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Late Nineteenth-Century Anglo-American Factor-Price Convergence: Were Heckscher and Ohlin Right?

KEVIN O'ROURKE AND JEFFREY G. WILLIAMSON

Due primarily to transport improvements, commodity prices in Britain and the United States tended to converge between 1870 and 1913. Heckscher and Ohlin, writing in 1919 and 1924, thought that these events should have contributed to factor-price convergence. It turns out that Heckscher and Ohlin were right: a significant share of the Anglo-American real-wage convergence was due to commodity-price convergence. It appears that this late nineteenth-century episode was the dramatic start of world-commodity and factor-market integration that continues today.

The immediate result of interregional trade is equalization of commodity prices between the several regions. But [the] equalization of the prices of factors of production is also involved. An example of change of this type is afforded by trade between Europe and America during the last half of the nineteenth century.

—Bertil Ohlin¹

THE FACTOR-PRICE-EQUALIZATION THEOREM AND HISTORY

The factor-price-equalization theorem has been a durable tool for trade theorists ever since Eli Heckscher and Bertil Ohlin made their seminal contributions shortly after World War I, although it must be said that Heckscher and Ohlin talked about partial equalization and convergence, whereas Paul Samuelson talked about equalization.² According to the Heckscher-Ohlin paradigm, countries export commodities that use intensively the factors in which they are well endowed and import commodities that use intensively the factors in which they are poorly endowed. Thus, commodity trade tends to equalize factor

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¹ Bertil Ohlin writing in 1924, in Flam and Flanders, eds., *Heckscher-Ohlin Trade Theory*, pp. 91, 181.

² Samuelson, "International Trade."

endowments among trading partners. Furthermore, under restrictive assumptions, it can be shown that a move from no trade to free trade can in fact equalize factor prices between countries where wide differences in such prices previously existed. Consider this example. Let falling transport costs and declining tariff barriers tend to equalize prices of traded commodities. Countries will now export more of the goods that exploit their favorable factor endowment. The demand for the abundant and cheap factor booms, whereas that for the scarce and expensive factor falls. Thus, commodity-price equalization tends to produce factor-price equalization, although theory is ambiguous about how much.

Both Heckscher and Ohlin were Swedes, and thus they were familiar with the small, open economy. Indeed, when Heckscher was writing in 1919 and Ohlin in 1924, they were motivated by the commodity-price convergence trends that they thought had taken place between Old World and New in the late nineteenth century.³ Their economic metaphor was driven by primary foodstuffs. What we now call the invasion of grains from the New World, driven by the sharp decline in transport costs, served to lower the relative price of grains in the Old World (like Britain) and raise it in the New World (like the United States). Britain did not respond to the challenge with tariffs, although countries on the continent did.⁴ What occurred in the late nineteenth century was exactly the kind of exogenous relative price shock that was supposed to set factor-price convergence in motion. Britain and other Old World countries in the free-trade zone had plenty of labor and little land, whereas the United States in the New World had the opposite. Thus, in 1870 the New World had high real wages and low farmland rents, and the Old World had the opposite. According to Heckscher and Ohlin, the invasion of grains should have raised real wages and lowered rents in the Old World free-trade zone and lowered real wages and increased rents in the New World, *ceteris paribus*. Did it?

In spite of the durability of the famous factor-price-equalization theorem, nobody to our knowledge has explored its empirical significance during the epoch that motivated Heckscher and Ohlin in the first place: the late nineteenth century. This odd state of affairs is all the more surprising given the attention that economic historians have devoted to the grain invasion, the decline in transport costs, and the convergence of prices internationally in the 40 years or so following 1870. Indeed, there has been little effort to explore the empirical relevance of the factor-price-equalization theorem in the better-known post-World War II period of convergence.⁵

The issues raised in this article also address recent scholarly interest

³ See the new translation edited by Flam and Flanders, *Heckscher-Ohlin Trade Theory*.

⁴ Kindleberger, "Group Behavior."

⁵ See, however, Mokhtari and Rassekh, "Factor Price Equalization"; and Rassekh, "The Role of International Trade."

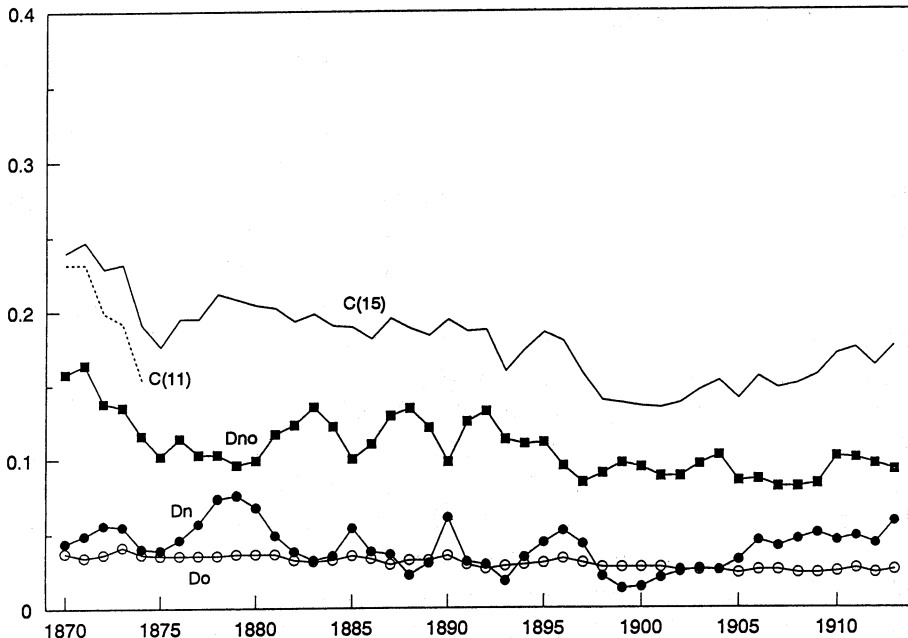


FIGURE 1

INTERNATIONAL REAL WAGE DISPERSION, 1870-1913

Source: Williamson, "The Evolution of Global Labor Markets."

in comparative growth performance over the past century or so. Moses Abramovitz captured these ideas with his apt phrase "catching up, forging ahead and falling behind."⁶ Although interest in comparative growth performance dates back to Alexander Gerschenkron's late-comer hypothesis of 1952, it has been reawakened with the appearance of *Productivity and American Leadership* by William Baumol and his collaborators, Gavin Wright's analysis of the origins of American industrial success, and what has come to be called the "new growth theory."⁷

Jeffrey Williamson recently constructed a real-wage database for 15 countries over the period 1870 to 1913. The data focused on the urban unskilled and they were purchasing-power-parity adjusted.⁸ The evidence, summarized in Figure 1 by a coefficient of variation $C(15)$, documents considerable convergence. Furthermore, the late nineteenth-century real-wage convergence is similar in magnitude to the better-known convergence of the great "Keynesian boom" after World War II. Perhaps most significant, however, is the finding that most of the late nineteenth-century real-wage convergence was attributable to an

⁶ Abramovitz, "Catching Up, Forging Ahead, and Falling Behind."

⁷ Gerschenkron, "Economic Backwardness"; Baumol, Blackman, and Wolff, *Productivity and American Leadership*; and Wright, "The Origins of American Industrial Success."

