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WERE HECKSCHER AND OHLIN RIGHT?
PUTTING THE FACTOR-PRICE-EQUALIZATION THEOREM BACK INTO HISTORY

Kevin O'Rourke

Jeffrey G. Williamson

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ABSTRACT

Due primarily to transport improvements, commodity prices in Britain and America tended to equalize 1870-1913. This commodity price equalization was not simply manifested by the great New World grain invasion of Europe. Rather, it can be documented for intermediate primary products and manufactures as well. Heckscher and Ohlin, writing in 1919 and 1924, thought that these events should have contributed to factor price equalization. Based on Williamson's research reported elsewhere, Anglo-American real wages did converge over this period, and it was part of a general convergence between the Old and New World. This paper applies the venerable Heckscher-Ohlin trade model to the late 19th century Anglo-American experience and finds that they were right: at least half of the real wage convergence observed can be assigned to commodity price equalization. Furthermore, these events also had profound influences on relative land and capital scarcities. It appears that this late 19th century episode was the dramatic start of world commodity and factor market integration that is still ongoing today.

Kevin O'Rourke
615 Uris Hall
Graduate School of Business
Columbia University
New York, NY 10027

Jeffrey G. Williamson
Department of Economics
Harvard University
Cambridge, MA 02138
and NBER

> The immediate result ofinterregional 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 Ohlin [1924] in Flan and Flanders [1991], pp. 91 and 181.)

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. The Heckscher-Ohlin paradigm has it that countries export commodities which use intensively the factors in which they are well endowed while they import commodities which use intensively the factors in which they are poorly endowed. Thus, commodity trade acts as if to equalize factor 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 where wide differences existed before. 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 which exploit their favorable factor endowment. The demand for the abundant and cheap factor booms while 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 very familiar with the small open economy. Indeed, when Heckscher was writing in 1919 and Ohlin in 1924, they were motivated by the commodity price equalization trends which they thought had taken place between Old World and New in the late 19th century (see the new translation edited by Flam and Flanders, 1991). 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 Sweden) and raise it in the New World (like America). Britain and the Scandinavian countries did not respond to the challenge with tariffs, although countries on the continent did (Kindleberger, 1951). What occurred in the late 19th century was exactly the kind of exogenous relative price shock which is supposed to set factor-price equalization in motion. Britain, Scandinavia and other Old World countries in the free trade zone had plenty of labor and little land, while America in the New World had the opposite. Thus, in 1870 the New World had high real wages and low farmland rents while the Old World had the opposite. According to the factor-price-equalization theorem, the invasion of grains should have raised real wages in the Old World free-trade zone while lowering them in the New World, <u>ceteris paribus</u>. 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 which motivated Heckscher and Ohlin in the first place -- the late 19th century. This odd state of affairs is all the more surprising given the attention which economic historians have devoted to the grain invasion, the decline in transport costs, and the convergence of prices internationally in the forty years or so following 1870.

There is another stream of literature which is relevant to the issues raised in this paper. For some time now, economists and historians have both been intrigued by comparative growth performance over the past century or so, manifested, in Moses Abramovitz's (1986) words, by catching up, forging ahead and falling behind. This recent literature has its antecedent with Alexander Gerschenkron's (1952) latecomer hypothesis, but it was reawakened with the appearance of Productivity and American Leadership by William Baumol and his collaborators (1989), by the even more recent appearance of Gavin Wright's (1990) work on US industrialization around the turn of the century, and by the emergence of what has come to be called the "new growth theory".

A recent paper by one of the present authors (Williamson, 1992) constructed a purchasing-power-parity adjusted urban unskilled real wage data base for 15 countries over the very long run. The 1870-1913 evidence is summarized in Figure 1 by a coefficient of variation, C(15), and it documents considerable convergence. Furthermore, the late 19th century real wage convergence is similar in magnitude to the better-known convergence during the great "Keynesian boom" after World War II. Perhaps most interesting, however, is the finding that most of the late 19th century real wage convergence was attributable to an 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). Around 1870, real wages in the labor scarce New World (Argentina, Australia, Canada and the USA) were much higher than in the labor abundant Old World (Ireland, Great Britain; Denmark, Norway, Sweden;

Germany; Belgium, Netherlands, France; Italy and Spain), about 136 percent higher. 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 twenty-five years, and by 49 percent over those forty-three years. The Old World caught up a bit with the New. While it was much less dramatic, what was true of Old and New World was also true of the two countries which best represented each: in 1870, real wages in the USA were 67 percent higher than in Britain while 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 twenty-five years, and by 13 percentage points over those forty-three years. Britain caught up a bit with the United States, a surprising finding given all that has been said about Britain losing her leadership to America (although it must be said that all of the British "catch up" took place prior to 1895, not afterwards, when American industrial ascendacy was most dramatic). Furthermore, the wage-(farm land) rental ratio doubled in Britain while it halved in America.

This paper links the factor-price equalization literature with the convergence literature. It asks: How much of the Anglo-American real wage convergence between 1870 and 1895 or 1913 can be explained by the convergence in commodity prices? Of course, America underwent superior industrial growth during this period (Wright, 1990), a force which should have tended to raise real wages in America relative to Britain. Knowing this, we can ask: By how much did commodity price equalization serve to mute the impact of the relatively superior American industrial performance on Anglo-American real wage gaps? Does the factor-price equalization theorem play a quantitatively significant role during the period of New World grain invasion, a period which motivated Heckscher and Ohlin in the first place?

The paper falls into two parts. The first documents the extent of commodity price equalization during the period, and for aggregate Anglo-American importables and exportables, not just grains. The second estimates the impact which these price shocks had on the British and the US economies, real wages in particular. To this end, computable general equilibrium (CGE) models for the two economies are constructed. 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 the Anglo-American wage gap have diminished? Since the aim of the paper is to assess whether commodity market integration would have led to some considerable real wage convergence even in the absence of factor flows, we shall assume initially that labor and capital were not mobile internationally. These assumptions about factor mobility can, of course, be progressively relaxed in just the way that Ohlin wanted to but couldn't in his formal analysis (Flam and Flanders, 1991, p. 22).

The British and the US models will be kept simple. They will explicitly take into account linkages such as the role of New World food as a key wage good in both economies, the role of New World cotton as a key input to manufacturing in both economies, and the role of Old World manufactured exports as they competed with domestic manufactures in US markets. In the tradition of Heckscher and Ohlin, we begin by taking the endowments of capital, labor and land as given. Later in the paper, we explore the impact of international capital flows by taking the returns on capital as determined exogenously (so that these two trading partners can import or export all the capital they wish). In a future paper we intend to explore the impact of labor migration on the real wage gap between Old and New World. Clearly, therefore, the present paper should be viewed as only the first stage in what we hope will become a much longer project.

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 19th century. Douglass North (1958, p. 537) called the decline "radical" both for railroads and ocean shipping. Since the UK imported foodstuffs and raw materials, and since these bulk commodities "were fundamental beneficiaries of the cheapening transport costs" (p. 544), he thought it was clear that it contributed in Britain to "lower priced foodstuffs and therefore rising real wages, and to the lowering in the cost of industrial raw materials" (p. 545) and therefore, we take it, rising rates of industrialization. Although North doesn't say so, symmetry suggests that real wages must have been lowered in the US while 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 US general price index, North's freight rate index along American export routes in Table 1 drops by more than 41% between 1870 and 1910. His wheat-specific American East Coast freight factor (percent share of freight costs in CIF value) fell by even more between 1870 and 1913, about 53%. The older Isserlis index (which includes many other non-Atlantic trade routes) displays a less spectacular decline up to 1913, about 25%. Similar evidence is offered in Figure 2 based on Knick Harley's (1988) British overseas coal freight rates. All in all, Table 1 and Figure 2 would appear to support North's choice of the word "radical" in describing the decline in transport costs linking US and British commodity markets, even though the table ignores the even more pronounced decline in transport costs into the interior of each nation due to the railroads. Writing in 1924, Edwin Nourse thought these forces threw British farming "which had been in orderly retreat for over fifty years ... into a rout" (Nourse, 1924, p. 19).

There were other forces at work, however, which should have influenced the evolution of Anglo-American price differentials after 1870 -- the slow erosion in the height of American Civil War tariffs. The ratio of duties to dutiable imports fell from 47% in 1870 to 42% in 1910; and as a ratio to total imports, it fell from about 45% to 21% (US Department of Commerce, 1975, p. 888). Since the US 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 US tariffs after 1870 should have served to aid commodity price equalization on manufactured goods, not just on primary products.

<u>Grain Market Integration</u>

In assessing the "radical" decline in overseas freight rates, the cost-reductions along the rails between Chicago and New York, or the erosion in Civil War tariffs, what mattered, of course, was its impact on the price convergence of tradables. By how much, for example, did these forces raise the price of foodstuffs in the US (like wheat, flour, meat and animal fats) and lower them in Britain? Almost without exception, the literature has explored the question by looking at the grain market. This is certainly true of Charles

Kindleberger's (1951) important contribution to the debate over the Old World defensive policy response to the grain invasion, and it is also true of Knick Harley's writings on late 19th century transport, trade and settlement in the New World (Harley, 1980, 1986). Thus, we start there.

Figure 3 documents the behavior of wheat prices quoted in three markets: Liverpool, New York, and Chicago. As Appendix 1 reports, these are dollar prices per bushel for American #2 winter wheat (Harley, 1980, pp. 246-7, with interpolation for early years in Chicago). Liverpool prices exceeded Chicago prices by 60.2% in the three years centered on 1870, they exceeded Chicago prices by 25.9% in the three years centered on 1895, and by 14.2% in the three years centered on 1912. While the rest of this paper will try to isolate the full general equilibrium effects of this massive price shock, the effect on Anglo-American real wage differentials through the cost of living was likely to have been large by itself. Since the share of wheat in the workers' budgets was about 16% (bread and flour: Williamson, 1985, p. 221, 1877-91 budgets), then Anglo-American real wage differentials would have declined about 7 percentage points between 1870 and 1912 due to wheat price convergence alone (.16x[.602-.142]=.0736). The share of meat and animal fats (beef, mutton, bacon, butter) in workers' budgets was about 30%, and if the Anglo-American price differentials for meat and animal fats declined by as much as wheat, then the figure would be augmented by about another 14 percentage points (.30x[.602-.142]=.138), for a total of 21 percentage points. Of course, the impact of manufactured tradable prices, presumably rising in Britain relative to America, would have had the opposite influence, but such items like clothing were a smaller share in workers' budgets (12%). In addition, we do not yet know what happened to trends in Anglo-American price differentials for non-tradable services (28% of the budget), or for other foodstuffs like sugar, tea and coffee. Therefore, the foodstuff price calculations are only a crude and incomplete first pass, and they totally ignore the employment effects central to the factor price equalization theorem, but they certainly suggest that Anglo-American commodity price equalization holds promise in accounting for a significant share of the real wage convergence which took place between 1870 and World War I.

Commodity Market Integration More Generally

Figures 3 and 4 plot the classic experience with Anglo-American price convergence for wheat. Figure 3 offers wheat price time series for Liverpool (the main British port of entry for American grain), Chicago and New York. Figure 4 plots the percentage price differentials for Chicago and New York, both relative to Liverpool. Thus, in 1870 wheat prices were more then 60 percent higher in Liverpool than in Chicago, while they were almost 20 percent higher than in New York. The price differentials diminished up to World War I, although the decline was more dramatic over the first two decades. Wheat (and flour) was a large share of US exports in 1880, 27.4%, and it was also a large share of British imports in the same year, 15.3%, so unless other US exportables and British importables had very different price behavior these trends in Figure 4 are likely to appear more generally.

