been understudied. This paper makes a modest beginning by analyzing American trade in manufactured goods between 1879 and 1940. The competitive success of American manufacturing exports in foreign markets is by no means a comprehensive measure of "success." But because the turn of the century marked the emergence of the United States to a position of world economic preeminence, we may hope to learn something about the broader questions by studying the characteristics of the country's trade with the rest of the world during that key era.

The results are surprising. They suggest that the single most robust characteristic of American manufacturing exports was intensity in nonreproducible natural resources. In fact, their relative resource intensity was *increasing* over the half-century prior to the Great Depression. This does not mean that there was no American technological leadership, in the broad sense of that term. Abundant resources were themselves in many ways a reflection of the advanced state of American technology. But the distinctively American industrial innovations were in many respects specific to the pre-World War II U.S. resource environment and national market, both of which were unique among the countries of the world. Since then, relative American resource abundance has greatly diminished, not primarily

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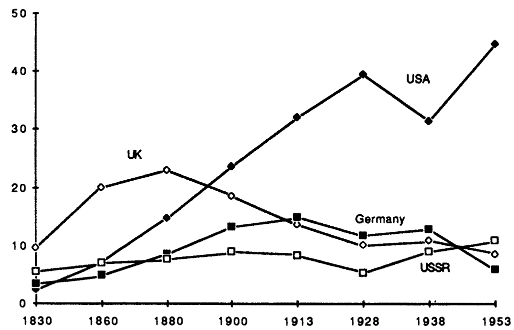
from depletion of national reserves but because of the integration of world markets for minerals and other commodities. Twentieth-century patterns of resource discovery and production suggest that the historic basis for U.S. mineral abundance was much more a matter of early "development" than of geological "endowment."

I. The Ascendance of American Industry on a Global Scale

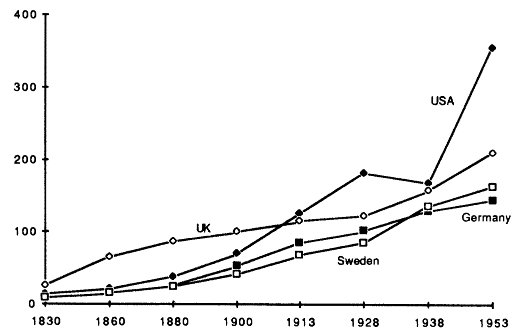
Americans have enjoyed high material living standards since the eighteenth century if not earlier, and the acceleration to modern rates of per capita growth occurred during the first half of the nineteenth century. Broadly based American *industrial* leadership on a worldwide basis, however, can only be dated from the very end of the nineteenth century. According to Paul Bairoch (1982), the U.S. share of total world manufacturing output passed Great Britain's between 1880 and 1900 (Chart 1). In per capita levels of industrial output, the United States was a weak fourth among the nations of the world in 1880, and surpassed Britain only after 1900 (Chart 2). Contemporary testimony suggests that American technology and manufactured goods began to play a qualitatively different role in the world as of the 1890s or shortly thereafter. The first wave of alarmist European books on "Americanization" dates from 1901 and 1902, with titles and themes (*The American Invaders*, 1901; *The Americanization of the World*, 1901; *The American Invasion*, 1902) that would again become familiar in the 1920s and 1960s (William Woodruff, 1975, p. 123). Rapid inflows of standardized, machine-made American shoes after 1894 (said to be more comfortable and more stylish than the traditional types) caused consternation in the British boot-and-shoe industry and forced a drastic technological overhaul (R. A. Church, 1968). Equally dramatic was the burst of American exports of machine tools and other engineering goods after 1895, not only to Britain but to the Continent and other parts of the world (Roderick C. Floud, 1974, pp. 60–62; 1976, pp. 72–82). Though the suddenness of the American

CHART 1. SHARES OF WORLD INDUSTRIAL OUTPUT, 1830–1953



Source: Bairoch (1982, pp. 296, 304).

CHART 2. INDUSTRIAL OUTPUT PER CAPITA



Source: Bairoch (1982, pp. 294, 302).

"invasion" after 1895 may be attributable to temporary factors, it seems clear that a crossover point of some sort was reached at that time.[1]

Industry studies seem to confirm this timing. Robert Allen has shown that prior to the 1890s American blast furnaces had no distinctive world-class status in either labor productivity or fuel efficiency (Allen, 1977, pp. 608–609). By 1900, after key break-

[1]S. J. Nicholas (1980) argues that the apparent decline in the price of American "engineering goods" mainly tracks the prices of iron and steel products, and that the sudden "invasion" of U.S. goods reflected temporary delivery lags by British firms during 1895–1900. As argued below, both of these elements reflected more lasting features of American industrial success.

throughs in adapting the technology to the new Mesabi iron ore, the U.S. industry was the world leader by both of these indicators. Pig iron was an input in the production of steel, which was in turn crucial for railroads, construction, and a wide range of machinery and manufactured goods. According to Allen, before the 1890s American steel rails would not have been competitive in the domestic market without tariff protection (Allen, 1981). Advances in steel were in turn complementary to progress in other industries. U.S. rubber-tire makers, for example, were well behind the French during the bicycle craze of the 1890s, and only gained a productivity advantage in conjunction with mass production of automobiles shortly before World War I (M. J. French, 1987, p. 66). None of this denies that twentieth-century U.S. technology emerged from an evolutionary learning process over a much longer period, as economic historians have long stressed (Paul David, 1975; Nathan Rosenberg, 1976; David Hounshell, 1984). But the qualitative changes in industrial America's place in the world after 1890 justify a closer look at this period.