⁸ Williamson, "The Evolution of Global Labor Markets."

erosion in the real-wage gap between the Old World and New (Dno in Figure 1) and not to any significant convergence within the Old World (Do) or within the New (Dn). In 1870 real wages in the labor-scarce New World (Argentina, Australia, Canada, and the United States) were 136 percent higher than in the labor-abundant Old World (Ireland, Great Britain; Denmark, Norway, Sweden; Germany; Belgium, Netherlands, France; Italy and Spain). But by 1895 real wages in the New World were "only" 100 percent higher, and in 1913 they were "only" about 87 percent higher. In short, the real-wage gap between Old World and New fell by 36 percentage points over those 25 years, and by 49 percent over those 43 years. The Old World caught up a bit with the New.

Although it was much less dramatic, what was true of the Old and New World was also true of the two countries that best represented each: in 1870 real wages in the United States were 67 percent higher than in Britain; in 1895 they were "only" 44 percent higher; and in 1913, "only" 54 percent higher. That is, the Anglo-American real-wage gap fell by 23 percentage points over those 25 years, and by 13 percentage points over those 43 years. Of course, the United States underwent superior industrial growth during this period,⁹ a force that should have tended to raise real wages in the United States relative to Britain. Over the period as a whole, however, Britain caught up a bit with the United States, which is surprising, given all that has been said about Britain losing its leadership to the United States (although it must be said that all of the British "catch-up" took place prior to 1895, and not afterwards when American industrial ascendancy was most dramatic). Furthermore, the wage (farmland)-rental ratio doubled in Britain whereas it halved in America.¹⁰

This article links the factor-price equalization literature with the convergence literature. It asks: How much of the Anglo-American factor-price convergence between 1870 and 1895 or 1913 can be explained by the convergence in commodity prices? Does the factor-price equalization theorem play a quantitatively significant role during the period of New World grain invasion, a period that motivated Heckscher and Ohlin in the first place?

It is of course true that international factor mobility will directly bring about factor-price convergence, a fact of which both Heckscher and Ohlin were well aware. But it was the insight that commodity trade can serve as a substitute for factor mobility that distinguishes their work. Both Heckscher and Ohlin recognized that capital was to a considerable extent internationally mobile, that labor was less so, and that land was completely immobile.¹¹ If returns to capital were broadly similar across

⁹ Wright, "The Origins of American Industrial Success."

¹⁰ O'Rourke, Taylor, and Williamson, "Land, Labor and the Wage-Rental Ratio."

¹¹ Flam and Flanders, *Heckscher-Ohlin Trade Theory*, pp. 53, 159.

countries, capital mobility would certainly offer an adequate explanation. International wage and land-rent convergence are analytically more interesting. They could be due to capital and labor mobility, technology transfer, or commodity trade. Wages and land rents are thus the focus of this article. Our aim is to isolate that portion of Anglo-American factor-price convergence that can be attributed to commodity trade. The strategy of the article will therefore be to assume that other forces of convergence, in particular migration, were absent and to see what the Heckscher-Ohlin mechanism might have done to factor prices on its own.

The article falls into two parts. The first documents the extent of commodity price-convergence during the period for aggregate Anglo-American importables and exportables, not just grains. The second estimates the impact that these price shocks had on the two economies, focusing on factor prices in particular. To this end, computable general equilibrium (CGE) models are constructed for Britain and the United States. These models are then used to answer questions like: If Anglo-American commodity-price differentials in 1870 had been like they were in 1895 or 1913, by how much would Anglo-American factor prices have changed? Since the aim of the article is to assess whether commodity-market integration would have led to some considerable factor-price convergence even in the absence of factor flows, we shall assume that labor and capital were not mobile internationally. The working paper underlying this published version explored the impact of commodity-price convergence on Anglo-American factor-price gaps when capital is mobile (the results were barely changed), and a separate paper explored the impact when foreign labor migration is taken into account.¹² Thus, the present article is one component of a larger project.

The British and the U.S. models will be kept simple, not much more complex than those that we use in the classroom. Our interest is historical, however, and so the models will differ in important respects from the 2×2 Heckscher-Ohlin-Samuelson models taught in standard trade courses. Any model in which foodstuffs are traded for manufactures (as Heckscher and Ohlin envisaged) must have at least three factors: land, labor, and capital. Moreover, land is of its nature specific to agriculture. It is the historical insight of Heckscher and Ohlin that is being tested here, not any particular theoretical model. Their models were considerably more general than the textbook versions that bear their name today; any model in which factor endowments determine trade can be said to descend from their work.

¹² O'Rourke, Williamson, and Hatton, "Mass Migration."

COMMODITY-PRICE CONVERGENCE 1870–1913

The Evolution of Anglo-American Transport Costs and Tariffs

Economic historians have long been aware of the revolutionary decline in transport costs underlying overseas trade in the late nineteenth century. Douglass North called the decline “radical” for both railroads and ocean shipping.¹³ Because Britain imported foodstuffs and raw materials, and because these bulk commodities “were fundamental beneficiaries of the cheapening transport costs,” North thought that lower transport costs contributed in Britain to “lower priced foodstuffs and therefore rising real wages, and to the lowering in the cost of industrial raw materials,” and therefore, we take it, rising rates of industrialization.¹⁴ Although North does not say so, symmetry suggests that real wages must have been lowered in the United States whereas industrialization must have been suppressed.

The kind of evidence that North used in his seminal 1958 article is reproduced in Table 1. When deflated by a U.S. general price index, North’s freight rate index among American export routes in Table 1 drops by more than 41 percent between 1870 and 1910. His wheat-specific American East Coast freight factor (percent share of freight costs in CIF value) fell by 53 percent between 1870 and 1913. The older Isserlis index (which includes many other non-Atlantic trade routes) displays a less spectacular decline of about 25 percent over the same period. Knick Harley offers similar evidence on British overseas coal freight rates.¹⁵ All in all, Table 1 appears to support North’s choice of the word “radical” to describe the decline in transport costs linking U.S. and British commodity markets, even though the table ignores the pronounced decline in transport costs from seaport to interior due to railroads.

It is important not to equate the fall in transport costs during this period simply with the fall in overseas shipping rates. The Heckscher-Ohlin mechanism posits that producers respond to price signals; and farm-gate prices in the United States were influenced at least as much by railroad rates as by overseas rates in the late nineteenth century. Harley’s data for wheat show that New York-Chicago price gaps were larger, and, if anything, fell more rapidly than did New York-Liverpool price gaps over the period.¹⁶ It was the joint impact of developments on land and sea that mattered, and that is what we examine in this article. Writing in 1924, Edwin Nourse thought these forces threw British

¹³ North, “Ocean Freight Rates,” p. 537.

¹⁴ *Ibid.*, pp. 544, 545.

¹⁵ Harley, “Ocean Freight Rates.”

¹⁶ O’Rourke and Williamson, “Were Heckscher and Ohlin Right?” fig. 4.