Was the experience in Anglo-American wheat markets repeated for other foodstuffs? The second biggest foodstuff tradable consisted of meat and animal fats (e.g., beef, pork, bacon, mutton, and butter): its share in US exports in 1880 was 18.3%, and in UK imports 9.3%. Figure 5 plots Anglo-American price differentials for this foodstuff. The series fluctuates widely, but figures implied by the estimated trend line suggests the following: meat price differentials between London and Cincinnati were higher than for wheat in 1870, about 93%; convergence up to 1895 was modest; but convergence over the full 43 years was, if anything, even more pronounced than that for wheat, price differentials declining from about 93% in 1870 to about 18% in 1913. Thus, there is certainly evidence of meat price convergence over the four decades as a whole.

What might come as a surprise even to the specialist is the impressive size of the price convergence for manufactures. We have been able to secure adequate information over the period as a whole only for cotton textiles and iron products. While textiles and iron and steel products accounted for a large share of both US imports and UK exports of manufactures, we would be happier if we had more comprehensive price information on Anglo-American trade in manufactures. The two items we can document are plotted in Figures 6 and 7. They exhibit striking convergence between 1870 and World War I, approximating those already seen for wheat and meat. Using the predictions from the trend regressions, the cotton textile price differential between Boston and Manchester falls from about 14% in 1870 to about 1% in 1913, while the average iron products' price differential between Philadelphia and London falls from 80% to 20% over the 43 years.

There is, however, an important and atypical case -- raw cotton. This key intermediate good claimed an important share of Anglo-American trade, 25.7% of 1880 US exports and 10.4% of 1880 UK imports. As Figure 8 suggests, Anglo-American cotton price differentials eroded only very modestly over the late 19th century, from about 13% in 1870 to about 10% 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 19th century.

We have been able to document Anglo-American price differentials for an additional seven tradables (O'Rourke and Williamson, 1992): price convergence was strong for the intermediates including coal, copper, hides, wool and tin; it was mixed for coffee; and modest price divergence was true of sugar. In this paper, however, we take those plotted in Figures 4-8 to be the representative (and large) components of Anglo-American trade.

The next step is to use the 1880 trade weights (O'Rourke and Williamson, 1992) to develop Anglo-American percentage price differentials for six aggregates: US exportable and UK importable foodstuffs (wheat and meat), US exportable and UK importable intermediates (cotton), and US importable and UK exportable manufactures (cotton textiles and iron products). These are used in the factor price equalization analysis which follows. They imply: the price differential on US exportable foodstuffs fell from 51.9 to 10.6%; the price differential on US importable manufactures fell from 56.6 to 8.9%; the price differential on UK importable foodstuffs fell from 56.8 to 11.4%; the price differential on UK exportable manufactures fell from 31.3 to 2.6%; and the price differential on tradable intermediates fell from 13.3 to 9.7% in both countries.

Had there been no other forces at work, the terms of trade between manufactures and foodstuffs must have changed dramatically in both countries. If Britain absorbed all the price shock, her terms of trade would have almost doubled. If America absorbed all the price shock, her terms of trade would have more than halved. These were very big price shocks indeed.

Some departures from the standard textbook case will of course be necessary, but the models will be kept as close to the spirit of Heckscher and Ohlin as possible. The non-traded sector in both economies will need to be modelled; further, the fact that land (a factor of production central to the thinking of Heckscher and Ohlin) is specific to agriculture introduces an element of Ricardo and Viner into the analysis. What follows is a brief statement of the models implemented, while Appendix 3 gives the details.

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 non-agricultural (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:

$$M = M(L_M, K_M, I_M) \tag{1}$$

$$A = A(L_A, K_A, R_A) \tag{2}$$

$$S = S(L_S, K_S, M_S) \tag{3}$$

Migration between country and town is modelled by endowing the economy with "raw" labor (L_R) which is transformed into agricultural and non-agricultural labor via a constant elasticity transformation function:

$$(L_A, L_{NA}) = L(L_R) \tag{4}$$

The elasticity of transformation indicates the extent to which domestic labor migration is sensitive to changes in wages in the two sectors.[1]

Britain imports intermediates and food, and exports manufactures. The trade deficit is taken as exogenous. Services are non-traded. We assume Britain to be a "small" country, in the sense that she cannot influence traded goods prices, and the commodity price equalization shocks observed in the previous section are exogenous to the modelled economy. However, those shocks are apportioned between the British and American economies by a procedure (Appendix 2) which recognizes the market power of both the Old World and the New in foreign markets (an innocuous simplification which makes the modelling considerably easier). We shall have more to say about this below. 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 CES utility function.

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

$$I = I(L_{AI}, K_I, R_I) \qquad (5)$$

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

[1] This specification is standard in applied work; see Harley (1990), or O'Rourke (1991). It allows for the reality of endogenous wage gaps.

$$M = M(L_M,\ K_M,\ A_M,\ I_M,\ T_M) \qquad (1')$$

where T represents imported tropical goods such as rubber and mahogany, not produced in the U.S. (These goods are also consumed.) Furthermore, domestic and imported manufactures are distinguished, and substitute less than perfectly with each other in consumption.[2] The U.S. exports food, intermediates and domestic manufactures, and imports foreign manufactures and tropical goods.

The commodity price equalization shocks are imposed exogenously on the American economy, in the same way as for Britain, with the exception of cotton (where the U.S. was the world's major producer by far). In all other cases, the commodity price equalization 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, and 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

$$X_E(p_E) + X_I(p_I(1+t)) = C_E(p_E) + C_I(p_I(1+t)) \qquad (6)$$

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 equalization observed between 1870 and 1913.

[2] The rationale and procedure for this are identical to those given in Harley (1990). In the trade and development literature, this known as the Armington specification.

The impact of transport cost declines on commodity price differentials is apportioned between regions in this way in all cases but one: there are strong general equilibrium forces that characterized the cotton market which 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 expands but the cotton sector contracts. But "small" country assumptions certainly do not hold for cotton. That is, U.S. cotton was "king" in a way that neither America nor Britain were so 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 modelled, even if it is not required for the other tradables. Briefly, we proceed in the following way: a "tariff" is imposed on U.S. cotton exports representing those transport costs; once abroad, U.S. cotton must face a constant elasticity demand function, forcing a new equilibrium.[3]

The American model is estimated for 1869, chiefly using Census data and the work of Gallman (1960, 1982) and Gallman and Weiss (1969). The British model is estimated for 1871, largely based on Census data and the work of Deane and Cole (1962), Feinstein (1972) and Williamson (1985). Full details on the models' empirical implementation are given elsewhere (O'Rourke and Williamson, 1992), but some summary information can be found in Appendix Tables 1 and 2.

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[3] 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.

ESTIMATING ANGLO-AMERICAN FACTOR-PRICE-EQUALIZATION EFFECTS

The results of the counterfactual analysis are summarized in Table 2. The table offers estimates of the impact of commodity price equalization on Anglo-American factor prices for both the earlier 1870-1895 period as well as the full 1870-1913 period. Furthermore, the table offers estimates under various assumptions: that all of the price shock was absorbed by the U.S. alone; that all of the price shock was absorbed by Great Britain alone; and (the more relevant case) that the incidence of the price shock was shared by the two. What follows will focus on the more relevant "apportioned" case: here, the estimated impact on Anglo-American factor price equalization is very big in all cases.

First consider the Anglo-American urban wage gap. As we indicated in the introduction, the Anglo-American (urban unskilled) real wage gap declined in fact by 23 percentage points up to 1895. Table 2 suggests that about half of that convergence can be assigned to commodity price equalization forces, 10.4 percentage points, under the more relevant assumption of shared incidence. For the full period 1870-1913, commodity price equalization served to reduce the Anglo-American real wage gap by 21.1 percentage points, a figure which exceeds the actual measured convergence over the four decades as a whole suggesting that the effects of the superior American industrial performance was dominant after 1895. The counterfactual impact on the two economies, however, was very different since, relative to the U.S., the contracting agricultural sector in Britain was far less labor intensive compared with the rest of the economy. Britain, it seems, conformed with the Heckscher-Ohlin factor intensity assumptions far better than did America. Nevertheless, commodity price equalization was playing a significant role in contributing to real wage convergence up to 1895, and in muting the divergence effects of superior American industrialization thereafter.

Second, note the big impact on real land rents. These price shocks served to raise land rents in America over the full period by 13.4 percentage points, helping explain the rise in farm land values of which so much has been made by American economic historians. Meanwhile, on the other side of the Atlantic, the same price shocks served to cause British real land rents to decline by an enormous 54.2 percentage points over the four decades as a whole -- a great agricultural depression of which so much has been made by British economic historians. Thus, due to commodity price equalization trends alone, the gap in real land rents between Old World and New collapsed by 67.6 percentage points.

Third, Anglo-American wage-rental ratios converged at an even greater rate, the gap between them falling by 88.7 percentage points. It appears that commodity price equalization accounts for about half of the observed change in Anglo-American relative wage-rental ratios.

Finally, commodity price equalization served to erode relative capital scarcity in America. Compared with the rest of the economy, agriculture was less capital intensive in both America and Britain. Thus, the price shocks served to lower the return to capital in America (where the relative size of agriculture rose) and raise it in Britain (where the relative size of agriculture fell). On net, commodity price equalization served to erode the rate of return gap (which favored "capital scarce" America) by 29.7 percentage points. These results suggest that if world capital markets were perfectly integrated, commodity price equalization must have served by itself to accelerate accumulation in Britain relative to America thus reinforcing real wage convergence. Table 3 suggests, however, that these accumulation forces could have had only a modest impact: an assumption of perfectly elastic world capital flows in response to the price shocks implies that induced real wage convergence up to 1913 would have been 26.3 percent (Table 2) rather than 21.1 percent (Table 3). Thus, our results are robust to assumptions about world capital markets.

A RESEARCH AGENDA

These are only tentative findings but the impact of Anglo-American commodity price equalization on factor price equalization is much too large to expect that ongoing improvements to the data base are likely to change them. We expect that the same is true of proposed modifications in the models -- including efforts to explore what happens when international labor migration is allowed to respond to the price shocks. We shall see whether future research will confirm our optimism.

In any case, 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 19th century suggest that much of the interwar cessation in long run real wage convergence can be explained by the disintegration of world commodity markets? Finally, can a good portion of the convergence which resumed in the post World War II period also be explained by a resumption of commodity price equalization?

These are exciting questions, but for the moment we have enough evidence from the late 19th 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.

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: L. Isserlis, "Tramp Shipping Cargoes and Freights," Journal of the Royal Statistical Society CI, Part I (1938), Table VIII, p. 122, col. (2) divided by Statist price index in the same source, col. (6): North, American Export Routes: D.C. North, "Ocean Freight Rates and Economic Development 1750-1913," Journal of Economic History 43, 4 (December 1958), Table 2, p. 549 divided by US BLS consumer price index, US Department of Commerce, Historical Statistics of the United States (Washington, D.C.: USGPO, 1975), series E-135. North, American East Coast Routes: North, "Ocean Freight Rates," Table 3, pp. 550-2.

