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ABSTRACT

For two decades, the consensus explanation of the British Industrial Revolution has placed technological change and the supply side at center stage, affording little or no role for demand or overseas trade. Recently, alternative explanations have placed an emphasis on the importance of trade with New World colonies, and the expanded supply of raw cotton it provided. We test both hypotheses using calibrated general equilibrium models of the British economy and the rest of the world for 1760 and 1850. Neither claim is supported. Trade was vital for the progress of the industrial revolution; but it was trade with the rest of the world, not the American colonies, that allowed Britain to export its rapidly expanding textile output and achieve growth through extreme specialization in response to shifting comparative advantage.

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The Industrial Revolution in Britain coincided with victory over the French in a struggle for world domination. After more than a century of struggle, in 1815 Britannia finally ruled the waves. The British used that mastery to gain access across the globe to raw materials and export markets. British trade with both the New World and the Old escalated.

Earlier histories of the Industrial Revolution linked military success, the expansion of trade, and the onset of modern growth (e.g., H. John Habakkuk and Phyllis Deane 1963). More recent accounts, however, starting with Joel Mokyr (1977), have emphasized in contrast its "home grown" nature. Technological advances in cotton textiles, iron and steel, and transport generated within Britain lie at its core (e.g., Nicholas F. R. Crafts, 1985, Mokyr, 2005). The struggle for world domination, for colonies and markets, was of secondary importance. As Robert P. Thomas and Deirdre N. McCloskey (1981, p. 102) memorably noted, "Trade was the child of industry." This consensus has been in turn challenged by Kenneth Pomeranz (2000). In his "coal and colonies" interpretation of the Industrial Revolution, Britain and not China had an Industrial Revolution in part because Britain had access to the raw materials of the New World, while China did not.

This paper sets out to test, with a formal CGE model, the role of trade with the New World, and trade itself, in explaining the growth of productivity and income in Industrial Revolution Britain. We find, to our surprise, that the New World mattered little, even by the 1850s. Had the Americas not existed, the Industrial Revolution would still have looked much as it did in practice. There were ready substitutes for the cotton, sugar, corn and timber of the New World in Eastern Europe, the Near East and South Asia.

However, had all trade barriers been substantial—if, say, a victorious France had cut off Britain's access to overseas trade—then British history would have been very different. British incomes per person, instead of rising by 45% between the 1760s and 1850s, would have risen by a mere 5%. The TFP growth rate, already a modest 0.4% per year, would have

fallen to 0.22% per year.

The magnitude, scale and transforming power of the Industrial Revolution lay in its unification of technological advance with the military power that generated easy British access to the markets of Europe, the Americas, the Near East and the Far East. As Ronald Findlay and Kevin H. O'Rourke (2007) emphasize, trade in a mercantilist world was not just the product of comparative advantage, but of comparative advantage married to the musket and the cannon. Britain's trading partners gained, however, along with Britain from the forced opening up of trade. A substantial share of the British TFP gain over these years was exported as cheaper manufactures to the rest of the world (Gregory Clark 2007a).

I. The Model

We ask what Industrial Revolution Britain would have looked like had trading opportunities with North America (and the Caribbean), or the rest of the world, been removed. We could use a simple Britain-only model and impose counterfactual trade levels, but as Nancy L. Stokey (2001) notes this approach is limited; absent detailed disaggregation it says nothing about cotton textiles and absent other regions and the terms-of-trade it says nothing about income and welfare. Our preferred tool is a three-region world economy model, for two benchmark periods, 1760–9 and 1850–9, the start and end of the Industrial Revolution. The model thus extends the two-region Industrial Revolution models developed by Crafts and Knick Harley (Harley and Crafts, 2000).

The computable general equilibrium model is fully described by two sets of information. The first is an accounting matrix for each region listing for each sector the value of goods produced, imported, and exported—and hence the domestic demand for those goods—and also the cost structure (inputs of primary factors and intermediate goods). The sectors are cotton textiles; other textiles; iron and steel; coal; agriculture; tropical raw materials; tropical food; and the rest of the economy. The factors are land, labor, and capital. All factors are

region-specific but mobile across sectors (although land is used only in agriculture, tropical raw materials, and tropical food). The intermediate inputs accounted for by this model are: coal into iron and steel; agricultural products into other textiles and coal; and tropical raw materials into cotton textiles and other textiles (and, for the 1850s, into agriculture and the rest of the economy as well).