TABLE 1
FREIGHT RATE INDICES, DEFLATED, 1870-1913: TRAMP SHIPPING, MOSTLY
ALONG ATLANTIC ROUTES
(1870 = 100)

	Isserlis: Many Routes	North: American Export Routes	North: American East Coast Routes
1869	95.1	102.7	112.3
1870	100.0	100.0	100.0
1871	95.1	128.4	119.8
1872	88.3	131.2	109.9
1873	98.5	166.9	146.9
1874	98.8	145.0	130.9
1875	96.1	146.3	153.1
1876	96.1	141.2	142.0
1877	98.1	128.4	101.2
1878	97.3	150.5	135.8
1879	95.1	157.7	116.0
1880	92.0	171.8	106.2
1881	95.1	145.2	74.1
1882	89.6	145.2	71.6
1883	85.0	124.7	82.7
1884	78.1	110.3	79.0
1885	82.1	106.5	79.0
1886	80.2	100.8	87.7
1887	89.6	95.1	64.2
1888	101.8	98.9	65.4
1889	97.8	110.3	107.4
1890	83.4	121.7	61.7
1891	82.1	116.0	70.4
1892	75.8	106.5	69.1
1893	82.7	98.9	75.3
1894	86.2	83.0	70.4
1895	84.6	94.5	91.4
1896	85.9	108.9	90.1
1897	84.6	113.0	81.5
1898	99.5	127.4	80.2
1899	89.6	104.8	76.5
1900	93.9	129.4	101.2
1901	76.4	78.1	37.0
1902	66.6	63.2	44.4
1903	66.6	60.9	45.7
1904	65.7	59.0	30.9
1905	66.5	68.5	45.7
1906	62.6	76.1	43.2
1907	62.7	71.5	44.4
1908	57.9	60.9	38.3
1909	57.6	60.9	37.0
1910	59.5	58.7	39.5
1911	67.3	—	50.6
1912	85.3	—	85.2
1913	74.4	—	46.9

Sources: Isserlis: Isserlis, "Tramp Shipping Cargoes and Freights," table VIII, p. 122, col. 2 deflated by Statist price index in the same source, col. 6; North, American Export Routes: North, "Ocean Freight Rates," table 2, p. 549 deflated by U.S. BLS consumer price index, U.S. Department of Commerce, *Historical Statistics of the United States*, series E-135; North: American East Coast Routes: North, "Ocean Freight Rates," table 3, pp. 550-52.

farming, "which had been in orderly retreat for over fifty years, . . . into a rout."¹⁷

Other forces were at work that should have influenced the evolution of Anglo-American price differentials after 1870, such as the slow erosion in the height of American Civil War tariffs. The ratio of duties to dutiable imports fell from 47 percent in 1870 to 42 percent in 1910; and as a ratio to total imports, it fell from about 45 percent to 21 percent.¹⁸ Because the United States was a net importer of manufactures during most of this period, and since the Civil War tariffs were high on those importables, the erosion in U.S. tariffs after 1870 should have served to aid commodity-price equalization on manufactured goods, not just on primary products.

Grain-Market Integration

In assessing the "radical" decline in overseas freight rates, the cost reductions along the rails between Chicago and New York, and the erosion in Civil War tariffs, what mattered, of course, was their impact on the price convergence of tradables. By how much, for example, did these forces raise the price of foodstuffs in the United States and lower them in Britain? Almost without exception, the literature has explored the question by looking solely at the grain market. This is certainly true of Charles Kindleberger's important contribution to the debate over the Old World defensive policy response to the grain invasion, and it is also true of Harley's writings on late nineteenth-century transport, trade, and settlement in the New World.¹⁹ Thus, we start there.

As Appendix 1 reports, wheat prices are quoted in gold-dollar prices per bushel for American No. 2 winter wheat in three markets: Liverpool, New York, and Chicago.²⁰ Liverpool was, of course, the major port handling Britain's grain trade, and Chicago was the city closest to America's grain producers; thus, it is the Liverpool-Chicago price gap that matters most to the questions raised in this article. Liverpool prices exceeded Chicago prices by 60.3 percent in the three years centered on 1870, by 25.4 percent in the three years centered on 1895, and by 14.9 percent in the three years centered on 1912.²¹ As it turns out, these price

¹⁷ Nourse, *American Agriculture*, p. 19.

¹⁸ U.S. Department of Commerce, *Historical Statistics*, p. 888.

¹⁹ Kindleberger, "Group Behavior"; Harley, "Transportation, the World Wheat Trade and the Kuznets Cycle" and "Late Nineteenth Century Transportation."

²⁰ Harley, "Transportation, the World Wheat Trade and the Kuznets Cycle," pp. 246–47, with interpolation for early years in Chicago. Winter prices are missing for Chicago for 1869–1871. We therefore take the ratio of No. 2 winter wheat to No. 2 spring wheat for 1868 and 1872 and interpolate geometrically between them. Multiplying the results by the reported prices of No. 2 spring wheat in Chicago gives an estimate of No. 2 winter wheat prices in Chicago for 1869–1871. From 1894–1896 on, data limitations require that the Chicago price be for No. 2 spring wheat. Thankfully, by 1884–1888 the spring and winter prices are exactly the same in Liverpool.

²¹ The price gap was only 4.8 percent for the three years centered on 1910. Indeed, Harley's

TABLE 2
ANGLO-AMERICAN COMMODITY PRICE CONVERGENCE:
LONG-RUN TRENDS 1870-1913
(percentages)

Commodity Traded	Markets in which Quoted	1870	1895	1913
A. Commodity Detail				
Wheat	Liverpool vs. Chicago	57.6	17.8	15.6
Meat and animal fats	London vs. Cincinnati	92.5	92.3	17.9
Cotton textiles	Boston vs. Manchester	13.7	3.7	-3.6
Iron bars	Philadelphia vs. London	75.0	43.4	20.6
Pig iron	Philadelphia vs. London	85.2	46.9	19.3
Cotton	Liverpool vs. New York	13.3	11.2	9.7
Coal	New York vs. London	-16.9	-2.0	8.8
Copper	Philadelphia vs. London	32.7	13.6	-0.1
Hides	Boston vs. London	27.7	16.6	8.7
Wool	Boston vs. London	59.1	65.8	27.9
Tin	New York vs. London	15.9	5.3	-2.3
Coffee	New York vs. London	-18.1	-3.5	8.2
Sugar	New York vs. London	50.9	74.2	91.0
B. Commodity Aggregates				
U.S. Exportable foodstuffs		51.9	33.0	10.6
U.S. Exportable intermediates		13.3	11.2	9.7
U.S. Importable manufactures		56.6	34.7	8.9
U.K. Importable foodstuffs		56.8	36.0	11.4
U.K. Importable intermediates		13.3	11.2	9.7
U.K. Exportable manufactures		31.3	14.6	2.6

Notes: These "long-run" figures are predicted from a nonlinear regression of annual data 1870-1913, where the percentage price gap is regressed on time and time squared. The price gaps themselves are calculated as percentage differentials (for example, in the case of wheat, the percent by which Liverpool prices exceeded Chicago). The commodity aggregates in Panel B use 1880 trade weights to construct weighted averages using six of the commodities documented in Panel A: foodstuffs (wheat, and meat and animal fats), intermediates (cotton), and manufactures (cotton textiles, iron bars, and pig iron).

Sources: See Appendix 1 and O'Rourke and Williamson "Were Heckscher and Ohlin Right?"

differentials fluctuated widely around the convergence trend, and Table 2 offers an alternative way to smooth out the annual instability—predictions from an estimated regression line. These imply instead that the price spread between Liverpool and Chicago fell from 57.6 percent in 1870, to 17.8 percent in 1895, and to 15.6 percent in 1913. Regardless of the smoothing device used, Anglo-American wheat prices clearly converged dramatically in the late nineteenth century. We should stress, however, that these estimates almost certainly *understate* the size of the price convergence because they ignore the collapse in the gap between farm-gate and Chicago prices.²²

figures show Chicago prices as higher than Liverpool prices in 1910. We preferred to concentrate on the 1912 average as it is less favorable to our argument.