The timing of U.S. industrial performance corresponds closely to the more comprehensive finding of U.S. world leadership by Angus Maddison, based on estimates of Gross Domestic Product per manhour (Maddison, 1982, p. 212; compare also Moses Abramovitz, 1986). But Maddison seems to assume that U.S. leadership in *productivity* corresponded closely to a position of "world leadership" in *technology*. This is surely not the only possibility. In terms of conventional growth-accounting, the U.S. edge could equally well have been attributable to capital or natural resources. Interestingly, Maddison's figures actually show that the world leader in GDP per man-hour prior to World War I was not the United States but Australia. His explanation is confined to a footnote: "In defining productivity leadership, I have ignored the special case of Australia, whose impressive achievements before the First World War were due largely to natural resource advantages rather than to technical achievements and the stock of man-made capital" (p. 258). Can we be certain that the United States was not also a "special case" whose performance depended on "natural resource advantages"?

Contrary to expectations of increasing resource scarcity, post-Civil War American development featured *declining* relative costs of materials (Louis P. Cain and Donald G. Paterson, 1981, pp. 358-360). Major new metals discoveries continued until World War I, while the rate of discovery of new oil fields accelerated after 1900 (U.S. National Resources Committee, 1937, p. 149). The timing of leadership in industrial production coincides remarkably with American world leadership in coal production (after 1900), and that margin also grew over time. The United States was also the world's leading producer of copper, petroleum, iron ore, zinc, phosphate, molybdenum, lead, tungsten, and many other minerals. At the same time, continuing advances in internal transportation reduced the real costs to manufacturers, creating what historical geographers call the "minerals-dominant economy" of the late nineteenth century (Harvey S. Perloff and Lowden Wingo Jr., 1961, pp. 193-197). The improvements were often qualitative as well as quantitative, most strikingly perhaps in the iron ore from the rich Mesabi range, which began to arrive in the steel mills of the lower Great Lakes in the 1890s. Allen's estimates of total-factor-productivity in iron and steel as of 1907-1909 put the United States at a par with Germany (15 percent ahead of Britain), but the ratio of horsepower to worker was twice as large in America as in either of the other two contenders (Allen, 1979, p. 919). If we were to adopt the conventional view that resource abundance is an *alternative* to technologically based manufacturing, we might well be led to question the authenticity of America's leadership position before World War II. But as argued below, this is not the only choice available to us.

II. Hypotheses from the International Trade Literature

A number of hypotheses bearing on American industrial history emerge from the literature on the bases for international trade. According to the Heckscher-Ohlin model, the composition of a country's trade reflects the relative abundance of factors in that country's endowment. Simple two-factor versions of this theory have frequently been rejected, beginning with the "Leontief Paradox," which revealed that in 1947 U.S. exports were more capital-intensive than were competitive imports (Wassily Leontief, 1953). Attempts to rationalize this result, however, have generated more refined propositions. According to the "neo-factor-proportions" approach, American exports have actually been intensive in skills or human capital. This interpretation was suggested by Leontief himself, and has been supported by an empirical regularity first identified by Irving B. Kravis (1956a), that average wage levels in American export industries have been persistently higher than wage levels in import-competing industries. It has become a standard convention in empirical trade studies to take the relative industry wage as a proxy for skill requirements, and on this basis the skill intensity of American exports has been claimed as a pattern as far back as 1899 if not earlier (Helen Waehrer, 1968). Studies for more recent periods have supported this view with detailed evidence on the occupational structure of the labor force (Donald B. Keesing, 1968).

An alternative "third factor" interpretation for the paradox is that capital is complementary to natural resources, and that the United States had moved into a position of resource scarcity by 1947 (Kravis, 1956b). This possibility is supported by Jaroslav Vanek's important study of the natural resource content of U.S. foreign trade, 1870–1955 (Vanek, 1963), which showed that the country had moved from a net export to a net import position in natural resources over that period. This finding raises the possibility that U.S. comparative advantage may have had a different basis at an earlier time.

A different (though not necessarily mutually exclusive) intellectual strategy is taken by the "neo-technology" approach. The concept of a "technological gap" between the United States and the rest of the world was a commonplace in discussions of trade and direct investment during the 1950s and 1960s (Atlantic Institute, 1970). Though theory makes a sharp distinction between "factor proportions" and "technology" effects, in practice the two ideas are often similar. Employment of skilled professional and scientific personnel is correlated with investment in research, often called "R&D intensity" or simply the "technology factor" (Raymond Vernon, 1970). Similarly, American "technology" has often been linked as much with managerial performance as with science-based production methods. Since the vertically integrated modern business corporation developed earlier and diffused more widely in the United States than elsewhere (Alfred D. Chandler and Herman Daems, 1980), the conceptual correlations among technology, organization, and personnel are likely to be high.

A more difficult conceptual challenge is technological leadership manifest in the form of new products, exported from the United States because they were unavailable elsewhere (Kravis, 1956b). Because exports were small as a percentage of output for almost all American industries, the U.S. case would seem to be a likely example of the historical process described by Staffan Burenstam Linder (1961) whereby new products originally designed for the domestic market begin to enter foreign trade as production expands: "International trade is really nothing but an extension across national frontiers of a country's own web of economic activity" (p. 88). Vernon's "product-cycle" model is perhaps the best-known version: *New products* tended to appear first in the United States because they were responsive to *high-income wants*, and because they were associated with an environment of *high labor costs*. As processes became more mature and routine, trade would be displaced by production abroad, but the volume of U.S. exports was maintained by a continuing flow of new innovations (Vernon, 1966).

There is an ever-present danger of anachronism in applying such concepts historically. The United States did not invent the firearm, the shoe, the bicycle, the camera, or the automobile, and the American versions of these goods were not regarded in European countries as well suited to "high-income wants" (which were better served by the English or French). The size and character of the U.S. domestic market were certainly crucial, but the bulk of the new American exports were producers goods, whose "novelty" lay not so much in consumer taste as in technical specifications or quality. The approach taken here therefore concentrates on the supply side, by analysis of the changing factor content of manufacturing trade over the era of American ascendancy. Though we cannot claim to measure or establish the nature of American "technological leadership" in a rigorous sense, we can illuminate that subject by finding the characteristics of those U.S. products that had the greatest impact on world markets.