Table 2

The Estimated Impact of Anglo-American Commodity Price Equalization on Factor Prices, Without International Capital Flows (Deflated by Cost of Living Index): 1870-1913 (in percent)

Variable	Price shock assumed to be absorbed by:		Price shock apportioned between:		
	United States alone	Great Britain alone	United States	Great Britain	Great Britain minus United States
Early Period: 1870-1895					
Urban wage	+0.1	+23.4	+0.1	+10.5	+10.4
Land rent	+9.3	-45.1	+5.0	-32.3	-37.3
Return to capital	-6.3	+22.1	-3.4	+9.8	+13.2
Wage rental ratio	-9.2	+68.5	-4.9	+42.8	+47.7
Full Period: 1870-1913					
Urban wage	+0.6	+53.3	+0.3	+21.4	+21.1
Land rent	+29.1	-80.8	+13.4	-54.2	-67.6
Return to capital	-18.5	+50.9	-9.2	+20.5	+29.7
Wage rental ratio	-28.5	+134.1	-13.1	+75.6	+88.7

Table 3

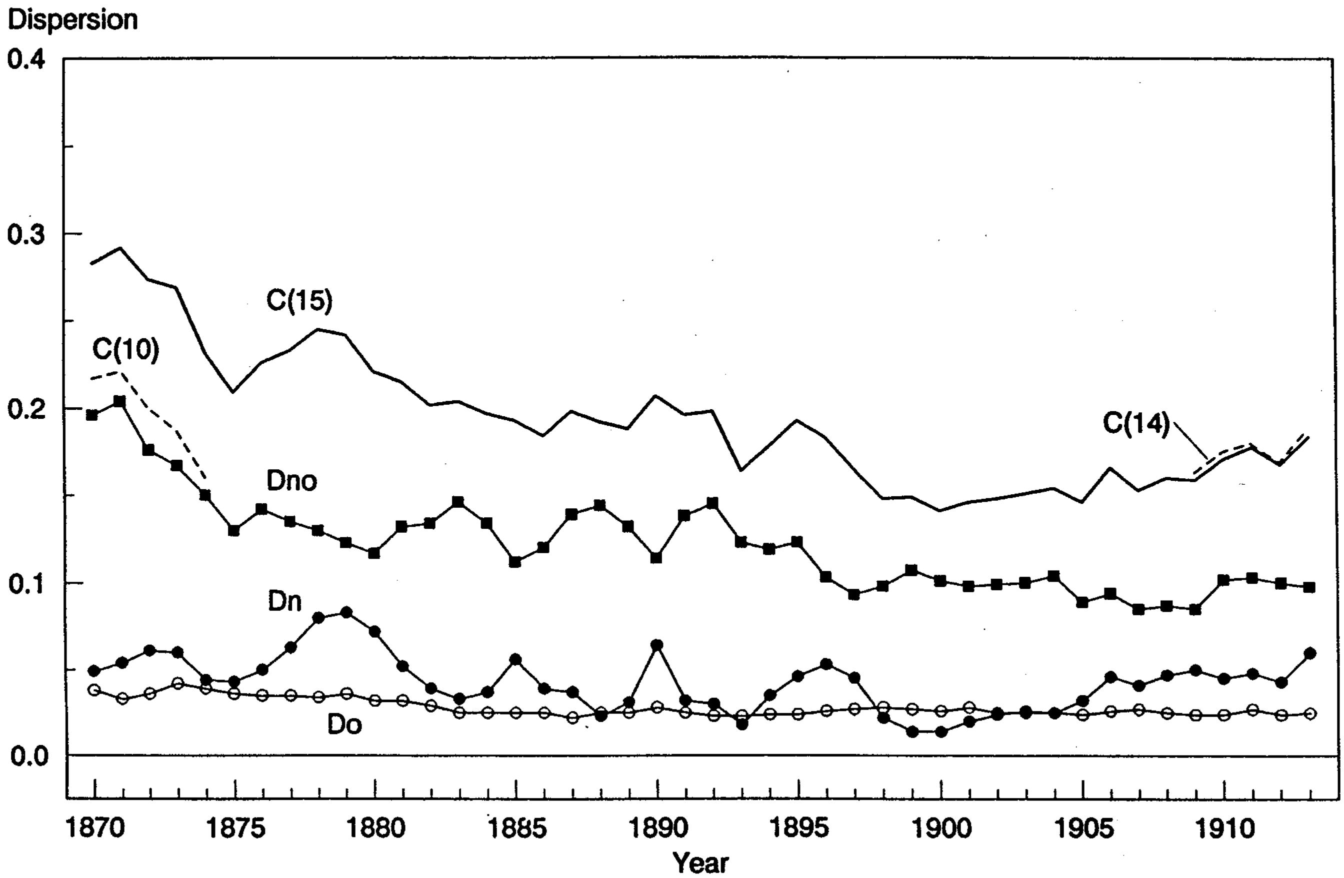
The Estimated Impact of Anglo-American Commodity Price Equalization on Factor Prices, With International Capital Flows (Deflated by Cost of Living Index): 1870-1913 (in percent)

Variable	Price shock assumed to be absorbed by: United States alone	Price shock assumed to be absorbed by: Great Britain alone	Price shock apportioned between: United States	Price shock apportioned between: Great Britain	Price shock apportioned between: Great Britain minus United States
Early Period: 1870-1895					
Urban wage	+2.4	+34.7	+1.2	+14.3	+13.1
Land rent	+9.8	-54.9	+5.2	-32.4	-37.6
Wage rental ratio	-7.4	+89.6	-4.0	+46.7	+50.7
Full Period: 1870-1913					
Urban wage	+3.8	+78.3	+1.7	+28.0	+26.3
Land rent	+30.0	-80.6	+13.6	-54.2	-67.8
Wage rental ratio	-26.2	+158.9	-11.9	+82.2	+94.1

Note: The nominal return to capital is fixed exogenously in these experiments.

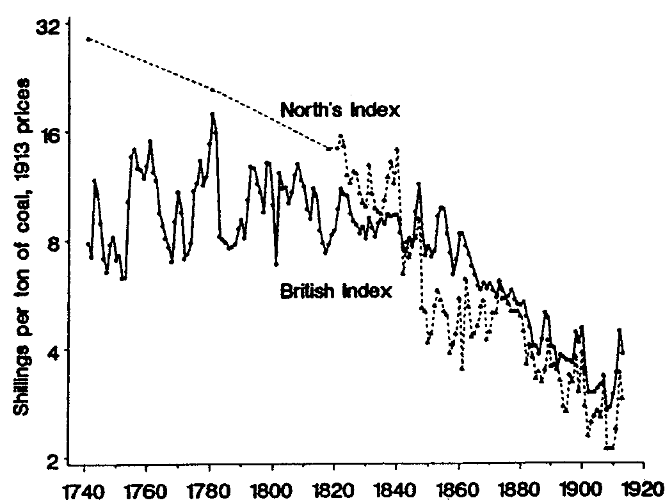
FIGURE 1

International Real Wage Dispersion, 1870-1913



Source: Williamson (1992).

FIGURE 2



FREIGHT RATE INDICES, 1741–1913
(deflated by U.K. GNP Deflator, Ratio Scale)

Source: Harley (1988), p. 853.