²² For example, from 1870 to 1895 rail rates between Council Bluffs and Chicago fell by more

Commodity-Market Integration More Generally

Wheat and flour constituted 27.4 percent of U.S. exports and 15.3 percent of British imports in 1880. Unless other U.S. exportables and British importables had considerably different price behavior, these dramatic Anglo-American wheat price-convergence trends likely characterized all Anglo-American commodity markets that were linked by trade. What we need to test that proposition is Anglo-American price data for a whole range of tradables, not just wheat. Surprisingly, the literature has little to say on the nonwheat tradables. By presenting evidence on other commodities, this article will fill that gap in the literature.

The second biggest tradable foodstuff consisted of meat and animal fats such as beef, pork, bacon, mutton, and butter. In 1880 18.3 percent of U.S. exports and 9.3 percent of British imports were meat and animal fats. When the Anglo-American price differentials are plotted for this foodstuff, the series, like that for wheat, fluctuates widely. Table 2 suggests that meat-and-animal-fat price differentials between London and Cincinnati—the meat-packing center of America—were higher than for wheat in 1870. Convergence up to 1895 was modest. But convergence after 1895 was spectacular. Over the 43-year period convergence was, if anything, even more pronounced for these products than that for wheat, as price differentials declined to about 18 percent in 1913. Thus, there is ample evidence of meat-and-animal-fat price convergence over the four decades.

We lack comprehensive price information on the full range of products involved in Anglo-American trade in manufactures during the period, but do have data on cotton textiles, iron bars, and pig iron, three products that contributed an important share to total trade in manufactures. We selected relevant market-price quotes from the most important production centers for these products, Boston and Manchester for textiles and Philadelphia and London for iron bars and pig iron. Even specialists in the field might be surprised by the degree of price convergence for these manufactures during the period. As shown in Table 2, Anglo-American prices exhibit striking convergence for these three products between 1870 and World War I, approximating those already established for wheat and meat. Using the predictions from the trend regressions, the cotton-textile price differential between Boston and Manchester fell from about 14 percent in 1870 to about -4 percent in 1913, the iron-bar price differential between Philadelphia and London fell from 75 percent to about 21 percent, and the pig-iron price differential fell from about 85 percent to about 19 percent.

Similar Anglo-American price convergence can be seen in Table 2 for

than those between Chicago and New York. See Williamson, *Late Nineteenth-Century American Development*, table A.7, p. 262.

coal, copper, hides, wool, and tin. There is, however, an important and atypical case: raw cotton. This key intermediate good claimed an important share of Anglo-American trade, 25.7 percent of 1880 U.S. exports and 10.4 percent of 1880 British imports. As Table 2 reports, Anglo-American cotton-price differentials eroded only slightly during the late nineteenth century, from about 13 percent in 1870 to about 10 percent in 1913 (based on the regression predictions). This is one important intermediate for which Anglo-American price differentials did not drop sharply during the late nineteenth century.

The next step is to use 1880 trade weights²³ and the price differentials for the six major commodities documented in Table 2 (wheat, meat, cotton textiles, iron bars, pig iron, and cotton) to develop Anglo-American percentage price differentials for six aggregates: U.S. exportable and British importable foodstuffs (wheat and meat), U.S. exportable and British importable intermediates (cotton), and U.S. importable and British exportable manufactures (cotton textiles and iron products). These are used in the factor-price convergence analysis that follows. They reveal the following trends (panel B, Table 2): the price differential on U.S. exportable foodstuffs fell from 51.9 percent in 1870 to 10.6 percent in 1913; the price differential on U.S. importable manufactures fell from 56.6 to 8.9 percent; the price differential on British importable foodstuffs fell from 56.8 to 11.4 percent; the price differential on British exportable manufactures fell from 31.3 to 2.6 percent; and the price differential on tradable intermediates fell from 13.3 to 9.7 percent.

Had there been no other forces at work, the terms of trade between manufactures and foodstuffs would have changed dramatically in both countries. If Britain had absorbed all of the transport-induced price shock, its terms of trade would have almost doubled. If the United States had absorbed all of the transport-induced price shock, its terms of trade would have more than doubled. These were very big price shocks indeed, and they are likely to be understated on the U.S. side to the extent that we have ignored significant price convergence between farm-gate and Chicago or Cincinnati markets.

FACTOR-PRICE CONVERGENCE: INTUITION, EVIDENCE, AND SIMPLE MODELS

Ever since Wassily Leontief uncovered his trade paradox for early post-World War II America, simple versions of the Heckscher-Ohlin model have been under attack. We contend, however, that the model fares far better when applied to the late nineteenth century, the period that motivated Heckscher and Ohlin when they were writing in 1919 and 1924: factor endowments *were* the key determinants of trade patterns

²³ O'Rourke and Williamson, "Were Heckscher and Ohlin Right?"

when Heckscher and Ohlin constructed their theory. Most of the evidence supporting this view comes from economic historians who have recently analyzed the determinants of comparative advantage in British and American manufacturing in the late nineteenth century. Nick Crafts and Mark Thomas defended the Heckscher-Ohlin hypothesis, arguing that endowments explain the pattern of trade in British manufacturing between 1910 and 1935 and in U.S. manufacturing in 1909. Gavin Wright discovered similar evidence in his study of the evolution of U.S. trade patterns between 1879 and 1940, an account that Richard Nelson and Wright recently expanded.²⁴ Based on a large sample of 18 countries around 1913, Antoni Esteveordal found even more support for the Heckscher-Ohlin model. Indeed, his 1913 evidence is far more supportive of the Heckscher-Ohlin model than that reported by Edward Leamer, based on post-World War II data.²⁵ And William Whitney found no evidence of a Leontief Paradox in the U.S. data from 1899.²⁶

Evidence from the late nineteenth century thus seems to support Heckscher and Ohlin's argument that factor endowments largely determined trade. Encouraged by that fact, we now press on to explore the implications of commodity-price convergence for factor prices. The simplest approach would be to take the standard 2×2 model that is used commonly in the classroom by trade theorists. More plausibly, we could take the standard sector-specific factor model, totally differentiate, and solve for percentage changes in factor prices as a function of percentage changes in commodity prices. For example, in each country let

$$A = A(L_A, R) \quad (1)$$

$$M = M(L_M, K) \quad (2)$$

where A and M are outputs of food and manufactures, L_A and L_M are inputs of labor in the two sectors, and R and K are inputs of land and capital, respectively. In each sector, price equals cost; as is well known, this implies that (\hat{a} denotes percentage change)

$$\hat{p}_A = \theta_{LA}\hat{w} + \theta_{RA}\hat{r} \quad (3)$$

$$\hat{p}_M = \theta_{LM}\hat{w} + \theta_{KM}\hat{r} \quad (4)$$

where on the right-hand side we have a weighted sum of percentage changes in wage rates (\hat{w}), land rents (\hat{r}), and returns to capital (\hat{r}). Note that this standard model assumes labor to be completely mobile, so that

²⁴ Crafts and Thomas, "Comparative Advantage in UK Manufacturing"; Wright, "The Origins of American Industrial Success"; and Nelson and Wright, "The Rise and Fall."