This has been the approach of earlier historical work.[2] Using the standard methodology of empirical trade studies, N. F. R. Crafts and Mark Thomas present an analysis of comparative advantage in British manufacturing trade between 1910 and 1935, which they contrast unfavorably with that of the United States (Crafts and Thomas, 1986). They find that Britain continued to export products intensive in capital and unskilled labor and to import goods intensive in human capital (as reflected in the average industry wage). A similar regression for the United States in 1909 shows a reverse result. They conclude: "The U.S. appears already to be following the 'advanced country' pattern of exporting human capital intensive goods and importing unskilled labor-intensive goods in 1909" (p. 637). The next section considers whether this impression should be modified on the basis of a richer data set.

III. New Evidence on American Trade in Manufactures

A. *Average Factor Intensities*

One of the reasons that American manufacturing trade has been understudied is that the Commerce Department trade data are entirely separate from the censuses of manufactures, which have no information about foreign markets. It is not a simple task to match these two sources. Fortunately, a Stanford dissertation by Mary Locke Eysenbach estimated production coefficients for 165 industries according to the system used in Leontief's 1947 interindustry study, and matched these to export and import data for 1879, 1899, and 1914 (Eysenbach, 1976). The present research has replicated her procedures and extended the data set to 1909, 1928, and 1940.[3] For most sample years there are just over 100 usable observations, providing a level of detail roughly comparable to three-digit SITC categories.

To explore the factor intensity of manufacturing trade, I have used Eysenbach's production coefficients to trace relative changes over the entire period of observation. Her capital and labor coefficients are primarily from the census of 1899, while the natural resource coefficients were taken from Vanek (1963) and hence originate in the input-input table for 1947. Thus, this is primarily a study of compositional changes in manufacturing trade over time rather than the actual implicit factor flows in each year. As a sensitivity check, however, estimated coefficients for alternative years have been

[2]An extensive literature on the so-called "labor-scarcity paradox" takes a similar tack, assessing U.S. performance indirectly by measuring the factor-saving bias of U.S. technology relative to British. The suggestion by H. J. Habakkuk (1962) that American technology was capital-intensive and labor-saving has given way to a more complex picture: American methods were more intensive in the use of raw materials and fuel and were characterized by a faster pace and more intensive utilization of capital (David, 1975; Field, 1983). The provocative early successes of the "American system" were limited to a small subset of industries in the 1850s (John James and Jonathan Skinner, 1985). This work concentrates on the mid-nineteenth century, giving little attention to change over time or to the overall scope of U.S. industrial performance.

[3]David Green deserves most of the credit for the detective work that this task entailed.

TABLE 1—CAPITAL-LABOR RATIOS FOR MANUFACTURED GOODS, 1879–1940
($000 PER EMPLOYEE IN 1909 DOLLARS)

	1879	1899	1909	1914	1928	1940
A. 1899 Coefficients						
Exports	4.186	4.059	4.052	3.961	3.946	3.374
Imports	2.608	2.886	2.785	2.850	2.907	3.221
Exports/Imports	1.61	1.41	1.46	1.39	1.36	1.05
B. 1909 Coefficients						
Exports	5.405	4.877	4.967	4.811	4.959	4.193
Imports	2.999	3.079	3.020	3.073	3.486	4.444
Exports/Imports	1.80	1.58	1.64	1.57	1.42	0.94
C. 1947 Coefficients						
Exports	4.725	5.170	6.350	6.790	6.330	5.265
Imports	2.910	3.440	3.420	3.690	4.325	5.850
Exports/Imports	1.62	1.50	1.86	1.84	1.46	0.90

Sources: 1899 coefficients from Mary Locke Eysenbach, *American Manufactured Exports*, 1897–1914, New York: Arno Press, 1976, pp. 302–306; 1909 coefficients from U.S. Census of Manufactures; 1947 coefficients form Wassily Leontief, "Factor Proportions and the Structure of American Trade," *Review of Economics and Statistics*, November 1956, *38*, 403–407.
Trade Figures: for 1879, 1899, 1914 from Eysenbach, pp. 271–275; 1909, 1928, 1940 from U.S. Commerce Department, *Foreign Commerce and Navigation of the United States*. Exact industry groupings available on request.

TABLE 2—MEASURES OF SKILL INTENSITY OF MANUFACTURED GOODS, 1879–1940

	1879	1899	1909	1914	1928	1940
A. Percentage Earning More than $12/Week in 1890						
Exports	52.3	48.7	48.2	45.9	46.6	42.9
Imports	48.5	45.7	47.1	44.1	42.3	41.3
Exports/Imports	1.08	1.07	1.02	1.04	1.10	1.04
B. Average Wage (1909)						
Exports	0.467	0.482	0.487	0.502	0.504	0.541
Imports	0.431	0.433	0.460	0.426	0.463	0.471
Exports/Imports	1.09	1.11	1.06	1.18	1.09	1.15
C. Percentage Women and Child Labor (1909)						
Exports	10.1	10.7	9.9	11.0	11.2	10.4
Imports	30.6	29.0	30.2	27.8	24.2	21.1
Exports/Imports	0.33	0.37	0.33	0.40	0.46	0.49

Sources: Percent $/week from Eysenbach, pp. 307–311; average wage from 1909 Census of Manufactures (wage bill divided by labor force); women and child labor from 1909 Census of Manufactures (females aged 16 and over, under 16, and males under 16, divided by labor force).

used wherever possible. Since all of the coefficients are U.S.-based, the question of whether the factor content of imports accurately corresponds to foreign production techniques is not addressed. Despite these limitations, the procedures follow the spirit of much of the literature on these subjects, and the results (shown in Tables 1 through 3) are suggestive.