FIGURE 3

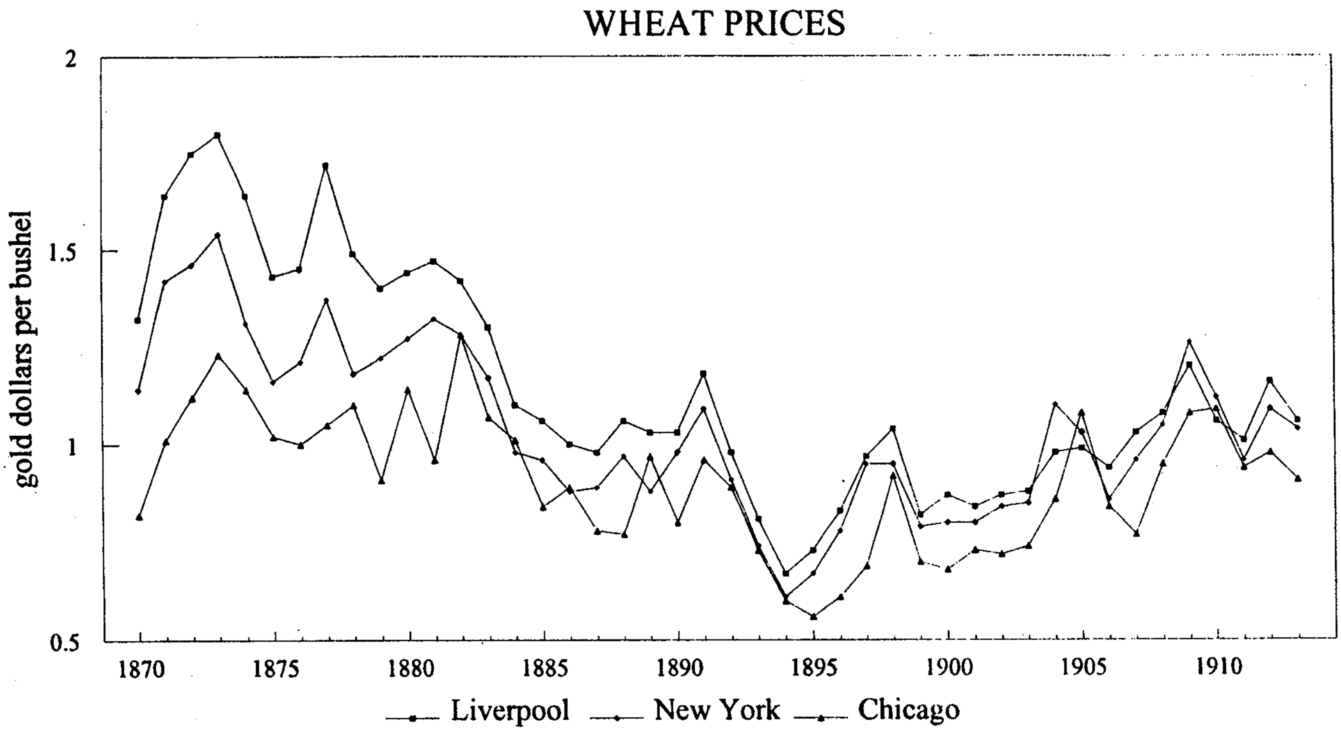


FIGURE 4

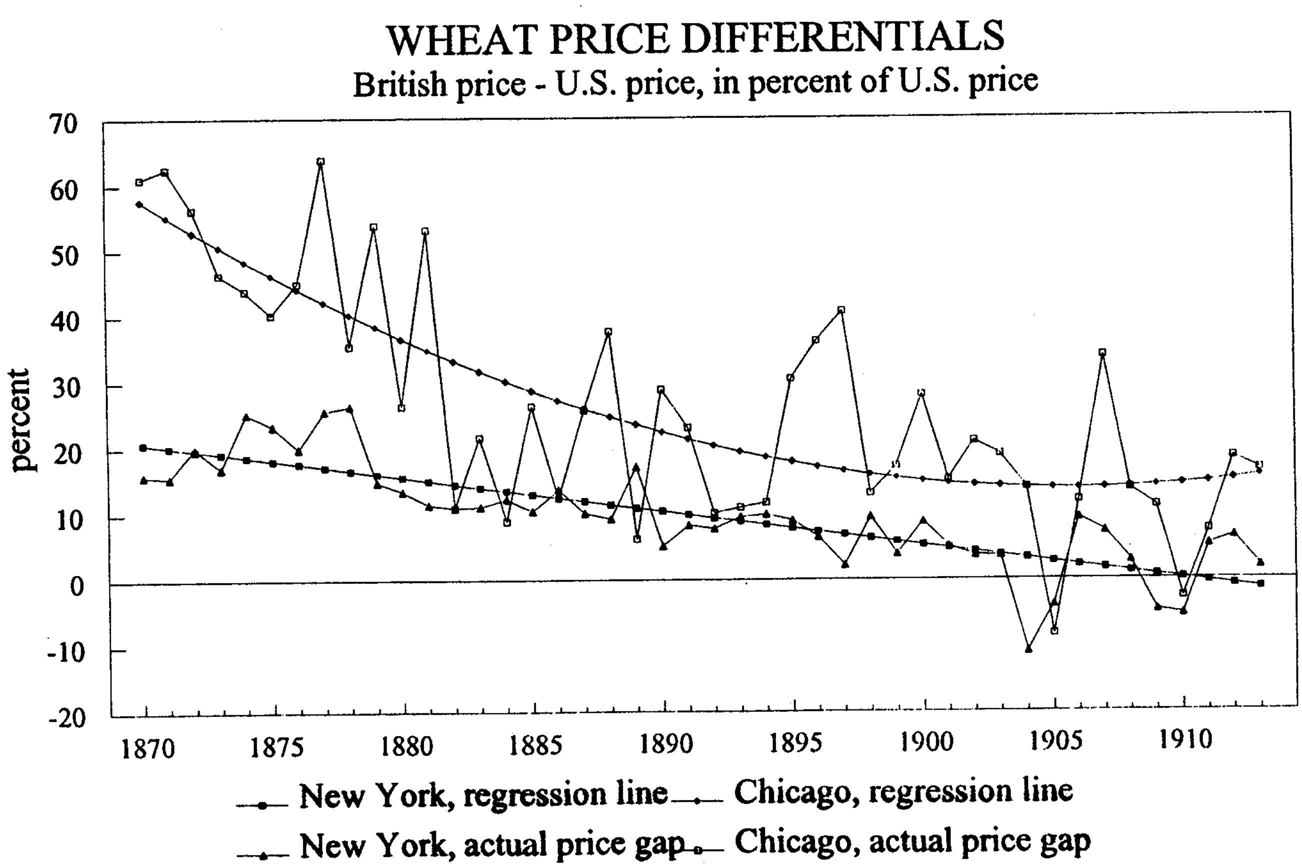


FIGURE 5

MEAT PRICE DIFFERENTIALS

British price - U.S. price, in percent of U.S. price

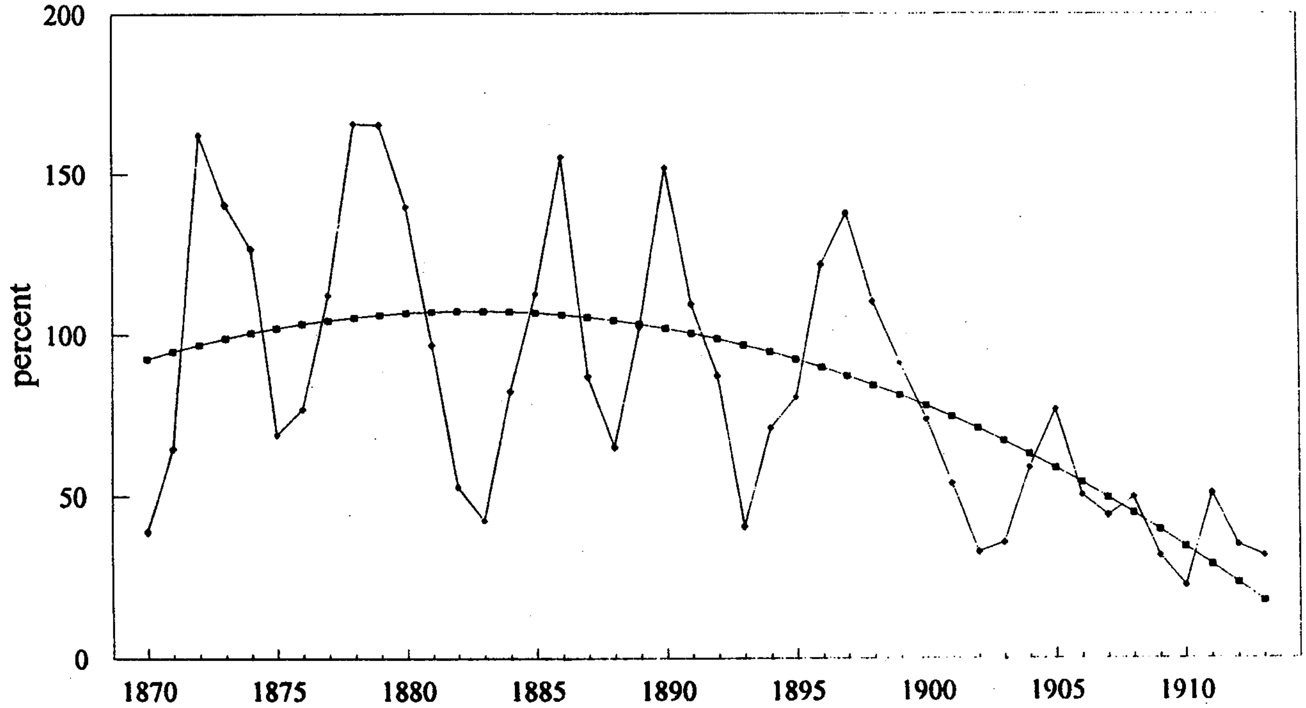


FIGURE 6

COTTON CLOTHS PRICE DIFFERENTIALS

U.S. price - British price, in percent of British price

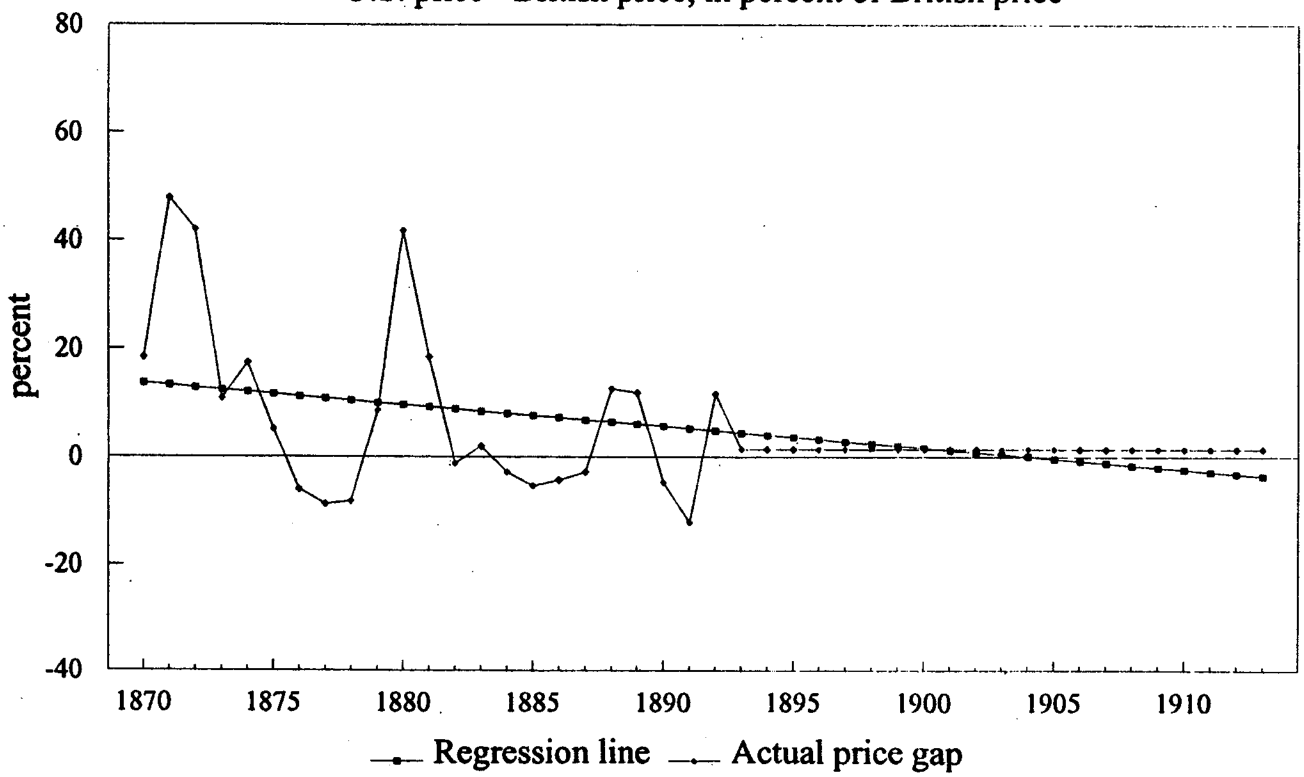


FIGURE 7

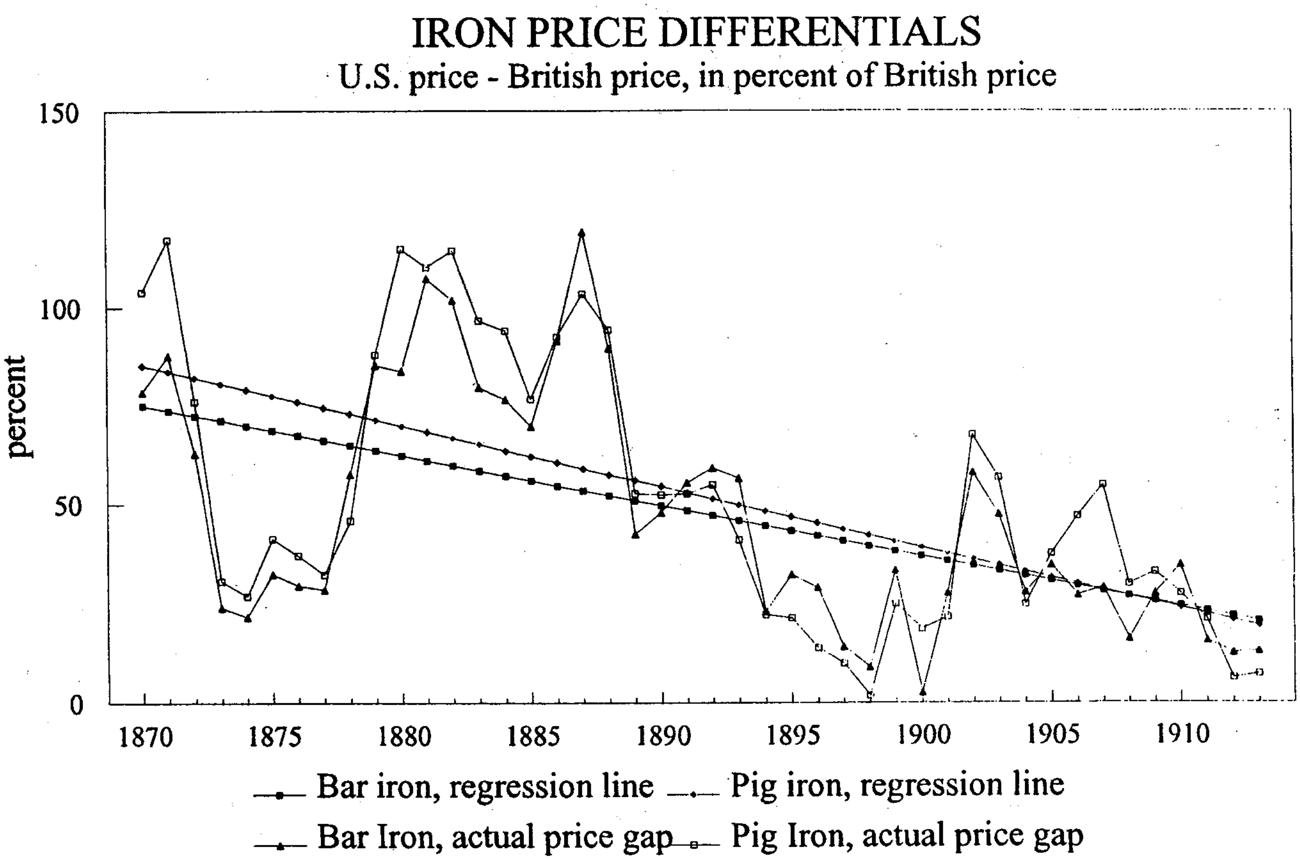


FIGURE 8

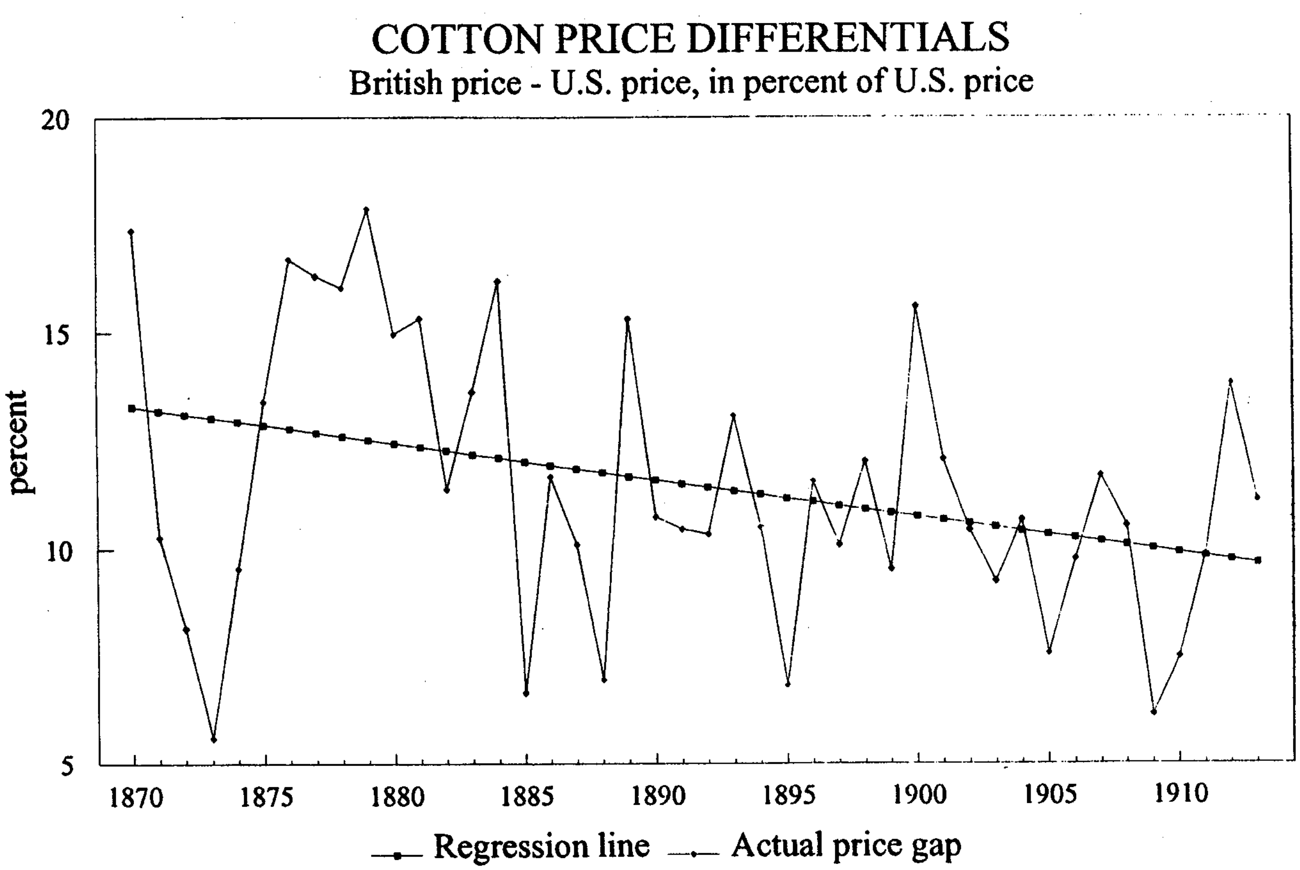


FIGURE 9

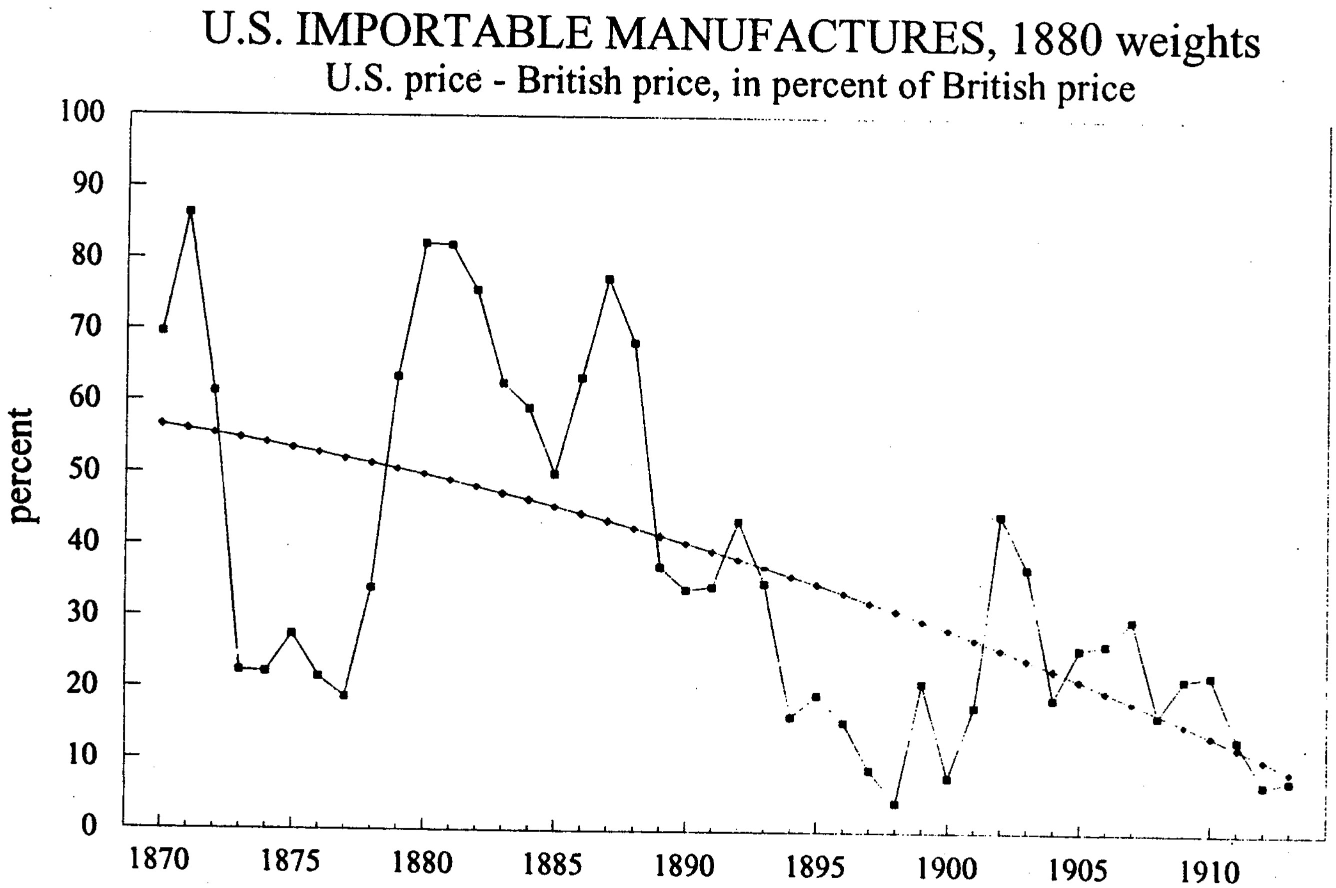


FIGURE 10

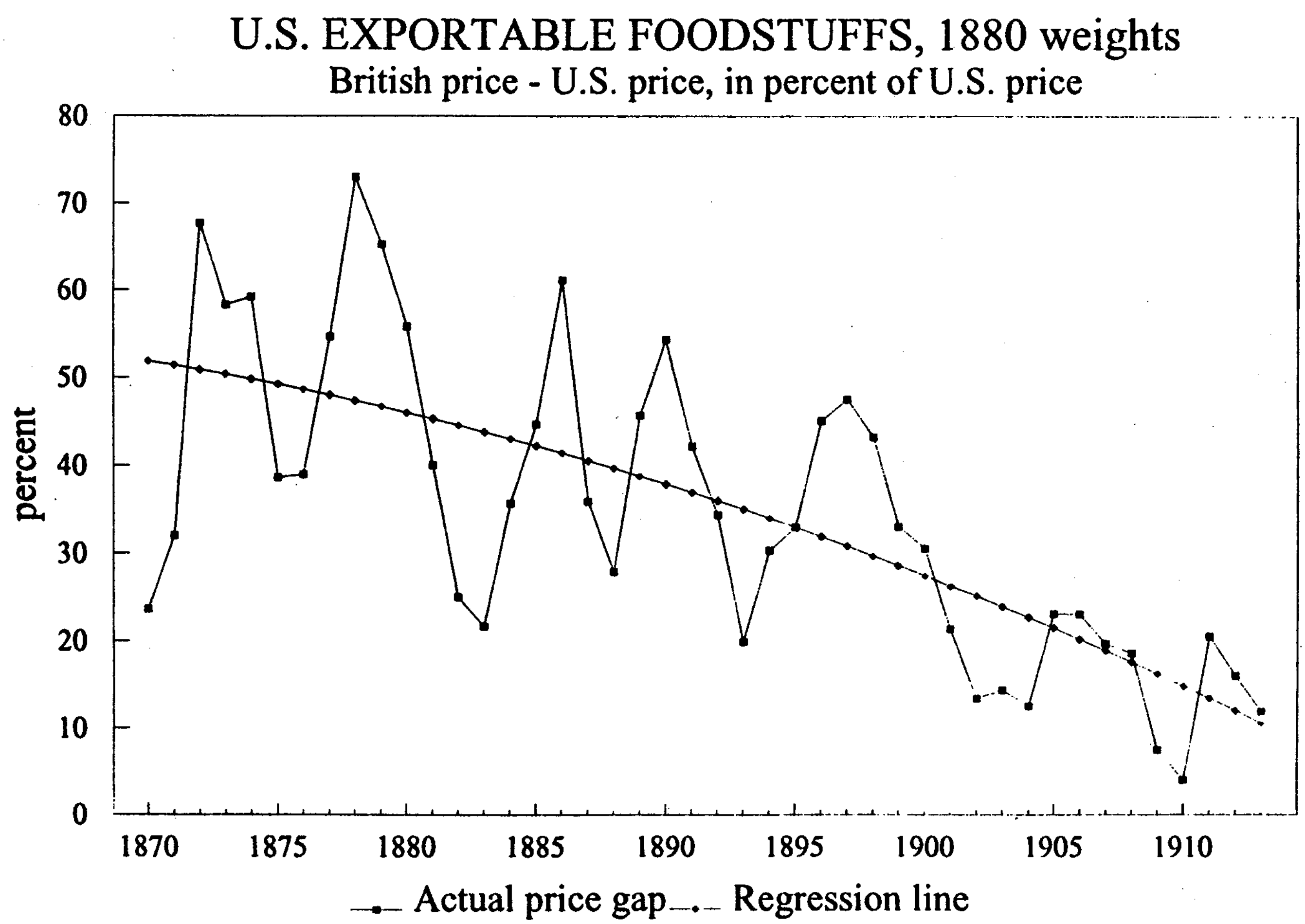


FIGURE 11

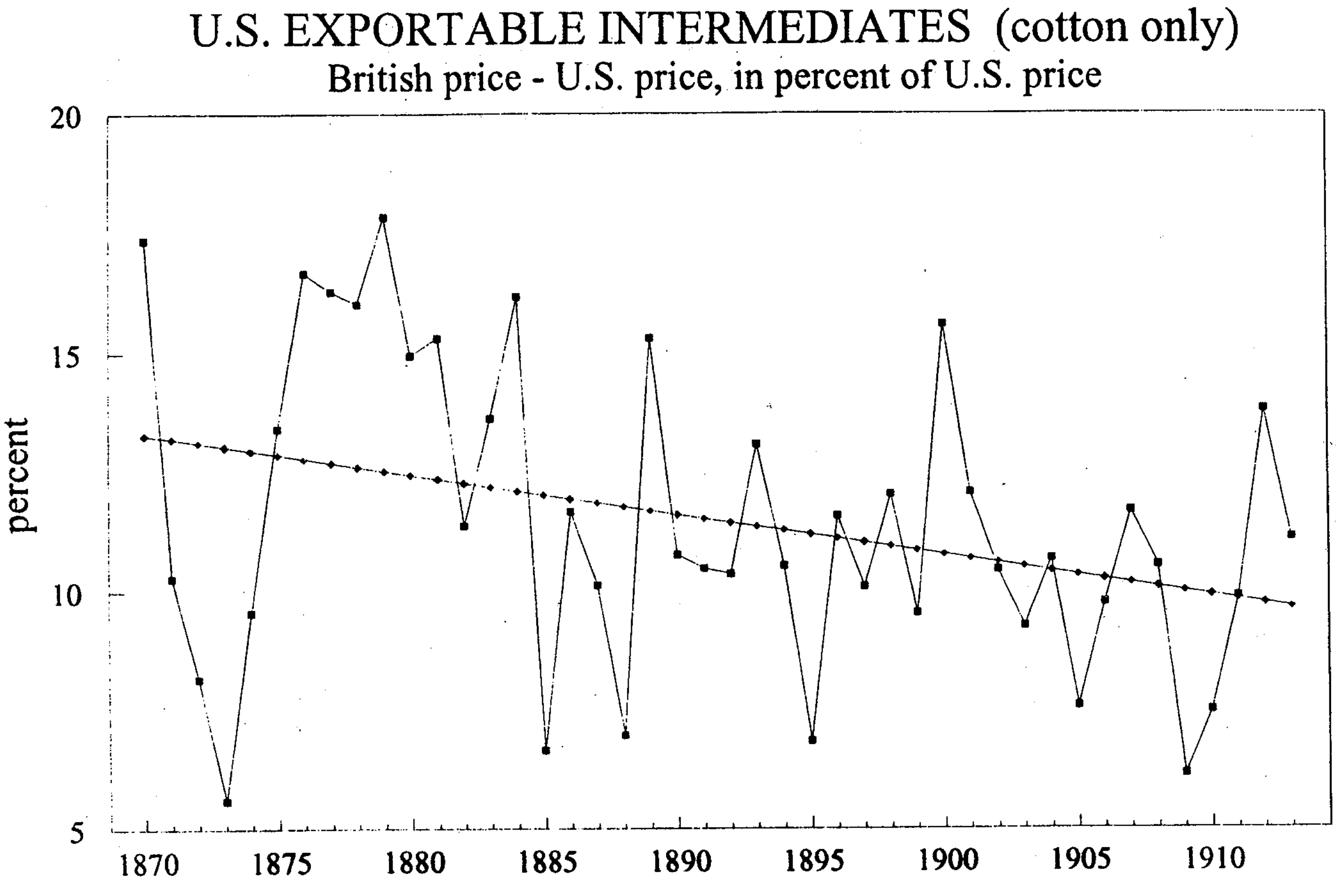


FIGURE 12

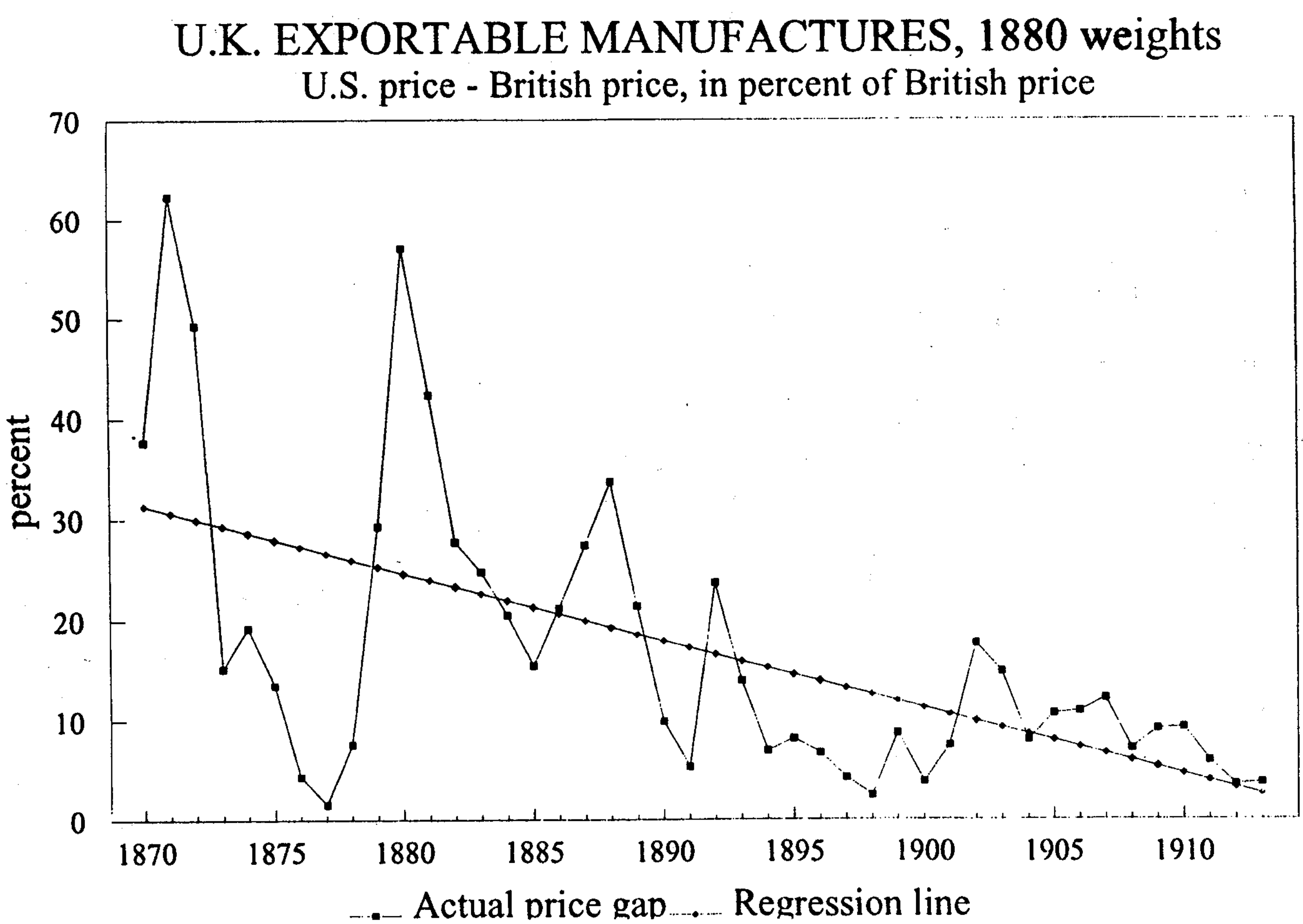


FIGURE 13

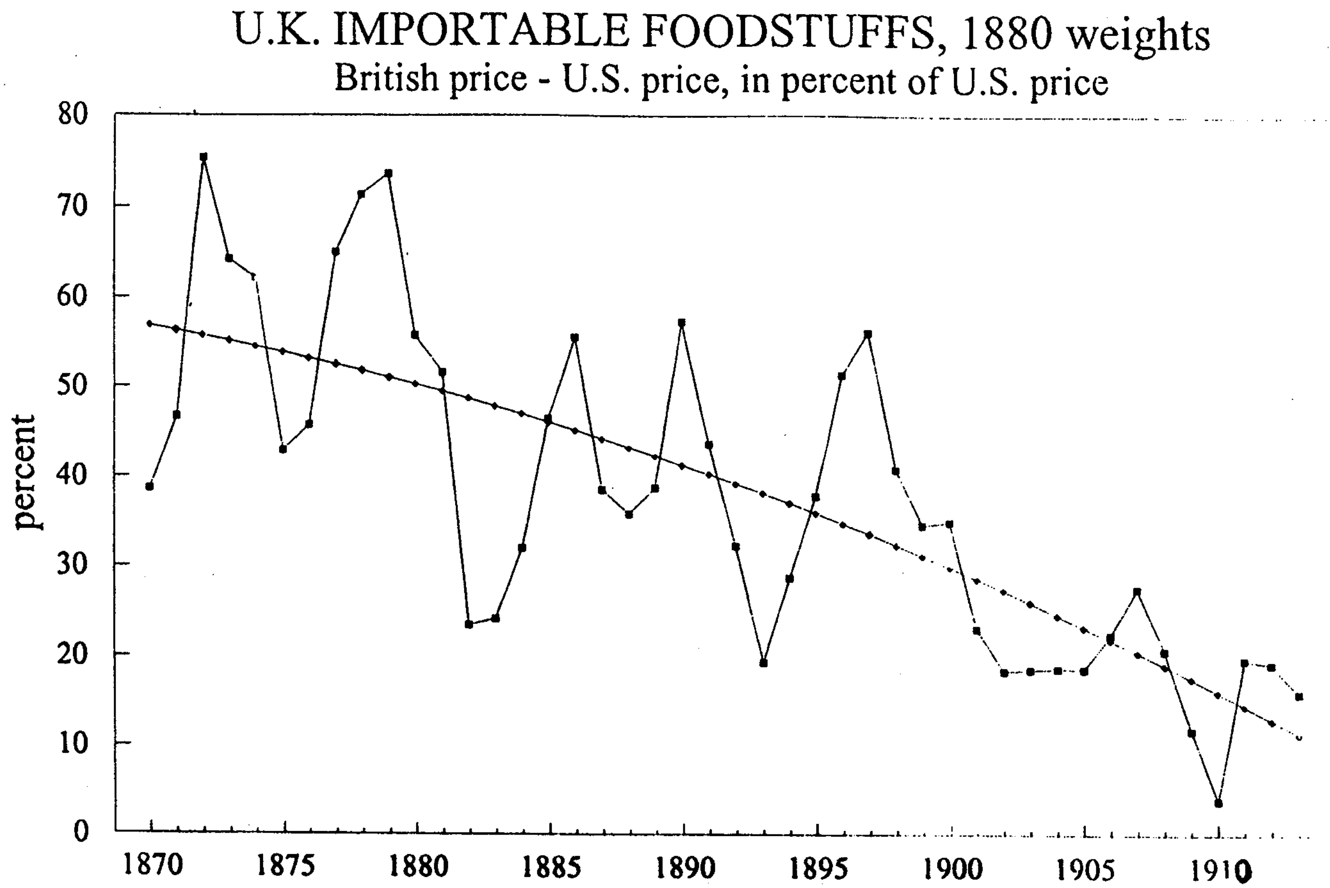
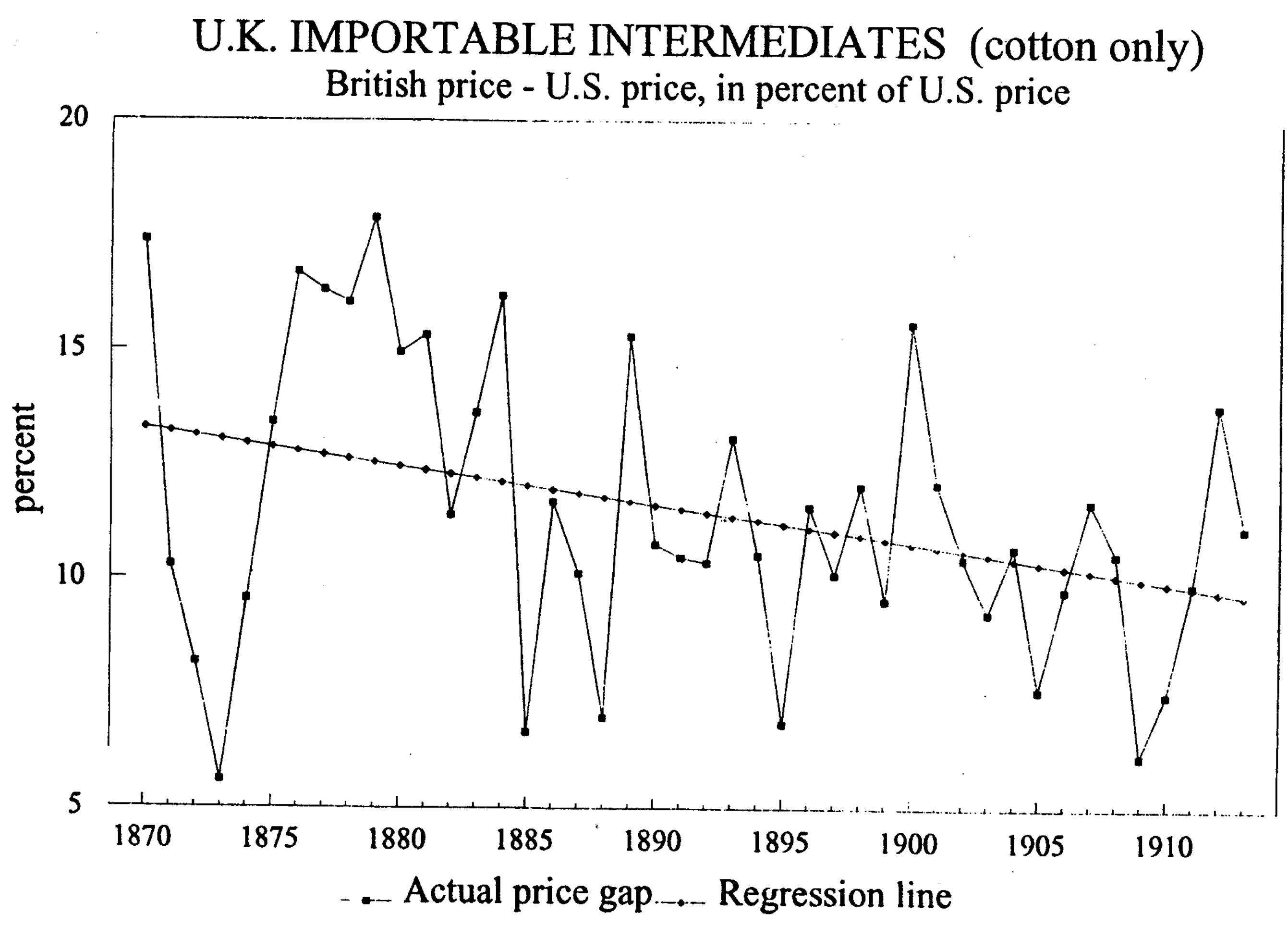


FIGURE 14



Appendix 1: Anglo-American Tradable Price Data

Three major sources have been used to document U. S. and British prices from 1870 to 1913: United States Congress, 52nd Congress, 2nd Session, Senate (1892-93), Wholesale Prices, Wages, and Transportation: Report by Mr. Aldrich, from the Committee on Finance (Washington, D.C.: USGPO). This report is also known as the "Aldrich Report"; U. S. Department of Labor, Bureau of Labor Statistics (1923), Wholesale Prices 1890-1922 (Washington, D.C.: USGPO); and A. Sauerbeck (1892-1913), "Prices of Commodities," Journal of the Royal Statistical Society. This is a once-yearly summary of prices for 56 commodities in England, compiled by Sauerbeck. Before 1892, these prices 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 1890-1912 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 dolar prices, using the dollar price of gold in J. K. Kindahl (1961), "Economic Factors in Specie Resumption: The United States, 1865-79," Journal of Political Economy, 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 the U. S. prices.

Special care has been taken to ensure the comparability of each pair of U.S. and English commodities for which prices are quoted. The details can be found in O'Rourke and Williamson (1992, 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 transprot costs in the late 19th 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

$$X_E[p_E] + X_I[p_I(1+t)] = C_E[p_E] + C_I[p_I(1+t)] \quad \textbf{(1)}$$

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