²⁵ Esteveordal, "Comparative Advantage," p. 9; and Leamer, *International Comparative Advantage*.

²⁶ Whitney, "Structure of the American Economy."

wages are the same in both sectors. In addition, full employment requires that

$$a_{LM}M + a_{LA}A = L \quad (5)$$

$$a_{RA}A = R \quad (6)$$

$$a_{KM}M = K \quad (7)$$

where the a_{ij} s are variable input-output coefficients, and L , R , and K are the endowments of the three factors. Converting these three equations to percentage-change form (again, where \hat{a} denotes percentage change), and using the fact that

$$\sigma_A = (\hat{a}_{RA} - \hat{a}_{LA})/(\hat{w} - \hat{d}) \quad (8)$$

$$\sigma_M = (\hat{a}_{KM} - \hat{a}_{LM})/(\hat{w} - \hat{r}) \quad (9)$$

we obtain

$$\sigma_M \lambda_{LM}(\hat{w} - \hat{r}) + \sigma_A \lambda_{LA}(\hat{w} - \hat{d}) = 0 \quad (10)$$

where the σ s are elasticities of substitution in the two sectors, and the λ s are the sectors' shares of total employment.

Equations 3, 4, and 10 can then be solved for \hat{w} , \hat{r} and \hat{d} , as functions of \hat{p}_A and \hat{p}_M . Furthermore, they can be estimated, here illustrated for 1870.²⁷ In the British case, $\theta_{LA} = 0.529$, $\theta_{LM} = 0.68$, $\lambda_{LA} = 0.226$, $\sigma_A = 1$, $\sigma_M = 0.5$, $\hat{p}_A = -0.187$, $\hat{p}_M = 0.113$. In the U.S. case, $\theta_{LA} = 0.594$, $\theta_{LM} = 0.479$, $\lambda_{LA} = 0.54$, $\sigma_A = 1$, $\sigma_M = 0.45$, $\hat{p}_A = 0.158$, $\hat{p}_M = -0.209$. The price shocks reflect the decline in the Anglo-American price gap between 1870 and 1913. In Britain food became cheaper and manufactured goods more expensive, whereas the opposite occurred in the United States. The standard (but simple) sector-specific factor model predicts for Britain that in response to the observed commodity-price shocks farm rents decline by 42.8 percent, returns to British capital increase by 29.4 percent, and British (nominal) wages increase by 2.8 percent. In the United States rents increase by 28.2 percent, returns to capital fall by 46.9 percent, and wages increase by 7.4 percent. The British wage-rental ratio increases by 79.7 percent and the U.S. ratio falls by 16.2 percent. According to these calculations, the standard model predicts that commodity-price convergence during the late nineteenth century must have had extremely large effects on factor prices.

One feature of these results deserves emphasis: returns to capital rise in Britain and fall in the United States. This is inevitable, given that capital is specific to manufacturing and given the impact of commodity-price convergence on manufactured-goods prices in the two countries. If capital could move internationally in response to these shocks, it

²⁷ See Appendix 2; and O'Rourke and Williamson, "Were Heckscher and Ohlin Right?" appendix 3.

would flow from the United States to Britain—not the reverse, as was in fact the case. Of course, there were many reasons why capital should have flowed from the Old to the New World during this period; we are simply suggesting that falling transport costs favored British manufacturing at the expense of U.S. manufacturing, and that such effects by themselves should have served to diminish the capital flow from Britain to the New World.²⁸ Finally, note that if capital is assumed to be perfectly mobile internationally, so that its nominal return is exogenous, then $\hat{r} = 0$, and equations 3 and 4 suffice to solve for \hat{w} and \hat{d} . Allowing the capital stock to adjust in this way exaggerates enormously the response of wages and rents to the price shocks. We view this assumption to be ahistorical in the extreme, and thus we ignore it in what follows.

Although the economic intuition of the standard model may be obvious, the framework is far too simple for empirical analysis of the late nineteenth century. In fact, capital was an input into agriculture as well as manufacturing (giving the analysis more of a Heckscher-Ohlin-Samuelson flavor); nontraded sectors were important in both countries; the United States was “large” in the world market for cotton; outputs from one sector could be used as inputs into another; and rural-urban wage gaps were substantial. Equally important, perhaps, these price shocks were large enough to imply that linear approximations (such as the one we have presented) are unlikely to yield reliable solutions.²⁹ Nonlinear solution methods are thus required.

The models we use in this article satisfy these objections. It should also be clear that they are not “black boxes” but rather are derived from the standard models used so freely in the classroom. What follows is a brief statement of the models.

~~There are three sectors in the British model: manufacturing and mining (M), agriculture (A), and services (S). There are three factors of production: land (R), capital (K), and labor (L). Labor comes in two varieties, agricultural and nonagricultural (L_A and L_{NA} respectively), of which more later. In addition, an imported intermediate (I) is used in manufacturing. Production in the three sectors is described by the following (CES) production functions:~~

~~$$M = M(L_M, K_M, I_M) \quad (11)$$~~

~~$$A = A(L_A, K_A, R_A) \quad (12)$$~~

²⁸ The simple model used here ignores the possibility of international capital flows responding to the price shocks implied by commodity-price convergence. In a more detailed working paper (“Were Heckscher and Ohlin Right?”) we allowed for such effects, and they did little to change the results reported here.

²⁹ If we pretend that land and capital are the same factor and attempt to solve a simple 2×2 model using this method, the return to the nonlabor factor actually becomes negative in both countries!

$$S = S(L_S, K_S, M_S) \quad (13)$$

Elasticities of substitution are 0.5 in manufacturing and services and unity in agriculture.³⁰

Migration between country and town is modeled by endowing the economy with "raw" labor (L_A), which is transformed into agricultural and nonagricultural lab, L_{NA} via a constant elasticity transformation function:

$$(L_A L_{NA}) = L(L_R) \quad (14)$$

The elasticity of transformation indicates the extent to which domestic labor migration is sensitive to changes in wages in the two sectors.³¹ Britain imports intermediates and food and exports manufactures. The nominal trade deficit is taken as exogenous. Services are nontraded.

We assume Britain to be a "small" country, in the sense that it cannot influence traded-goods prices, and the commodity-price convergence shocks observed in the previous section are exogenous to the modeled economy. Those shocks, however, are apportioned between the British and American economies by a procedure (see Appendix 2) that recognizes the market power of both the Old World and the New in foreign markets (an innocuous simplification that makes the modeling considerably easier). We shall have more to say about this later. There is a single British consumer, endowed with all factors of production and enough foreign exchange to finance the trade deficit. She consumes food, manufactures, and services, and maximizes a Cobb-Douglas utility function.³² A consumer price index is computed for each simulation, using the consumer's budget shares as weights.

The U.S. model is similar to the British, but some essential amendments have been added. Most importantly, there is an additional fourth sector in the United States that produces intermediates such as cotton and tobacco (I). Production in this sector obeys CES assumptions:

$$I = I(L_I, K_I, R_I) \quad (15)$$

In addition, the data permit a more detailed specification of American manufacturing:

$$M = M(L_M, K_M, A_M, I_M, T_M) \quad (16)$$

³⁰ This follows Williamson, *Did British Capitalism*. Elasticities in the American model are taken from Harley, "The Antebellum American Tariff." They are: unity in the agricultural sectors, 0.45 in manufacturing, and 0.1 in services.