Table 1 does confirm that American manufacturing exports were more capital-intensive than American imports from 1879 to 1928. But in terms of contemporary coefficients, the country's surge to world indus-

TABLE 3—NONRENEWABLE NATURAL RESOURCE COEFFICIENTS IN MANUFACTURING GOODS, 1879-1940 (1947 COEFFICIENTS)

	1879	1899	1909	1914	1928	1940
A. Direct Use						
Exports	0.0742	0.0677	0.0918	0.0988	0.09984	0.0564
Imports	0.0131	0.0194	0.0170	0.0133	0.0290	0.0369
Exports/Imports	5.66	3.49	5.40	7.43	3.39	1.53
B. Direct and Indirect Use						
	1879	1899	1909	1914	1928	1940
Exports	0.1107	0.1239	0.1647	0.1800	0.1635	0.1240
Imports	0.0565	0.0747	0.0766	0.0749	0.0934	0.1127
Exports/Imports	1.96	1.66	2.15	2.40	1.75	1.10

Sources: Coefficients from Eysenbach, pp. 297–301; trade figures, see Table 1.

trial supremacy was not marked by a shift toward capital-intensive manufacturing exports, nor by an increasing tendency to trade capital-intensive for labor-intensive manufactures with the rest of the world. (It is interesting that the relative capital intensity of exports *in terms of 1947 coefficients* did rise until 1914, after which it declined.) Movement in the direction of the Leontief Paradox within manufacturing is detectable, at least after World War I.

It should be noted that the figures in Table 1 omit refined sugar, an industry that if included would single-handedly generate a Leontief Paradox for manufacturing in every sample year. If classified as a manufactured good (following Eysenbach), refined sugar would account for nearly one-quarter of manufacturing imports before 1900, and sugar refining (in the United States, at any rate) had a capital-labor ratio five times as high as the average for manufacturing. It is open to question whether sugar refining techniques outside the United States were really this capital-intensive. Because the industry is exceptional and because we are not in any case trying to account for all international flows, it seems more informative to leave it out. Though extreme, sugar refining does illustrate one of the compositional reasons for the trend shown in the first two panels of Table 1, namely, the high capital intensity of many agricultural processing industries, which were declining in relative prominence among U.S. exports. Two of the largest contributors to the decline in relative capital intensity of exports were grain mill products, and meat packing and wholesale poultry.

Table 2 displays two indices of skill intensity: (1) following Eysenbach, the percentage of the labor force earning more than \$12 per week in 1890, and (2) the average industry wage in 1909.[4] By both measures, there is some tendency for export industries to pay higher wages than import-competing industries. But there is little sign of a trend in the relative skill intensity of exports and imports. As measured by the 1890 "high-wage" index, the skill content of exports went steadily downward. As measured by the 1909 average wage, however, the skill content of exports had an upward trend. There was also an upward trend, however, in the skill content of imports by the same measure (excepting 1914). One of the reasons for this puzzling pattern is suggested by the third panel of Table 2, which reveals a much more dramatic contrast between exports and imports in the percentage of the labor force who are women and children (under the age of 16). It is perhaps not surprising to see that imports are far more women-and-child-intensive than exports, since these workers are associated with "low-wage" and labor-intensive processes (but it is interesting that this direct measure of labor-force composition is a clearer sepa-

[4]Several other skill indices were proposed by Eysenbach, all based on 1890 data. They give results similar to those presented here.

rator than capital-intensity or wage levels, which one might take to be more fundamental). What is striking is the decline over time in this relative intensity, entirely concentrated on the import side. Here we have another likely contributor to the trend toward the Leontief Paradox. Employment of women and child workers in American manufacturing was concentrated in only a handful of industries: canning, preserving, and freezing on the one hand, and textiles and apparel on the other. The first remained a strong net export category, but in the second, the growth of imports was increasingly stifled by tariff barriers, particularly after the 1922 Fordney-McCumber tariff.

Easily the largest factor-intensity differentials were in nonreproducible natural resources, as shown in Table 3. Recall that these are weighted averages for manufactured goods alone and exclude entirely exports of agricultural goods and crude materials. We still find not only that U.S. exports had far higher natural resource content than imports but that this trend was growing both absolutely and relatively over *precisely the historical period when the country was moving into a position of world industrial preeminence*. Using the more inclusive index of direct and indirect use, the resource intensity of manufacturing exports grew by 64 percent to its peak, and even after a slight decline, the 1928 level was still nearly 50 percent higher than that of 1879. The figures confirm a little-noticed analysis by Robert E. Lipsey (1963): "The composition of manufacturing exports has been changing ceaselessly since 1879 in a fairly consistent direction—*away from products of animal or vegetable origin and toward those of mineral origin*" (p. 59; emphasis added).

Table 3 also clearly shows that the resource intensity of imports was growing as well, and that signs of a reversal in the relative balance are detectable even in 1928. By 1940, the historic U.S. specialization had virtually disappeared. This is the modern trend identified first and most clearly by Vanek (1963), of no small importance for interpreting recent American industrial history. But because of his choice of dates and coverage, Vanek missed the fact that the declining phase had been preceded by a long epoch of rising natural resource intensity, of no less importance in interpreting the country's place in the industrial world.

B. *Regression Analysis*

Simple factor-intensity comparison between exports and imports is not conclusive in the presence of more than two factors (Edward Leamer, 1980). An apparent pattern of specialization may merely represent the effect of a third factor, acting as a complement or substitute for one of the other two. This section therefore follows the general format of Crafts and Thomas (1986) and earlier studies in the international trade literature by regressing the net trade balance for each industry against measures of factor intensity. On no account should the coefficients be viewed as structural estimates within a Heckscher-Ohlin framework (compare Leamer and Harry P. Bowen, 1981). They are best considered as descriptive summaries of trade patterns in a multifactor setting, a way of pointing out areas of distinctive strength and tracking changes over time. Because the industry or commodity groupings are inevitably arbitrary, R^2 levels by themselves are not particularly meaningful; but t-tests on individual coefficients are a reasonable standard for confidence in that factor's contribution, and R^2 comparisons across years should reflect changes in the tightness-of-fit according to factor content. Following Crafts and Thomas, all reported standard errors were recomputed according to the procedure suggested by Hal White (1980) to adjust for heteroskedasticity in the error structure. The effect generally is to reduce the larger t-ratios, so that what is reported here is a conservative version of the account that leaps from the data using ordinary-least-squares. The results are robust to changes in precise variable definitions and to transformations of the coefficients into factor shares at various discount rates. Trade values have been deflated by export and import price indices (Lipsey, 1963, pp. 142–143; 1913 = 100) so that coefficients may be compared across years.