The three regions are England (1760s) and later Britain (1850s); North America (including the Caribbean); and the Rest of the World (including Ireland). Trade is assumed costless. Goods produced in each region are assumed to be imperfect substitutes for each other, which allows two-way trade in the model. Imports and exports for each commodity are thus broken down by source and destination. Tropical raw materials and foods are produced in North America and the Rest of the World, but not in Britain. The regional production and trade matrices fully describe the static benchmark equilibrium, and are given in the appendix.

The second thing we need is a set of elasticities that describe the response of the economy to perturbations. Sectoral production is modelled as a Leontief combination of intermediate inputs and a value added aggregate. Value added is in turn a CES aggregate of the primary inputs. The elasticities of substitution in each sector are similar to those used by Harley and Crafts (2000): elasticities are 1 (Cobb-Douglas) in cotton textiles, other textiles, iron and steel, coal, and the rest of the economy; elasticities are 0.5 in agriculture, tropical raw materials, and tropical food. Consumption is modelled by assuming a representative agent in each region, endowed with all primary factors of production in that region, and spending all her income on a composite utility good (the production of which thus serves as a welfare indicator). The utility good is produced by a CES utility function, with all eight commodities as inputs, and an elasticity of substitution of 0.5.

What consumers consume, and what sectors use as intermediate inputs, are actually aggregates of the different varieties of each commodity produced in each of the three regions.

These 24 Armington aggregates, one for each sector and region, are again CES combinations of the three varieties of the relevant commodity. Values of the Armington elasticities of substitution used for each commodity are close to those used by Harley and Crafts: we used values of 5 for cotton textiles, iron and steel, and coal; 2 for 'other textiles' and the rest of the economy; and 100 for agriculture. The Armington elasticities for tropical raw materials and food are particularly important for the counterfactual experiments we conducted, and we consider these separately below.

II. Calibration and Counterfactuals

To set up the model we sourced data as follows. The total value of English/British expenditure and its composition across different goods was taken from Clark (2007b). Imports and exports of each type of good were then taken from Ralph Davis (1962, 1979). Thus, the value of the production of each good could then be inferred. We imposed zero production of both tropical goods in Britain. Next, based on our rough estimates of factor shares and intermediate costs shares we were able to compute the input-output structure and the value of payments to factors in each sector, and thus in the aggregate. Via the circular flow, these factor payments equal total expenditure. For simplicity, we adjusted the rest of the economy sector's output and exports to impose balanced trade, although our results do not depend on this assumption.

A different procedure was followed for the other two regions. For North America we assumed that final expenditure in each period on each good was a simple multiple of British expenditure, scaling by population relative to England/Britain, and thus assuming the same relative living standard (except that coal consumption was set equal to imports from Britain). For the Rest of the World we assumed that incomes per person relative to England were the same in the 1760s, and at 40% of the British level by the 1850s. In the rest of the world we imposed an assumed pattern of final consumption in each period, with the following weights

for each sector: cotton textiles, 0.02, other textiles, 0.04, iron and steel, 0.01, coal, 0.001, temperate agriculture, 0.375, tropical agriculture, 0.375, rest of the economy, 0.18. Thomas Ellison's discussion of cotton consumption per person in India in the 1850s suggests this is probably an underestimate of cotton and cotton goods production in the rest of the world, even though it implies that the cotton industry in the rest of the world was nearly 5 times as large as in England (Ellison, 1858, p. 73). Import and export data were then constructed using the Davis (1962, 1979) data for trade with England/Britain and some auxiliary data and assumptions.[1] Table 1 shows the resulting estimated trade patterns in the 1760s and 1850s. From the consumption and trade patterns we infer production patterns and, assuming that input cost shares in each sector were like those in Britain, we infer payments to intermediates and to all factors. Once again, factor incomes are equal to expenditure by construction, and trade was forced to be balanced by adjusting the rest of the economy sector in each case.