³¹ This specification is standard in applied work. See Harley, "The Antebellum American Tariff"; O'Rourke, "Burn Everything British But Their Coal"; or Rutherford, *General Equilibrium Modeling*. It allows for the reality of endogenous wage gaps. The elasticity of transformation is set to 10 in both models.

³² In other experiments performed for purposes of sensitivity analysis, more general CES utility functions were assumed.

where T represents imported tropical goods, such as rubber and mahogany that are not produced in the United States. (These goods are also consumed.) Furthermore, domestic and imported manufactures are distinguished, and substitute less than perfectly with each other in consumption.³³ The United States exports food, intermediates, and domestic manufactures; and it imports foreign manufactures and tropical goods.

The commodity-price convergence shocks are imposed exogenously on the U.S. economy in the same way as for Britain, with the exception of cotton (as the United States was the world's major producer by far). In all other cases, the commodity-price convergence shocks are apportioned between the two countries according to the following logic. Transport-cost declines affected trade between Europe and the rest of the world (ROW). Production and consumption in Europe and ROW for each good must therefore be calculated for a year as close to 1870 as possible. Given elasticities of supply and demand, the effects of a transport-cost decline in exporting and importing regions can be calculated from the expression

$$X_E(p_E) + X_I(p_E(1+t)) = C_E(p_E) + C_I(p_E(1+t)) \quad (17)$$

where X_E and X_I are production, C_E and C_I are consumption (in the exporting and importing region respectively), and t is the transport cost wedge assumed to have driven the commodity-price convergence observed between 1870 and 1913. Equation 17 states that production and consumption in the exporting region depend on the export price, p_E , and production and consumption in the importing region depend on the import price, $p_E(1+t)$.

The impact of transport-cost declines on commodity price differentials is apportioned between regions in this way in all cases except cotton. The strong general equilibrium forces that characterized the cotton market simply cannot be ignored. Wheat-transport costs declined a lot, leading to a large expansion of U.S. wheat production in response to rising farm-gate prices. In contrast, cotton-transport costs declined only a little. Under "small" country assumptions, the wheat sector should expand at the expense of the cotton sector. But "small" country assumptions certainly do not hold for cotton. That is, U.S. cotton was "king" in a way that neither the United States nor Britain

³³ The rationale and procedure for this are identical to those given in Harley, "The Antebellum American Tariff." In the trade-and-development literature, this is known as the Armington specification. The elasticity of substitution between domestic and imported manufactures is taken to be five. The Armington assumption is not made for British food imports, as food is a more homogenous commodity than manufactured goods.

TABLE 3
THE ESTIMATED IMPACT OF ANGLO-AMERICAN COMMODITY PRICE
CONVERGENCE ON FACTOR PRICES, 1870-1913
(percentages)

Variable	Actual Movement in Factor Prices		Estimated Impact	
	United States	Great Britain	United States	Great Britain
Early Period: 1870-1895				
Nominal returns				
Urban wage	-10.5	+14.2	+6.5	+7.5
Land rent	+19.9	-51.3	+11.7	-34.1
Return to capital	n.a. ^a	n.a.	+2.8	+6.9
Wage-rental ratio	-25.3	+134.4	-4.7	+63.1
R	+213.9		+71.1	
Real returns				
CPI	-31.3	-21.0	+6.4	-2.7
Real urban wage	+30.3	+44.6	+0.1	+10.5
Real land rent	+74.5	-38.3	+5.0	-32.3
Real return to capital	n.a.	n.a.	-3.4	+9.8
Full Period: 1870-1913				
Nominal returns				
Urban wage	+16.8	+30.3	+14.1	+12.0
Land rent	+171.1	-49.5	+28.9	-57.8
Return to capital	n.a.	n.a.	+3.3	+11.1
Wage-rental ratio	-57.0	+158.2	-11.5	+165.4
R	+500.3		+199.9	
Real return				
CPI	-22.2	-11.0	+13.7	-7.8
Real urban wage	+50.1	+46.4	+0.3	+21.4
Real land rent	+248.9	-43.3	+13.4	-54.2
Real return to capital	n.a.	n.a.	-9.2	+20.5

^a n.a. = data not available.

Note: R is the percentage increase in the British relative to the U.S. wage-rental ratio.

were dominant in food or manufactures. Thus, the world price of cotton must rise by enough to maintain U.S. production at levels consistent with world cotton-textile production. For these reasons, U.S. market power in cotton must be explicitly modeled, even if that is not required for the other tradables. Briefly, we proceed in the following way: a "tariff" is imposed on U.S. cotton exports representing its transport costs; once abroad, American cotton must face a constant elasticity demand function, forcing a new equilibrium.³⁴

The American model is estimated for 1869, chiefly using census data and the work of Robert Gallman and Thomas Weiss.³⁵ The British model is estimated for 1871, largely based on census data and the work

³⁴ The "tariff" revenue accrues to the American consumer, on the assumption that transport revenues accrued to American shipping interests. It would be a simple matter to let them accrue to foreign shipping interests; in any case, the amounts involved are too small to affect the results.

³⁵ Gallman, "Commodity Output" and "The United States Capital Stock"; and Gallman and Weiss, "The Service Industries."

~~of Phyllis Deane, W. A. Cole, Charles Feinstein, and Williamson.³⁶ Full details on the models' empirical implementation are given elsewhere.³⁷~~

ESTIMATING ANGLO-AMERICAN FACTOR-PRICE CONVERGENCE EFFECTS

The results of the counterfactual analysis are summarized in Table 3. The table offers estimates of the impact of commodity price convergence on Anglo-American factor prices for both the earlier years (1870 to 1895) as well as the full period (1870 to 1913). The table also reports actual movements in factor prices.³⁸ In what follows, we first discuss the effect of commodity-price convergence alone, and then ask what share of the observed movements in factor prices can be attributed to these Heckscher-Ohlin forces.

Although the model was never designed to predict the behavior of the general price level and other monetary events, it may still help clarify tales of factor-price convergence if we start by looking at nominal returns to the three factors and compare the results in Table 3 with those arising from the simple sector-specific factor model discussed in the previous section. A big difference between the models is that now capital is used in agriculture as well as in manufacturing. Thus, the return to capital in the United States does not collapse as before, and land rents do not change as dramatically either. As before, nominal wages increase moderately in both countries.

What about real wages? As we indicated in the introduction, the Anglo-American (urban-unskilled-worker) real-wage gap declined from 67 percent in 1870 to 44 percent in 1895. Table 3 implies that commodity-price convergence forces by themselves reduced the wage gap to 51.3 percent in 1895. That is, the forces of commodity-price convergence can explain two-thirds of the decline in the real-wage gap over the quarter century ending in 1895 ($[(67 - 51.3) / (67 - 44)] = .68$). Between 1870 and 1913, the real-wage gap actually declined from 67 to 54 percent. Table 3 implies that the forces of commodity-price convergence alone eroded the gap from 67 to 38 percent over the full period. Thus, Heckscher-Ohlin forces by themselves would have produced a far bigger Anglo-American real-wage convergence than the actual real-wage convergence observed, confirming the view that the effects of superior American industrial performance were dominant after 1895. Commod-

³⁶ Deane and Cole, *British Economic Growth*; Feinstein, *National Income*; and Williamson, *Did British Capitalism*.

³⁷ O'Rourke and Williamson, "Were Heckscher and Ohlin Right?" appendix 3.