TABLE 4—REGRESSIONS FOR MANUFACTURED NET EXPORTS OF THE UNITED STATES, 1879–1940

	Constant	Capital/ Labor	Natural Resource Coefficient	Average Wage	Percent Women and Children	R^2
1879	−3127	2092**	−10830	−1853		0.079
	(0.68)	(2.24)	(0.74)	(0.27)		
	−228	1725*	−12690		−156	0.103
	(0.06)	(1.77)	(0.83)		(1.53)	
1899	−4068	3729*	−4324	−802		0.075
	(0.66)	(1.73)	(0.11)	(0.07)		
	1735	3140	−8727		−255**	0.093
	(0.28)	(1.46)	(0.21)		(2.02)	
1909	−8965	2648	46950	959		0.146
	(0.92)	(1.17)	(1.17)	(0.06)		
	260	1810	44154		−380**	0.193
	(0.04)	(0.75)	(0.99)		(2.25)	
1914	−21041**	1600	103103*	28468**		0.261
	(2.56)	(0.53)	(1.71)	(2.12)		
	216	1038	98271*		−329*	0.275
	(0.02)	(0.33)	(1.55)		(1.93)	
1928	−21067	5040	112264**	18856		0.143
	(1.20)	(0.83)	(2.19)	(0.52)		
	−4342	4413	107406**		−333	0.149
	(0.17)	(0.67)	(2.01)		(0.87)	
1940	−31898	−1862	126449**	85642		0.085
	(1.13)	(0.42)	(2.22)	(1.38)		
	23714	−2750	117138**		−629*	0.077
	(1.24)	(0.58)	(2.11)		(1.79)	

Notes: Method of estimation is ordinary least-squares, *t*-ratios (in parentheses) adjusted for heteroscedasticity following procedure of White (1980). *Denotes statistical significance at the 5 percent confidence level; **denotes the 1 percent confidence level. There are 64 nonzero observations in 1879, 83 in 1899, and 96 in the remaining years.

The results in Table 4 are broadly consistent with those of the previous section. The capital-labor coefficient is significant in 1879, but it becomes steadily less so in subsequent years and is actually negative by 1940. Thus indications that the Leontief Paradox emerged historically are still present in a multivariate setting. The natural resource coefficient, on the other hand, begins negative and becomes significantly positive after 1909, reaching its peak (in both level and significance) in 1928.

The coefficients of the two labor force variables are also interesting. The coefficient of the average wage is significantly positive in only one year (1914). The coefficient on the percentage of women and child laborers, by contrast, is significantly negative in four of the six years and nearly so in the remaining two. When both variables are included (not shown), the coefficient on the average wage is negative or insignificant in every year. Furthermore, there is an evident inverse relationship between natural resource intensity and the presence of women and children. It appears, therefore, that the concentration of American net exports in "high wage" industries early in the century was attributable to the absence of women and child workers in these "heavy" industries.[5]

An important amendment to this account emerges from Table 5, which uses a new

[5]This does not necessarily mean that the effect is purely compositional, that is, directly explained by the lower wages paid to women and children. Men who worked in these occupational-industrial categories also received lower wages. But these wages did not reflect "skill" levels so much as the ease with which women and children could be substituted for men in these industries.

TABLE 5—REGRESSIONS FOR MANUFACTURED NET EXPORTS OF THE U.S., 1879–1940

	Constant	Capital and Natural Resources/Labor	Average Wage	Percentage Women and Children	R^2
1879	236	2741**	977		0.058
	(0.05)	(2.17)	(0.14)		
	3815	2234		−182*	0.095
	(1.31)	(1.54)		(1.88)	
1899	2495	5650**	4617		0.057
	(0.32)	(2.81)	(0.40)		
	10015*	4677*		−314**	0.088
	(1.98)	(1.95)		(2.58)	
1909	−2974	9312**	6052		0.165
	(0.31)	(3.46)	(0.37)		
	6955*	8045**		−428*	0.229
	(1.93)	(2.68)		(2.67)	
1914	−15799**	13279**	33918**		0.299
	(2.08)	(3.50)	(2.57)		
	7317**	12198**		−386**	0.321
	(2.23)	(3.07)		(2.68)	
1928	−10667	24084**	28310		0.241
	(0.75)	(2.87)	(0.88)		
	9857	22954**		−399	0.252
	(1.09)	(2.61)		(1.40)	
1940	−33084	12118**	86974		0.095
	(1.14)	(2.23)	(1.36)		
	19478**	10590**		−575	0.083
	(2.00)	(1.89)		(1.87)	

Note: See Table 4.

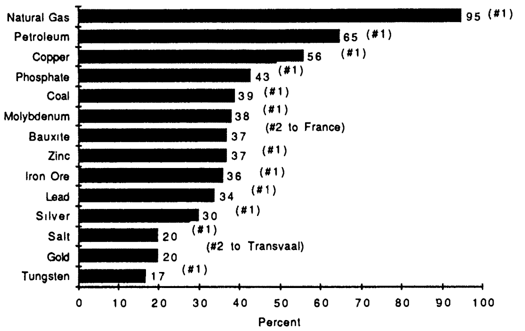
variable created by multiplying the capital-labor ratio and the natural resource coefficient. The results strongly imply that capital and natural resources were complementary factors of production. The coefficient of the new variable is positive through the entire period, growing steadily larger and more significant through 1928. Comparison of R^2 levels between Tables 4 and 5 shows that this new interactive variable is more powerful in accounting for net export performance than the combined effect of its two components, entered separately. The strongest effects are found in 1914 and 1928; in the latter year, for example, the R^2 rises from 0.149 to 0.252 merely by substituting a single variable, the product, for the original two.