With the model set up we impose various counterfactual shocks and see how the model world economy would react. Our interest is in evaluating the hypothesis that the British Industrial Revolution depended crucially on international trade—either with North America, the Rest of the World, or both. To that end, we impose three different counterfactual shocks on the model:

a. "No NA": Reduce North American endowments by a factor of 20;

b. "No ROW": Reduce Rest of the World endowments by a factor of 20;

c. "No NA/ROW": Reduce both sets of endowments by a factor of 20;

Note that we cannot entirely eliminate each region's endowments since each region makes a differentiated product, whose price would be infinite were its supply to be reduced to zero,

[1] In the 1760s case, we assume the Navigation Acts excluded direct trade between North America and the Rest of the World, and use Davis's re-export data to estimate the bilateral trade pattern between North America and the Rest of the World. In the 1850s, the assumption is dropped, so we use Douglas Irwin's North American trade data (Susan Carter et al. 2006) by good and by region, assuming that America's import pattern from the Rest of the World was similar to Britain's, and its export pattern to the Rest of the World was similar to its export pattern to Britain.

but these endowment shocks provide a reasonable estimate of the gains from trade to the British economy that would have been sacrificed had trade been made almost impossibly costly.

The purpose of the three experiments is to gauge how vital a contribution trade with each region, and trade as a whole, made to the structural transformation and growth of the British economy. For example, the "No NA" shock permits us to grapple with the thesis of Pomeranz (2000) and see how critical New World supplies of raw cotton were to the rise of Lancashire. The "No ROW" shock allows us to see the importance of other major export markets for Lancashire's cotton products, as well as the role played by alternative suppliers of raw cotton like Egypt and India. In the remainder of the paper we describe the results of these counterfactuals and how they pose a challenge to current interpretations of the Industrial Revolution.

III. Results

The results are given in Tables 2 and 3, but the intuition behind the results comes from the trade data in Table 1. The results depend largely on trade patterns in the 1760s and 1850s. Several differences between the two periods stand out. First, and most obviously, in the 1760s England was still a large net importer of cotton textiles from the rest of the world, which also exported textiles to North America. By the 1850s, Britain was a large net exporter of cotton textiles to both the other regions, thanks to the new technologies of the Industrial Revolution. Second, in the 1760s England was paying for her imports of food and tropical products primarily with net exports of "other" goods, and of woollens and other textiles. By the 1850s, exports of non-cotton textiles had declined in relative importance: cotton textiles and exports of "other" goods were now relatively speaking far more dominant. A third point to note is that in the 1760s, imports of tropical raw materials came predominantly from the rest of the world, while imports of tropical food came predominantly from North America.

By the 1850s, imports of tropical raw materials from North America had considerably grown in relative importance, thanks to the boom in raw cotton exports, while the rest of the world was now more important than North America as a source of tropical food imports.

Both "tropical raw materials" and "tropical food" cover a wide variety of goods from many regions of the world. From the British point of view, a crucial question, had trade with North America been impossible, is how easily could the raw cotton crucial for the growing cotton textile industry have been provided by the rest of the world. The experience of the early 1860s, when Brazil, Egypt and above all India sharply increased their exports to Britain in response to the "cotton famine," suggests there would indeed have been a compensatory supply response from the rest of the world, although not a perfectly elastic one, since British industry did suffer during the cotton famine.

In our model, the issue boils down to the size of the Armington elasticity of substitution between the tropical raw materials Britain was importing from North America and the rest of the world. We experimented with several values for this elasticity, as well as with the corresponding elasticity for tropical food. While the elasticity of substitution between New World sugar and Asian pepper, say, might not have mattered for the fortunes of British industry, it should have had an impact on British consumer welfare, in a counterfactual world in which Britain was prevented from trading with either of the two regions. In our benchmark specification, these elasticities are both set to 5, since these are the 'upper end' Armington elasticities used by Harley and Crafts, but we also tried lowering the elasticities to 2, and increasing them to 100 (equivalent to making the different varieties of these goods almost perfect substitutes).