$$\epsilon^S{}_E X_E dp_E/p_E + \epsilon^S{}_I X_I[dp_E(1+t)/p_E + dt] =$$
$$\epsilon^D{}_E C_E dp_E/p_E + \epsilon^D{}_I C_I[dp_E(1+t)/p_E + dt] \quad \textbf{(2)}$$

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 **(2)** 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 judgement. If we take the view that the major goods flows were of food and raw materials into Europe, and exports of manufactures from Europe, and 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 U.S.

We take Europe and the rest of the world as the two relevant regions in equation **(2)** above. 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 below; 'I', 'M' and 'F' stand for cotton, manufactures and food respectively. We calculate transport cost shocks for both 1870-1895 and 1870-1913. In all cases, inital wedges are 1870 wedges; thus, the figures below 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. perspective. 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; and similarly 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, both because it bulked so large in world trade, and because the data are readily available. In millions of imperial quarters, production in the exporting regions was 145, and in the importing regions 123; consumption in the exporting regions was 124.4, and in the importing regions 143.6 (Harley, 1980, Table 5, p. 228). The elasticity of demand was taken to be -0.3, and the elasticity of supply 1.0 (Harley, 1986, p. 604).

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

Manufactures

According to Bairoch, Europe accounted for 61.3% of world manufacturing output in 1880. Britain accounted for 22.9% of the world total (Bairoch, 1982, Table 10, p. 296). Output in British manufacturing, mining and building amounted to £395.9 m. in 1881, or $1926.7 m (Deane and Cole, 1962, Table 37, p. 166). This implies a world output of $8413.5 m., a European output of $5157.5 m., and a non-European output of $3256.0 m.

According to Yates (1959, Table A20, p. 228), European exports of manufactures amounted to $2155 m. over the period 1876-1880; European manufactured goods imports amounted to $1005 m. 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 $1150 m. over the period. This implies European consumption of manufactures of $4007.5 m., and non-European consumption of $4406 m.