This result should caution us against a too-hasty and too-complete rejection of "capital intensity" as a characteristic of American industry. The suggestion is, however, that capital intensity derived not from economy wide abundance of capital per se, but from specialization in an industrial technology in which capital was complementary to natural resources. Strictly speaking, these sorts of tests only describe the direction of trade, not the overall "success" of American industry. But the coincidence of timing between resource intensity and American industrial ascendance obliges us to consider the proposition that the abundance of industrial minerals was a deeper cause of American industry's distinctive strength.

IV. Natural Resources and American Industrial Success

Since industrial success like other historical outcomes requires an uncountable number of mutually interdependent elements, do natural resources really deserve special attention? The scope of America's world leadership in natural resources is displayed in Chart 3, which shows U.S. production of 14 major industrial minerals as a percentage

CHART 3. U.S. MINERAL OUTPUT, 1913: PERCENTAGE OF WORLD TOTAL



Source: Smith (1919), using data from U.S. Geological Survey (1913).

of world totals in 1913. The 95 percent of world natural gas and 65 percent of world petroleum were perhaps of somewhat less economic moment in 1913 than they would be at a later date. But copper, coal, zinc, iron ore, lead, and other minerals were at the core of industrial technology for that era, and in every single case the United States was the world's leading producer by a wide margin. In an era of high transport costs, the country was *uniquely* situated with respect to almost every one of these minerals. Even this understates the matter. Being the number one producer in one or another mineral category is less important than the fact that the *range* of mineral resources abundantly available in the United States was far wider than that in any other country. Surely the link between this geographical status and the world success of American industry is more than incidental. Cain and Paterson (1986) find that between 1850 and 1919, material-using technological biases were significant in nine of twenty American sectors, including those with the strongest export performance, such as petroleum, metals, and machinery.

Resource abundance was a background ingredient in many other distinctively American industrial developments. Continuous-process, mass-production methods, closely associated with modern forms of corporate organization in the analysis of Chandler (1977), were characterized by "high throughput" of fuel and raw materials relative to labor and production facilities (compare Michael Piore and Charles Sabel, 1984). Oliver Williamson (1980) notes that cheap, reliable sources of energy and heat were crucial to this development. Coal was of strategic early importance as a direct source of heat and power, and at a later point as a source of thermal energy for electricity, essential to the efficiency of the moving assembly line and other quasi-flow processes. Alex Field (1987) points out that organizational innovations of this type may be considered "capital-saving" overall, even though firm-level capital requirements were high. In export markets, contemporary comments emphasized non-price competition and particularly the short delivery lags on the part of U.S. suppliers (Nicholas, 1980, pp. 581–587). Quick delivery is a feature one would expect to see where exports have a "vent-for-surplus" quality, because of the length of a production run on a standardized item. In addition, American producer and consumer goods were often specifically designed for a resource-abundant environment. Some of the adjustment problems of U.S. auto companies in recent years stem from their decades of specialization on large, fuel-using cars. There was a parallel problem facing U.S. locomotive manufacturers in the 1920s, who found their foreign sales handicapped by their design for standard-gauge rails, heavy motive power, and heavy train loads (*Markets of the United States*, p. 71).

The emergence of cheap American steel at the end of the nineteenth century was particularly important. Whereas S. J. Nicholas (1980) suggested that the fall in relative U.S. machinery prices was misleadingly proxied by iron and steel prices, it may be that the world success of American engineering goods was buoyed by exactly that development. Table 6 shows the major role played by iron and steel exports over the half-century under discussion. If we aggregate the three headings under which iron and steel products were listed, we find that their share of U.S. manufacturing exports grew steadily, from 5.5 percent in 1879 to 37.5 percent in 1929. If we add in one other

TABLE 6—SHARES OF UNITED STATES MANUFACTURING EXPORTS, 1879–1929 (PERCENT)

	Iron and Steel Products (except Machinery and Vehicles)	Machinery	Automobiles and Parts	SUM (1,2,3)	Petroleum Products	SUM (1,2,3,5)
1879	2.1	3.4	–	5.5	12.1	17.6
1889	2.4	6.1	–	8.5	13.3	21.8
1899	7.6	10.7	–	18.3	9.2	27.5
1913	10.9	14.5	2.3	27.7	10.1	37.8
1923	8.8	12.4	6.4	27.6	13.1	40.7
1926	5.6	12.9	11.5	30.0	16.8	46.8
1927	5.1	13.9	13.3	32.3	14.7	47.0
1928	5.3	16.4	15.7	37.5	13.9	51.4
1929	5.4	16.4	15.7	37.5	13.9	51.4

Source: 1879–1923 (1963), Tables A-8 and A-12; 1926–1929, U.S. Department of Commerce, *Foreign Commerce and Navigation of the United States for the Calendar Year 1929*, Vol. 1, Tables XII and XXIV.

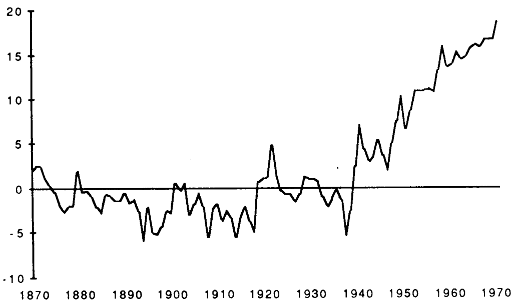
heading in which resource abundance was evidently important, petroleum products, we find that by late 1920s, we have accounted for more than half of all American manufacturing exports. The union of these two sectors is, in essence, the automobile industry. The United States was unquestionably the world's technological leader in automobile production during the 1920s. At the same time, American producers had enormous cost advantages over competitors in raw materials, especially steel. Ford UK faced steel input prices that were higher by 50 percent or more than those paid by the parent company (James Foreman-Peck, 1982, p. 874). It was not accidental that Leontief chose motor vehicles as his most prominently displayed example of the economy as an intricate input-output machine: each million dollars worth of automobiles in 1947 "contained" nearly half that much value in iron and steel, nonferrous metals, and other fabricated metal products (Leontief, 1953, p. 334).