³⁸ The actual movements in factor prices were calculated by taking fitted values from regressions of nominal wages and cost of living indices in the two countries on time and time squared. The same procedure was applied to British nominal farm rents but not to U.S. farm rents. U.S. rents are only available at census dates prior to 1910. Here, we accept the observation for 1870, obtain a figure for 1895 by interpolation, and take the average for 1912–1914 as the 1913 observation. The data underlying these calculations are available on request, but they are taken from Williamson, "The Evolution of Global Labor Markets"; and O'Rourke, Taylor, and Williamson, "Land, Labor, and the Wage-Rental Ratio," appendix table 1.

ity-price convergence played a significant role in fostering real-wage convergence up to 1895—just as Heckscher and Ohlin predicted—and in muting the powerful divergence forces set in motion by Edwardian industrial failure in Britain and Chandlerian industrial success in America.³⁹

Commodity-price convergence would have raised nominal wages in each country by approximately the same rate. When cost of living implications are taken into account, however, we see the substantial rise in relative British real wages already noted. Table 3 offers support for the importance that contemporaries attached to food in determining living standards of European workers.⁴⁰ After all, food was an important part of the household budget during this period. The share of wheat (bread and flour) in workers' budgets was about 16 percent; the share of meat and animal fats (beef, mutton, bacon, butter) was about 30 percent.⁴¹ This implies that commodity-price convergence, by reducing the cost of food in Britain relative to that of the United States, reduced relative British cost of living and hence increased relative British real wages. The impact of manufactured tradable prices, rising in Britain relative to the United States, would, of course, have had the opposite effect, but such items constituted a much smaller share of workers' budgets. For example, clothing accounted for 12 percent of workers' budgets. The model's consumer price index (CPI) calculations also take into account the rise in nontradable service prices (bigger in the United States than in Britain) generated by commodity-price convergence.

What about real rents on farm land? Commodity-price convergence served to raise real land rents in the United States by 13.4 percent over the four decades, helping explain at least some of the rise in farmland values, of which so much has been made by American economic historians. Meanwhile, on the other side of the Atlantic, the same events

³⁹ These conclusions about trends in the Anglo-American real-wage gap induced by commodity-price convergence are robust to assumptions made about the various elasticities embedded in the model. Experiments were performed for the full period, letting substitution elasticities in both production and consumption range between 0.25 and 4; letting the elasticity of transformation in the migration function decline to 0.25; and letting the Armington elasticity of substitution between home and imported manufactures for the U.S. consumer equal 10 rather than 5. (Details are available on request.) The only factor prices that showed much sensitivity to these experiments were land rents in Britain and returns to capital in the United States. Even here, however, the main conclusions of the paper were unaffected.

⁴⁰ This is one reason why during the debate in England the Corn Laws were called a "bread tax" on labor. This might be a good place to point out that the U.S. cost of living index used to deflate nominal wage rates is a midwestern CPI. The "actual" U.S. real-wage trends in Table 3 thus apply to urban unskilled workers in the Midwest, where grain prices were rising in response to transport improvements to the interior. In contrast, unskilled workers in eastern cities presumably benefitted from lower food prices. We hope to examine the U.S. regional dimensions of commodity-price convergence in future work. That is, how much of regional per capita income convergence since the Civil War can be explained by the same Heckscher and Ohlin forces being assessed here for Anglo-America in the late nineteenth century?

⁴¹ Williamson, *Did British Capitalism*, p. 221, 1877–1891 budgets.

served to reduce real land rents in Britain by an enormous 54.2 percent, precipitating a great agricultural depression, of which so much has been made by British economic historians.

Commodity-price convergence led to an even greater rate of wage-rental convergence than was true of either wages or rents separately. This is hardly a surprise, given that both numerator and denominator were converging. The British wage-rental ratio rose in fact by 158.2 percent over the period, whereas the U.S. ratio fell by 57 percent; the British ratio thus rose relative to the American ratio by 500.3 percent. Table 3 implies that commodity-price convergence by itself would have raised the British relative ratio by 199.9 percent (the British ratio rising 165.4 percent and the U.S. ratio falling 11.5 percent). Commodity-price convergence can account for all of the rise in the British ratio (165.4 versus 158.2), for about a fifth of the fall in the U.S. ratio (-11.5 versus -57.0), and for about four-tenths of the relative rise in the British ratio (199.9 versus 500.3).

In addition, note that commodity-price convergence tended to erode U.S. capital scarcity. In real terms, returns to capital in the United States fell by 9.2 percent over the full period in response to these Heckscher-Ohlin events, whereas they rose in Britain by 20.5 percent.⁴²

Finally, consider how much more important commodity-price convergence was in accounting for British factor-price trends than it was for U.S. factor-price trends. Over the four decades as a whole, commodity-price convergence accounted for the entire decline in British (deflated) rents, for the entire rise in the British wage-rental ratio, and for almost half of the rise in British real wages. The impact was much smaller for the United States, about a fifth of the fall in the wage-rental ratio. Some of the difference in impact is likely to be explained by the fact that we have understated the convergence of farm-product prices by ignoring the eroding gap between farm-gate and Chicago or Cincinnati markets. Some of the difference may also be explained by the fact that Britain was a far less dynamic economy. Thus, it seems inevitable that trade should have had a far bigger impact on the evolution of British factor prices than on the evolution of factor prices in North America, where endowments and technologies were changing more rapidly.

A RESEARCH AGENDA

These are only tentative findings, but the impact of Anglo-American commodity-price convergence on factor-price convergence is much too large to expect that ongoing improvements to the database are likely to

⁴² This result follows from two sources: commodity-price convergence helped manufacturing in Britain and hurt it in the United States; and manufacturing was relatively capital intensive. The implications of this result for trans-Atlantic capital flows is discussed in our working paper, "Were Heckscher and Ohlin Right?"

change them. It appears that Heckscher and Ohlin were right. Trade did have a powerful impact on factor prices, living standards, and income distribution in the United States and in Britain in the late nineteenth century.

What about the rest of the New World? Were the same forces at work in Australia and Argentina? And what about the rest of the Old World? Were the factor-price influences more modest on the Continent, where tariffs were thrown up in the face of the New World grain invasion? And what about the interwar interruption in real-wage convergence? Do these results for the late nineteenth century suggest that a significant share of the interwar cessation in long-run real-wage convergence can be explained by the disintegration of world-commodity markets? Can a significant portion of the convergence that resumed after World War II also be explained by a resumption of commodity-price convergence? And what about regional convergence *within* the United States from the 1870s to the 1990s? Did interregional trade have the same impact here?

These are exciting questions, but for the moment we have enough evidence from the late nineteenth-century Anglo-American economies to suggest that Heckscher and Ohlin were absolutely right when they were cultivating the factor-price-equalization theorem just after World War I. What we need now are more price histories documenting commodity-price convergence in the late nineteenth century, its likely cessation during the interwar years, and its resumption after 1950.