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. Since 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%, the output of British manufactures rises by 11.9%, 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:

UK, 1870-1895: +0.0658

UK, 1870-1913: +0.1131

US, 1870-1895: -0.0961

US, 1870-1913: -0.2094

Cotton

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

Appendix 3: The Models in Detail

While they are very similar, the US model is more complicated than the British in several ways. This appendix will therefore explain the former in some detail. The major simplifications made to the latter are then indicated; the text and the US model exposition here should make the structure of the British model clear.

The US Model

The US model is in the neoclassical, general equilibrium tradition. It has three components. Sector supplies obey standard production functions; output and factor prices are endogenously determined. Each commodity has a price, which may or may not be endogenous, depending on whether the good is tradable in world markets. Consumers are constrained by endowments and maximize some utility function; their income and expenditures are endogenous.

The alogrithm used here, MPS\GE, is taken from Rutherford (1988). Production and utility functions are specified; the algorithm then calculates cost, factor demand and commodity demand. Equilibrium is defined by a set of prices, activity levels and incomes such that: (i) no sector earns a positive profit; (ii) supply minus demand for each commodity is nonnegative; and (iii) income from factor endowments is fully distributed.

Production

There are four production activities: food (A); agricultural intermediates (I); non-food manufacturing (M_A); and services (S). In addition to the four commodities produced, there are three primary factors of production -- land (R), raw labor (L_R) and capital (K); two 'produced' factors of production -- agricultural labor (L_A) and non-agricultural labor (L_{NA}); and two imported goods -- tropical goods (T) and imported manufactures (M_F). Finally, an artificial good, 'foreign exchange', is used in modelling trade flows, and serves as the numeraire.

MPS\GE insists that production functions be C.E.S., of which Cobb-Douglas is a special case. (Given the elasticity of substitution, all the parameters of such functions can be conveniently estimated from a micro-consistent data set.) Production in both agricultural sectors is Cobb-Douglas, production in the other two sectors C.E.S.:

$$A = L_{AA}^{\theta AL} K_A^{\theta AK} R_A^{\theta AR} \tag{1}$$

$$I = L_{AI}^{\theta IL} K_I^{\theta IK} R_I^{\theta IR} \tag{2}$$

$$M_A = [a_{ML} L_{NAM}^{\tau M} + a_{MK} K_M^{\tau M} + a_{MI} I_M^{\tau M} + a_{MT} T_M^{\tau M} + a_{MA} A_M^{\tau M}]^{1/\tau M} \tag{3}$$

$$S = [a_{SL} L_{NAS}^{\tau S} + a_{SK} K_S^{\tau S} + a_{SM} M_{AS}^{\tau S}]^{1/\tau S} \tag{4}$$

where the left-hand side variables are outputs, X_i is the input of commodity X into sector i, the output elasticities, θ_{ij}, always sum to one; the a_{ij}'s are constants; and

$$\tau_M = (\sigma_M - 1)/\sigma_M \tag{5}$$

$$\tau_S = (\sigma_S - 1)/\sigma_S \tag{6}$$

where the σ's are pairwise elasticities of substitution.

Firms minimize costs, which generates factor demand and cost functions. In the Cobb-Douglas case, where Q is output, X_i is the input of factor i, and w_i is the price of factor i, production is described by (choosing units so that the constant term is unity)

$$Q = \Sigma_i X_i^{\theta i} \tag{7}$$

the demand for factor i equals

$$X_i(\{w_j\}, Q) = Q(\theta_i/w_i)\Sigma_j(w_j/\theta_j)^{\theta j} \tag{8}$$

and the cost function is given by (where B is a constant)

$$c(\{w_i\},\ Q) = BQ\Sigma_i(w_i/\theta_i)^{\theta i} \tag{9}$$

In the more general C.E.S. case, production is given by

$$Q = [\Sigma_i a_i X_i^{\tau}]^{1/\tau} \tag{10}$$

where $\tau = (\sigma-1)/\sigma$, and factor demands are given by

$$X_i(\{w_j\},\ Q) = Q[(a_i/w_i)\{\Sigma_j(a_j^{\sigma}w_j^{1-\sigma})\}^{1/1-\sigma}]^{\sigma} \tag{11}$$

and the cost function is

$$c(\{w_i\},\ Q) = Q[\Sigma_i(w_i/a_i)^{1-\sigma}]^{1/1-\sigma} \tag{12}$$

The model assumes perfect competition; thus, in each sector price equals unit cost (which depends uniquely on factor prices, given constant returns to scale):

$$p_A = c_A(w_A,\ r,\ d) \tag{13}$$

$$p_I = c_I(w_A,\ r,\ d) \tag{14}$$

$$p_{MA} = c_{MA}(w_{NA},\ r,\ p_I,\ p_T,\ p_A) \tag{15}$$

$$p_S = c_S(w_{NA},\ r,\ p_{MA}) \tag{16}$$

Here p_i stands for the price of good i; w_A and w_{NA} are the wages of agricultural and non-agricultural labor respectively; r and d are the returns to capital and land respectively; and the c_i functions are unit cost functions as in **(9)** and **(12)** above.