We may also conjecture that there were links between the economy of high throughput and the intensity of the work pace, which also seems to have been a distinctive feature of U.S. industry (Clark, 1987). American firms paid the world's highest real wages and apparently extracted greater effort from the labor force in return. But it is an anachronism to associate "high wages" with "high skill" technologies for the era in which the United States surged to world industrial preeminence. The United States was a well-educated country, but most of the workers in the fast-paced, heavy-industry, mass-production manufacturing in which the country led the world were not well-educated native-born Americans. In 1910 the foreign born and sons of foreign born were more than 60 percent of the machine operatives in the country, and more than two-thirds of the laborers in mining and manufacturing (U.S. Senate, 1911, pp. 332, 334). There is no reason to believe that this labor force was particularly well educated by world standards. Key industries like iron and steel and motor vehicles paid high wages to unskilled workers (who were nonetheless much cheaper than the skilled craft workers used with older technologies), presumably because it was rough, disagreeable, dangerous, demanding work, and because it was vital to have an ample excess labor supply available (compare Daniel Raff, 1988). In the 1930s these industries were central to the movement for industrial unionism, which subsequently provided an alternative mechanism for the continued association between high-wage industries and American industrial success.

V. What Became of American Resource Abundance?

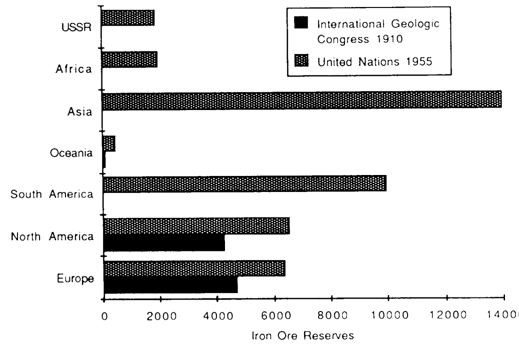
The marked changes in coefficients for 1940 seem to portend the post–World War II pattern, when the United States moved

CHART 4. U. S. NET MINERAL IMPORTS AS A PERCENTAGE OF CONSUMPTION



Source: Manthy (1978, Tables MC1 and MC2).

CHART 5. WORLD IRON ORE RESERVES, 1910 AND 1955



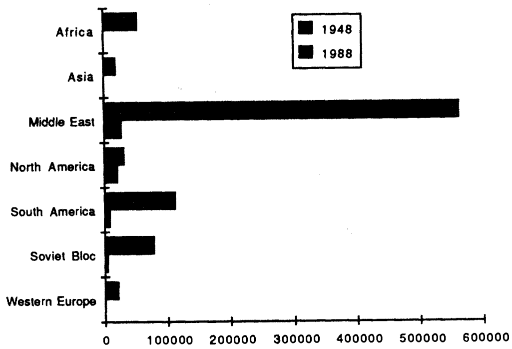
Sources: International Geologic Congress (1910, pp. 1–56): "Actual Reserves" in millions of tons of metallic iron; United Nations (1955, pp. 19–34): "Reserves" in millions of tons of iron content.

steadily and increasingly into a position of net mineral imports (Chart 4). Beginning mainly in the 1920s, one important mineral after another began to enter the net import column: nonferrous metals, bauxite, lead, zinc, copper, iron ore, and petroleum among others. Without conducting extensive global cost comparisons, it is evident that a country for whom resource prices are determined at the margin by imports is not going to have a major locational advantage in resource costs over its industrial rivals. But what exactly was the process of change in America's resource position? A popular conception is that the country has largely exhausted its resource endowment and has had to import so as to avert domestic shortages. Kindleberger has proposed a weaker version of this scenario within the Heckscher-Ohlin framework, in which the more rapid growth of labor and capital relative to resources has turned the country from a net-export to a net-import position with respect to resources (Charles P. Kindleberger 1960, pp. 347–348). It is doubtful that this account is generally valid. Indeed, a closer look at the trend in world mineral supplies casts a different light on the character of the original position.

In 1919 it could confidently be written that "the United States is more richly endowed with mineral wealth than any other country" (George Otis Smith, 1919, p. 282), and such a statement was consistent with the best geological and industrial knowledge of the day. But the clear pattern of discoveries since that time indicates that there was a systematic historical bias in these perceptions, in that American resources had been much more thoroughly explored and exploited than those of other parts of the world. Chart 5 illustrates this process, by comparing world iron ore "reserves", as indicated by a 1910 survey by the International Geologic Congress, with those reported in a United Nations survey in 1955. Granted that quality differences and extraction and transport costs are neglected in a simple chart, nonetheless the pattern is so clear as to be beyond dispute. Europe and North America had by far the largest reserves in 1910, but their "endowments" (which, to be sure, had increased and not decreased) had grown only slightly in the intervening 45 years. What had been a dominating advantage in 1910 was no more than a respectable presence in 1955.

The case of petroleum is even more extreme (Chart 6). Recall that the United States in 1913 (and for a half-century before) had been the world's largest petroleum producer and exporter, by a wide margin. As Chart 6 shows, as late as 1948, North American reserves were nearly equal to those of the Middle East. In 1988, though again reserves of all areas had increased, North America was a minor part of the world petroleum picture. It is difficult to

CHART 6. WORLD CRUDE OIL RESERVES, 1948 AND 1988



Source: American Petroleum Institute (1988, Section II, Table 1): "Estimated Proved Reserves of Crude Oil Annually as of January 1 (millions of barrels)."

avoid the inference that mineral supplies were more a matter of "development" than "endowment."