Table 2 gives the results of isolating England from its trading partners in the 1760s. For each of our three counterfactual scenarios, the model generated outputs in each sector; prices in each sector; nominal factor prices; the price of the utility good, which is equivalent to a

consumer price index; nominal household income; real factor prices and household income; and utility (i.e. the output of the utility good). The most important point is that preventing trade between England and North America would have had barely any effect on England. In the benchmark case, utility declines by less than 2%, with a modest real wage decline of 4.3%, a decline in real profits of 5.7%, and a rise in real land rents of 9.4%. Cotton textiles output would have gone down only barely: by just 1.1%, as compared with a decline in the output of other textiles of almost a tenth, the latter due to the disappearance of North American markets.

Removing the rest of the world would have had a bigger effect, since it was a much bigger region. Strikingly, eliminating trade between England and the rest of the world in the 1760s would have *increased* English cotton textile output by a third, since England was still a net importer of Indian cotton textiles. Similarly, English agricultural output would have expanded (by 8.8%) to replace food imported from the rest of Europe. As a result all other sectors would have contracted, as resources were sucked away from them. Utility would have declined less than previously (1.7%), but with greater distributional shifts, since in the 1760s English imports of temperate climate agricultural products still came predominantly from Europe rather than from North America (or other continents). Thus English landlords would have seen real incomes rise by over a quarter, while workers and capitalists would have seen real incomes declines of 7.9% and 10.6% respectively.

Not surprisingly, 'eliminating' both North America and the rest of the world has an even bigger impact on the traditional textile sector, cutting it by over a quarter. Cotton textiles production would have increased by a quarter, and agriculture by 14.5%. Real rents increase by 44.9%, at the expense of real wages (down 13.9%) and real profits (down a fifth), but the aggregate utility effect would still have been surprisingly small (a decline of less than 4%). Finally, note that varying the Armington elasticities for tropical food and tropical raw

materials would have barely changed the results.

Table 3 shows that the results are very different for the 1850s. Cutting off trade with North America in the benchmark case would have lowered cotton textiles output by 8%, and other textiles output by a tenth. Cotton textiles output would have declined both because of the disruption to raw cotton supplies, and because of the loss of markets. On balance, the former effect seems to be more important, since the real price of British cotton textiles increases in this simulation. Furthermore, when the elasticity of substitution between tropical raw materials from North America and the rest of the world is lowered to from its benchmark value of 5 to 2, implying that the rest of the world was less able to substitute for lost American raw cotton supplies, British cotton textiles output contracts by more (15%-18%). On the other hand, if that elasticity is raised to 100, then the output only falls by 2%. Utility falls by between 1.6% and 3.6%, depending on the sizes of Armington elasticities chosen, with larger elasticities corresponding to lower welfare losses. While these are larger welfare effects than those calculated for the 1760s, they are still modest. The rest of the world could have filled in for a missing North America, providing markets, raw materials and tropical food products, and so minimising the overall loss to the British economy. Once again, landlords would have gained by roughly 10%, at the expense of workers and capitalists.

On the other hand, the welfare loss is much greater—over 10%—when trade with the rest of the world, rather than North America, is eliminated. Cotton textiles output contracts by over a third, as the foreign markets upon which Lancashire was increasingly dependent vanish. (Note the difference with the results for the 1760s: by the 1850s Britain was a net exporter of cotton textiles to India and the rest of the world, rather than a net importer.) Since the rest of the world mattered for the British cotton textiles industry more by providing markets than by providing raw cotton, it is not surprising that the two Armington elasticities highlighted earlier turned out to be essentially irrelevant for this counterfactual experiment.

Consistent with Stokey (2001), the distributional effects of this shock are enormous, with real rents more than doubling, and real wages and profits declining by over a fifth. In terms of TFP performance, a decline of a third in the cotton textile sector would have lowered the economy-wide TFP growth rate by .06% per annum, or by 6% over the entire 1760s-1850s period (assuming unchanged sector-specific TFP growth rates).