Equations **(13)** through **(16)** incorporate the model's assumptions about factor mobility across sectors. Capital is perfectly mobile across all sectors. Land and agricultural labor are perfectly mobile between A and I. Non-agricultural labor is perfectly mobile between manufacturing and services. Labor is, however, imperfectly mobile between agriculture and the rest of the economy.

Rural-Urban Migration

By allowing labor be less than perfectly mobile between sectors, rural-urban wage gaps are determined endogenously. Workers are endowed with 'raw' labor, which, by their migration decisions, is then transformed into agricultural and non-agricultural labor via a pseudo-production function, $(L_A, L_{NA}) = f(L_R)$. Collectively, potential migrants solve the following problem:

maximize $w_A L_A + w_{NA} L_{NA}$ s.t.

$$[\delta_A L_A^{(\mu-1)/\mu} + \delta_{NA} L_{NA}^{(\mu-1)/\mu}]^{\mu/\mu-1} = \mathbf{L_R}$$

where $\mathbf{L_R}$ is the fixed endowment of raw labor, and μ is the constant elasticity of transformation of this joint production function, which determines how sensitive the intersectoral allocation of labor is to changes in the urban-rural wage gap. Their solution to this problem is:

$$L_A = \mathbf{L_R}[w_A/\delta_A \Gamma]^{\mu}; \; L_{NA} = \mathbf{L_R}[w_{NA}/\delta_{NA}\Gamma]^{\mu} \tag{17}$$

where $\Gamma = [\delta_A^{\mu} w_A^{1-\mu} + \delta_{NA}^{\mu} w_{NA}^{1-\mu}]^{1/1-\mu}$.

Since the worker is endowed with raw labor, we need to determine the price of raw labor, w_R; given w_A and w_{NA} (and hence, via **(17)**, L_A and L_{NA}), we can calculate it from the zero-profit condition in the migration 'sector':

$$w_R L_R = w_A L_A + w_{NA} L_{NA} \tag{18}$$

Trade Flows

Pseudo-production functions are also used to model trade flows. Export sectors convert the export good into foreign exchange, and import sectors convert foreign exchange into import goods. In the benchmark equilibrium, the US ran a trade deficit. The US consumer is therefore endowed with enough foreign exchange to allow her to finance this deficit. This (together with the assumption that 'foreign exchange' is the numeraire) amounts to assuming that the nominal trade deficit is exogenous. This is of course unsatisfactory; but it is no more convincing to assume, for example, that trade is always balanced, or that the real value of the deficit is exogenous.

As is well known, an intertemporal model would be required to model the current account rigorously; in the context of a static model, some ad hoc assumption is required.

The US is assumed to be 'small' in the markets for food, foreign manufactures and tropical goods; thus prices are exogenous. This is modelled by allowing exports or imports to be converted into foreign exchange at a fixed ratio. Let E_i and I_i stand for exports and imports of good i respectively, and let F_i denote the amount of foreign exchange used as an input into, or derived as an output from, the relevant trade sector:

Sector	Output		Input
Food exports	F_A	=	$p_A E_A$
Manufactured imports	I_M	=	F_M/p_{MF}
Tropical good imports	I_T	=	F_T/p_T

The price-cost equations for these three sectors tie down the exogenous prices of these three goods; it remains to determine the level of exports or imports of the goods.

The US is assumed to be 'big' in cotton, so cotton exports cannot be modelled in this way. The more cotton the US exports, the lower will be the price of cotton. Thus, the production function converting cotton exports into foreign exchange will exhibit decreasing rather than constant returns to scale. This fact is incorporated in the following way:

$$F_I = A E_I^{\alpha} Z^{1-\alpha} \quad (19)$$

where A is a constant and Z is a fictitious factor of production. The factor is in fixed supply, which is what generates the decreasing returns to scale. By 'minimizing costs' in this sector, a constant elasticity foreign demand for

US cotton is generated:

$$E_I = Cp_{IE}^{\beta} \tag{20}$$

where C is a constant, β is the elasticity of demand and p_{IE} is the price of US cotton abroad. Transport costs in this sector are explicitly modelled by assuming that they act as a tax t on exports, the revenue from which accrues to the US consumer (that is, we assume that shipping receipts went to US nationals). The domestic and foreign price of intermediates are, of course, related as follows:

$$p_{IE} = p_I(1 + t) \tag{21}$$

Finally, services are non-traded; domestic demand equals domestic supply.

<u>Demand</u>

The representative consumer is endowed with raw labor, capital, and land. In addition, she is endowed with enough foreign exchange to run the exogenous trade deficit, and she consumes manufactured goods (both foreign and domestic), food, services and tropical goods. She maximizes

$$U(C_M, C_S, C_A, C_T) = C_M^{\Theta M} C_S^{\Theta S} C_A^{\Theta A} C_T^{\Theta T} \tag{22}$$

subject to $\Sigma_i p_i C_i = Y$, where M refers to a composite manufactured good. As is well known, Cobb-Douglas utility implies constant expenditure shares:

$$C_S = \Theta_S Y/p_S \tag{23}$$

$$C_A = \Theta_A Y/p_A \tag{24}$$

$$C_T = \Theta_T Y/p_T \tag{25}$$

The utility function is, however, nested; at a lower level the consumer determines how much of the two manufactured goods (home and foreign) to consume, by solving

$$\max\ [a_A C_{MA}^{s} + a_F C_{MF}^{s}]^{1/s}$$

$$\text{s.t. } p_{MA}C_{MA} + p_{MF}C_{MF} = \theta_M Y \quad (26)$$

which yields the following demand functions for manufactured goods:

$$C_{MA} = \theta_M Y p_{MA}{}^{t-1}/a_A{}^t[(p_{MA}/a_A)^t + (p_{MF}/a_F)^t] \quad (27)$$

$$C_{MF} = \theta_M Y p_{MF}{}^{t-1}/a_F{}^t[(p_{MA}/a_A)^t + (p_{MF}/a_F)^t] \quad (28)$$

where $t = s/(s-1)$.

Equilibrium

Equilibrium is defined by the following conditions: for every sector, price equals cost; for every commodity, demand equals supply; and the consumer's income equals the rents on all endowments. If there are n sectors and m commodities, this implies n + m + 1 equations (and, owing to Walras' Law, n + m independent equations), to solve for n + m + 1 unknowns (n activity levels, m prices and the consumer's income). Sectors here include those which transform goods into foreign exchange or vice versa, and that which transforms raw labor into agricultural and non-agricultural labor.

More concretely, there are 13 prices endogenously determined in terms of the numeraire (foreign exchange): p_{MA}, p_{MF}, p_A, p_T, p_Z, p_I, p_{IE}, p_S, w_R, w_A, w_{NA}, r, and d. There are 9 activity levels endogenously determined: M_A, A, I, S, E_A, E_I, I_T, I_M and that associated with the migration sector. Finally, there is the income of the representative consumer to determine, making 23 endogenous variables in all.

The following equations are available to solve the model. First, there are the zero-profit equations for the four production sectors [**(13)-(16)**]. Second, there is the zero-profit equation for the migration sector [**(18)**]. Third, there is the equation giving p_{IE} in terms of p_I [**(21)**]. Fourth, there are the zero-profit conditions for the four trade sectors (three tradeable and foreign exchange):

$$p_A = \underline{p}_A \quad (29)$$

$$p_{MF} = \underline{p}_{MF} \quad (30)$$

$$p_T = \underline{p}_T \quad (31)$$

$$1 = Kp_{IE}^{\alpha}p_Z^{1-\alpha} \quad (32)$$

Fifth, there are the following statements that equate demand and supply (letting $\underline{X}$ stand for the endowment of factor X):

$$M_A = M_{AS} + C_{MA} \quad (33)$$

$$I = I_M + E_I \quad (34)$$

$$S = C_S \quad (35)$$

$$A = C_A + A_M + E_A \quad (36)$$

$$\underline{L}_R = L_R \quad (37)$$

$$L_A = L_{AA} + L_{AI} \quad (38)$$

$$L_{NA} = L_M + L_S \quad (39)$$

$$\underline{K} = K_A + K_I + K_M + K_S \quad (40)$$

$$\underline{R} = R_A + R_I \quad (41)$$

$$I_M = C_{MF} \quad (42)$$

$$I_T = C_T + T_M \quad (43)$$

Finally, there is the equation defining the income of the consumer:

$$Y = w_R\underline{L}_R + r\underline{K} + d\underline{R} + \underline{F} \quad (44)$$

where $\underline{F}$ is the consumer's endowment of the fixed factor.

There are thus these 22 equations, plus the full employment condition for the fixed factor Z, with which to solve for the 23 unknowns.

The British model

The British model is very similar to the US model, but is considerably simpler. First, there are only three sectors: agriculture (Cobb-Douglas production), manufacturing and services (both C.E.S. production). Second, Britain is assumed to be 'small' in world markets for both food and manufactures; thus these prices are exogenous to the model, and there is no need to treat foreign demand for either good explicitly, as was the case for US cotton exports. Third, Britain exports manufactures and imports food (the opposite from the US case); food is assumed to be a homogenous good, and so domestic and foreign food do not substitute imperfectly in British consumption (as do domestic and foreign manufactures in US consumption). The British utility function is thus assumed to be a single-level Cobb-Douglas function, whereas the US utility function was a two-level nested function.

Appendix Table 1

Estimated Factor Intensities: Share of Input Costs in Gross Output (θ_{ij})

Industry	θ_L	θ_K	θ_R	θ_I	θ_A	θ_T	θ_M
United States c. 1869							
M	0.401	0.437		0.052	0.097	0.013	
A	0.553	0.213	0.234				
I	0.684	0.230	0.086				
S	0.718	0.249					0.34
Great Britain c1871							
M	0.510	0.240		0.250			
A	0.529	0.196	0.275				
S	0.491	0.505					0.004

Source: See text for notation and sources.

Appendix Table 2

Estimated National Accounts

Industry	Gross Output	Input Costs							Value Added
		L	K	R	I	A	T	M	
<u>United States c. 1869</u> ($m.)									
M	2009.9	805.8	878.7		104.5	194.5	26.4		1684.5
A	2457.2	1359.2	522.3	575.7					2457.2
I	285.0	194.9	65.6	24.5					285.0
S	2995.9	2149.7	745.5					100.7	2895.2
Total	7748.0	4509.6	2212.1	600.2	104.5	194.5	26.4	100.7	7321.9
<u>Britain c. 1871</u> (£m.)									
M	465.5	237.3	111.6		116.6				348.9
A	130.4	69.0	25.6	35.8					130.4
S	399.2	196.2	201.6					1.4	397.8
Total	995.1	502.5	338.8	35.8	116.6			1.4	877.1

<u>Source</u>: See text for notation and sources.

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