Appendices

APPENDIX 1: ANGLO-AMERICAN TRADABLE PRICE DATA

~~Three major sources have been used to document U.S. and British prices from 1870 to 1913: U.S. Congress, *Wholesale Prices, Wages, and Transportation* (also known as the "Aldrich Report"); U.S. Department of Labor, *Wholesale Prices 1890-1922*; and Sauerbeck, "Prices of Commodities" (a once-yearly summary of prices for 56 commodities in England, compiled by Sauerbeck). Before 1892, the prices for the commodities listed by Sauerbeck are also quoted in the Aldrich Report. Other sources used are given below.~~

~~Average annual prices are used throughout. The prices in Sauerbeck and *Wholesale Prices 1890-1922* are reported as yearly averages. In the Aldrich Report, if yearly quotes were available, they were used directly. However, a number of price series reported in Aldrich give four quotes for each year, usually for January, April, July, and October. In such cases, an average of the four quotes was used.~~

~~All prices in Aldrich before the return to gold in 1879 are given in greenback (paper) dollars. To ensure comparability with British prices, the Aldrich prices for 1870 to 1878 have been converted to gold-dollar prices, using the dollar price of gold in Kindahl, "Economic Factors in Specie Resumption," table 2.~~

~~For Sauerbeck prices, the Aldrich Report gives both the original price quotes and a price converted to U.S. gold dollars per unit. The implied conversion factors from the~~

Aldrich Report are used to make the English Sauerbeck prices taken from the *Journal of the Royal Statistical Society* compatible with U.S. prices.

Special care has been taken to ensure the comparability of each pair of U.S. and British commodities for which prices are quoted. The details can be found in O'Rourke and Williamson, "Were Heckscher and Ohlin Right?" appendix 1.

APPENDIX 2: APPORTIONING PRICE SHOCKS

Obviously, a decline in transport costs raises prices in the exporting region and lowers prices in the importing region. But did the convergence of Anglo-American prices due to the decline in transport costs in the late nineteenth century impact more on British or American prices? The answer clearly depends on the elasticities of supply and demand in the two regions.

Let X_E and X_I represent production of the good in question in the exporting and importing regions respectively; let C_E and C_I be consumption of the good in the two regions; let p_E be the price of the good in the exporting region; and let t be the transport cost wedge between prices in the two regions. Thus, the price in the importing region equals $p_E(1 + t)$. If the two regions together comprise the whole world, or if there is no trade in this good between these two regions and the rest of the world, then it has to be the case that

$$X_E[p_E] + X_I[p_E(1 + t)] = C_E[p_E] + C_I[p_E(1 + t)] \quad (18)$$

Totally differentiating this expression, we obtain (after some simple manipulation):

$$\epsilon_E^S X_E dp_E/p_E + \epsilon_I^S X_I [dp_E(1 + t)/p_E + dt] = \epsilon_E^D C_E dp_E/p_E + \epsilon_I^D C_I [dp_E(1 + t)/p_E + dt] \quad (19)$$

where dt is the (negative) change in the transport-cost wedge.

It is a simple matter to calculate the effects of a decline in transport costs on prices in the exporting and importing regions. Defining units such that the initial p_E equals one, the percentage change in the export region price is simply dp_E ; the percentage change in the import region price is $dp_E(1 + t) + dt$. Therefore, we need only use equation 19 to calculate what dp_E must be, given dt .

To do this we need the following data: quantities of the good produced and consumed in the importing and exporting regions and the elasticities of demand and supply in the two regions.

What are the relevant regions? This is clearly a matter of judgment. If we accept that the major goods flows were of food and raw materials into Europe and exports of manufactures from Europe, and if we consider that the major impact of transport-cost decline during this period was to reduce transport costs between Europe and the rest of the world, then it makes sense to take Europe and the rest of the world (or perhaps Europe and the frontier economies) as the two regions. This certainly seems to make more sense than to only look at Britain and the United States.

We take Europe and the rest of the world as the two relevant regions in equation 19. Thus, for food and raw materials, the importing region is Europe, and the exporting region is the rest of the world. For manufactures, Europe is the exporting region, and the rest of the world is the importing region. In what follows, we indicate the sources of the data used to infer the incidence of the price shock. These data (and hence the apportioning of shocks) are, of course, rough, but they should serve to offer a plausible intermediate case to the upper and lower bounds reported in the text.

The transport cost wedges in 1870, 1895, and 1913 are given in the following table. I , M , and F stand for cotton, manufactures, and food respectively. We calculate transport cost shocks for both 1870 to 1895 and 1870 to 1913. In all cases, initial wedges are 1870 wedges; thus, the figures that follow can be used to calculate the relevant dt .

Because the composition of U.S. exports was not identical to that of U.K. imports, and vice versa, the transport-cost wedge for food and manufactures will look different from the U.K. and U.S. perspectives. It makes sense to use the U.S. food exportable wedge when calculating the change in the U.S. food export price, and to use the U.K. food importable wedge when calculating the change in the U.K. food price; we do the same for manufactured goods.

Year	US EX.I	US IM.M	US EX.F	UK IM.I	UK EX.M	UK IM.F
1870	0.133	0.566	0.519	0.133	0.313	0.568
1895	0.112	0.347	0.330	0.112	0.146	0.360
1913	0.097	0.089	0.106	0.097	0.026	0.114

Food

We take wheat to be the prototypical food because it bulked so large in world trade and because the data are readily available. In millions of imperial quarters, production was 145 in the exporting regions and 123 in the importing regions. Consumption was 124.4 in the exporting regions and 143.6 in the importing regions (Harley, "Transportation, the World Wheat Trade and the Kuznets Cycle," table 5, p. 228). The elasticity of demand was taken to be -0.3 , and the elasticity of supply, 1.0 (Harley, "Late Nineteenth Century Transportation," p. 604).

Over the period 1870 to 1895, the foregoing data imply a change in the European price of -0.0857 , and a change in the U.S. price of 0.0720 . Over the period 1870 to 1913, the change in the European price was -0.1870 , and the change in the U.S. price was 0.1578 .

Manufactures

According to Paul Bairoch, Europe accounted for 61.3 percent of world manufacturing output in 1880. Britain accounted for 22.9 percent of the world total (Bairoch, "International Industrialization Levels," table 10, p. 296). Output in British manufacturing, mining, and building amounted to £395.9 million in 1881, or \$1,926.7 million (Deane and Cole, *British Economic Growth*, table 37, p. 166). This implies a world output of \$8,413.5 million, a European output of \$5,157.5 million, and a non-European output of \$3,256.0 million.

According to Yates (*Forty Years of Foreign Trade*, table A20, p. 228), European exports of manufactures amounted to \$2,155 million over the period 1876 to 1880; European manufactured goods imports amounted to \$1,005 million over the same period. These figures include intra-European trade. However, when calculating net exports for Europe as a whole, these internal flows will cancel out: European net exports were thus \$1,150 million over the period. This implies a European consumption of manufactures of \$4,007.5 million and a non-European consumption of \$4,406 million.

We have not been able to find good estimates of supply and demand elasticities for the manufacturing sector as a whole. The best alternative seems to be to adopt the elasticities embodied in the models used here. As demand is assumed to be Cobb-Douglas, the demand elasticity is -1.0 . Starting from the benchmark equilibrium of the British model, when the price of manufactures is increased by 10 percent, the output of British manufactures rises by 11.9 percent, implying a supply elasticity of 1.19 . This implied supply elasticity is assumed to hold for both countries in assigning incidence of the price shock.

The price shocks implied by the above data are:

U.K., 1870-1895: $+0.0658$

U.K., 1870-1913: $+0.1131$

U.S., 1870-1895: -0.0961

U.S., 1870-1913: -0.2094

Cotton

~~We treat the apportionment for cotton prices differently, and the reader can find that discussion in the text.~~

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