Where world geological surveys are not available, similar conclusions can be reached by other routes. In the case of bauxite, which takes its name from the French village where it was first developed, the United States and France alternated as first and second in the world until the 1950s. With discoveries in the West Indies in the 1950s, Jamaica quickly moved into first place, at annual production levels larger than those ever achieved in either France or the United States, despite the fact that production levels in those two countries did not decline but continued to grow to levels higher than they themselves had ever achieved. In the late 1960s, Australia replaced Jamaica as number one, again setting new production records without causing an absolute decline in any of the older countries. In both Jamaica and Australia, bauxite production was negligible before World War II. Since the real price of bauxite has declined, it is not the case that domestic reserves have been "exhausted" or that distant supplies have simply been coaxed out along a world supply curve. Rather, early discoveries and mining took place in areas proximate to the early centers of industrial and technological development and within the boundaries of their national jurisdiction.

The last phrase points toward another sense in which resource abundance was historically rather than geologically determined. The United States was the world's largest mineral producing nation, but it was also one of the world's largest countries! Even without Alaska, at 3.5 million square miles, the United States is twice the size of all the countries of eastern and western Europe and Scandinavia combined (excluding Russia). Yet coal and iron ore production in Europe was 30 to 50 percent higher than the U.S. total in the 1910–1913 era. If coal and iron were the imperatives of industrial location ca. 1900, a hypothetical United States of Europe would have rivaled America.

More important than sheer geographic size is economic distance. The United States was a vast free trade area for internal commerce, and the opportunities created by this status provided the incentive for massive investment in transportation infrastructure, including the highly efficient lake transport system that linked Mesabi ore to Pennsylvania coal. In the case of copper, only the combination of national size and efficient internal transportation allow use to say that the "same" economy retained world leadership across the period of American industrial ascendancy, since the early production center in Michigan gave way to remote but larger and richer locations in the Mountain and Southwest regions between 1870 and 1930.

The argument does not stop with national size and efficient transportation. The process of mineral discovery and development was also a prime outlet for creative energies and innovations, often at high levels of technical and organizational sophistication. The United States Geological Survey, formed in 1879 by consolidation of several existing federal surveys, had intimate links with the mining industry. Reports by government geologists in Colorado in the 1880s were crucial in encouraging mining activity and adapting metallurgical knowledge to local requirements (Rodman Wilson Paul, 1960). The American Institute of Mining Engineers became the first speciality group to break away from the American Society of

Civil Engineers. Scientifically trained personnel were also important in expanding the range of *uses* for available minerals. An early report by Yale geologist Benjamin Silliman, Jr., foresaw the commercial possibilities of "cracking" petroleum into various compounds, opening up arrays of new uses for what had been considered a useless waste material (Robert V. Bruce, 1987, pp. 140–142). But as Nathan Rosenberg (1985) points out, much of the early use of science by American industry did not deploy new knowledge at the scientific "frontier," but involved repetitive procedures (such as grading and testing materials) for which scientific training was needed but where the learning was specific to the materials at hand. The abundance of mineral resources, in other words, was itself an outgrowth of America's technological progress.

This view of the matter suggests the answer to the question posed above. The country has not become "resource poor" relative to others, but the unification of world commodity markets (through transport cost reductions and elimination of trade barriers) has largely cut the link between domestic resources and domestic industries. American corporations and engineers have been in the forefront of the globalization of the mineral economy. In essence, the process by which the United States became a unified "economy" in the nineteenth century has been extended to the world as a whole. To a degree, natural resources have become commodities rather than part of the "factor endowment" of individual countries.[6] Presumably this is why international economists now distinguish resource-based "Ricardo goods" from others and treat them separately (for example, Robert Stern and Keith E. Maskus, 1981). This procedure may be appropriate for the contemporary world, but it would be hard to do justice to the historic success of American industry within this conception.

[6]Wilfred J. Ethier and Lars E. O. Svensson (1986) show that in a Heckscher-Ohlin framework with mobility of some factors a country's trade pattern in goods is affected only by its endowment of *nontraded* factors.

VI. Conclusion

Why has the importance of mineral resources in American industrial history been underappreciated? Concern for the future of natural resources is an ancient theme in economics, but most of the attention has been channeled into two rather different issues: fear of rising costs from increased resource scarcity and fear of national strategic inadequacy in the event of war. Refuting the first fear has long been the economist's favorite pastime, as it has been easy to show that producers substitute away from relatively scarce resources and that the real prices of "nonrenewable" resources have historically declined. The second fear has always seemed noneconomic in character, if not indeed a cooked-up rationalization for subsidy or protection. Having thus dealt with the "problem" of resource exhaustion, it was easy to overlook a logically distinct aspect of the matter: the contribution of resource location to the competitive potential of a country's industries. Some economic historians, to be sure, have long analyzed national economic histories in terms of world geographical patterns (William N. Parker, 1984). But it is perhaps understandable that Americans have not been inclined to attribute their country's industrial success to what appear to be accidental or fortuitous geographic circumstances. Another reason is that American industrial leadership took on a rather different shape after World War II. Over the course of the twentieth century, the country was able to parley its resource-based industrial prosperity into a well-educated labor force, an increasingly sophisticated science-based technology, and world leadership in scientific research itself. In the wake of World War II, there were no serious international rivals in such a wide range of industries that it was easy to lose sight of the resource dimension of industrial performance. After the war, there was a brief period of concern that the nation's resource position had been eroded, culminating in the Paley Commission Report of 1952. But such doubts and fears were largely swept away in the American-led world prosperity of the next 25 years.

To be clear about the argument, there is no iron law associating natural resource abundance with national industrial strength. But the distinctive *American* technologies have, as a matter of history, been relatively resource-using. We have now moved from an era in which the rest of the world adapted to an American technology, with varying degrees of difficulty, to an era in which U.S. firms have had to do the adjusting. The adjustment is not made much easier by the consideration developed in this paper, that historical resource abundance was itself largely an outgrowth of American industrial success.

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