Finally, "eliminating" all of Britain's trading partners would have had an even bigger effect on the economy, with utility falling by over 27% in the benchmark case (again, this result was invariant to changes in the two afore-mentioned Armington elasticities). This is an enormous effect in the context of a model with no increasing returns or other non-concavities, and is much larger than previous estimates in the literature (for example, according to Harley (2004, p. 194), "Self-sufficiency in 1860...would have cost Britain only...about 6 per cent of national income"). Cotton textiles output would have declined by almost three-fifths, implying a reduction in the economy-wide TFP growth rate of 0.11%, more than a quarter of the Industrial Revolution productivity growth rate, while real wages and profits would have declined by over a third. If we had been able to go further, and completely eliminate Britain's trading partners, the effects on economy-wide welfare and textiles output would obviously have been even greater (and the crucial cotton textiles sector would of course have vanished altogether). And ours may yet be a conservative estimate of hypothetical TFP losses, for if the dynamic cotton textiles sector had grown more slowly, then the incentives to innovate (or even passive "learning by doing" opportunities) might have been scaled down too.

IV. Conclusion

While colonies were not required for an Industrial Revolution, supply-side TFP growth was not alone sufficient. In Smithian terms, in the 19th-century global "division of labor" it was the "power of exchanging" that "gave occasion" to the Industrial Revolution. The highly specialized British economy was extremely dependent on foreign trade by the 1850s.

It is worth emphasising why the 1850s results are so different from the 1760s. This has nothing to do with model specification. The model is identical in both cases, as are all the embedded elasticities. The different results arise from the data fed into the model, which in turn reflect the profound shifts in the structure of the British economy during the Industrial Revolution. First, unbalanced productivity growth meant that British autarkic relative prices diverged from those in the rest of the world, implying much larger gains from trade. The cotton textiles sector became dependent on foreign markets for about 60% of its total sales. Second, British population growth meant that the island depended on foreign agriculture for both food and raw materials, implying that it needed to export a growing amount of manufactures to pay for these imports (Harley and Crafts 2000; Clark 2007a).

As a famous Welsh economic historian put it, "How could this unprecedented swarming of people on a small, offshore island be made consistent with a rising standard of living? It was impossible on the fixed area of English cultivable land, whatever miracles English technological progress in agriculture might accomplish. The way out was for England (through a transportation revolution and international trade) to endow itself with the equivalent of a vast extension of its own land base" (Brinley Thomas 1985, p. 731). In that context, by the mid 19th century, the maintenance of an open international trading system was of vital strategic importance to Britain.

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Table 1. Trade flows, 1760s and 1850s (£ millions)

1760	Cotton textiles	Other textiles	Iron & Steel	Coal	Agricul-ture	Rest of Economy	Tropical raw mat.	Tropical food
ROW to GB	0.697	1.766	0.471	0.000	2.729	0.117	1.139	1.047
GB to ROW	0.045	3.053	0.826	0.321	0.422	3.892	0.000	0.000
NAM to GB	0.000	0.000	0.010	0.000	0.602	0.001	0.255	3.901
GB to NAM	0.176	1.962	0.372	0.012	0.150	1.504	0.000	0.000
ROW to NAM	0.085	0.495	0.000	0.000	0.210	0.016	0.001	0.165
NAM to ROW	0.000	0.000	0.001	0.000	0.048	0.000	0.020	0.310

1850s	Cotton textiles	Other textiles	Iron & Steel	Coal	Agricul-ture	Rest of Economy	Tropical raw mat.	Tropical food
ROW to GB	0.000	8.695	0.000	0.000	67.268	16.677	25.120	15.297
GB to ROW	33.889	11.471	14.710	5.534	0.000	82.677	0.000	0.000
NAM to GB	0.000	0.008	0.000	0.000	13.014	2.705	19.845	8.659
GB to NAM	5.691	6.829	4.866	0.291	0.000	11.330	0.000	0.000
ROW to NAM	0.000	1.441	0.000	0.000	15.140	28.782	8.998	6.899
NAM to ROW	0.000	0.008	0.000	0.000	13.545	2.815	20.655	9.012

Source: See text.

Table 2. Counterfactual results, 1760s

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Elasticities:		TRM=5; TFOOD=5			TRM=2; TFOOD=5			TRM=5; TFOOD=2			TRM=2; TFOOD=2			TRM=100; TFOOD=100		
	BM	No NAM	No ROW	Neither	No NAM	No ROW	Neither	No NAM	No ROW	Neither	No NAM	No ROW	Neither	No NAM	No ROW	Neither
Outputs																
Cotton textiles	100	98.9	133.4	125.6	98.6	133.3	125.4	101.6	133.3	128	100.7	133.3	127.6	98.7	134.2	124.5
Other textiles	100	90.7	86.8	73.9	90.7	86.8	73.9	90.9	86.8	74.1	90.8	86.8	74	90.9	87.2	73.9
Iron and steel	100	107.4	83.5	65.3	107.6	83.5	65.4	108.9	83.5	66.1	109.4	83.5	66.3	106.2	83.9	64.4
Coal	100	100.7	92.3	92.7	100.7	92.3	92.7	100.1	92.3	92.2	100.1	92.3	92.2	101	92.3	93
Agriculture	100	103.7	108.8	114.5	103.7	108.8	114.5	103.8	108.8	114.5	103.8	108.8	114.5	103.5	108.6	114.4
Other	100	98.3	93.8	90.9	98.3	93.8	90.9	98.1	93.8	90.8	98.1	93.8	90.8	98.5	93.9	91
Prices																
Cotton textiles	100	94.3	82.6	75.2	94.5	82.6	75.4	94.5	82.6	75.4	95	82.6	75.8	93.9	83.1	74.8
Other textiles	100	94.9	84.1	77.6	94.9	84.1	77.6	94.9	84.1	77.7	95.1	84.1	77.8	94.6	84.7	77.4
Iron and steel	100	92.8	79.8	70.4	92.7	79.8	70.4	92.8	79.8	70.5	92.7	79.8	70.5	92.7	80.5	70.4
Coal	100	93.5	81.3	72.8	93.5	81.3	72.8	93.5	81.3	72.9	93.4	81.2	72.8	93.4	82	72.8
Agriculture	100	99.7	94.7	94.7	99.7	94.7	94.7	99.7	94.7	94.7	99.7	94.7	94.7	99.3	95.2	94.5
Other	100	93.2	80.5	71.9	93.1	80.5	71.8	93.1	80.5	71.9	93	80.5	71.9	93.1	81.2	71.8
Wages	100	93.6	81.3	73.3	93.5	81.3	73.3	93.5	81.3	73.3	93.4	81.2	73.3	93.5	81.9	73.3
Profits	100	92.2	78.9	68.6	92.2	78.8	68.6	92.3	78.8	68.7	92.2	78.8	68.7	92.2	79.6	68.6
Rents	100	107	111.6	123.3	107.1	111.6	123.3	107.1	111.5	123.4	107.2	111.5	123.4	106.3	111.8	123
Price of utility	100	97.8	88.3	85.1	97.8	88.3	85.1	99.3	88.3	86.1	99.5	88.3	86.3	96.6	89	84.2
Nominal income	100	96.0	86.8	82.3	95.9	86.8	82.2	95.9	86.8	82.3	95.9	86.8	82.3	95.8	87.4	82.2
Real wage	100	95.7	92.1	86.1	95.6	92.1	86.1	94.2	92.1	85.1	93.9	92.0	84.9	96.8	92.0	87.1
Real profits	100	94.3	89.4	80.6	94.3	89.2	80.6	93.0	89.2	79.8	92.7	89.2	79.6	95.4	89.4	81.5
Real rents	100	109.4	126.4	144.9	109.5	126.4	144.9	107.9	126.3	143.3	107.7	126.3	143.0	110.0	125.6	146.1
Real income	100	98.1	98.3	96.7	98.1	98.3	96.6	96.6	98.3	95.6	96.4	98.3	95.4	99.2	98.2	97.6
Utility	100	98.1	98.3	96.7	98.1	98.3	96.6	96.6	98.3	95.6	96.4	98.3	95.4	99.1	98.3	97.6

Notes: BM = Benchmark. No NAM = North American endowments set to 5% of actual. No ROW = rest of world endowments set to 5% of actual. Neither = North American and rest of world endowments set to 5% of actual. TRM = Armington elasticity of substitution between North American and rest of world tropical raw materials. TFOOD = Armington elasticity of substitution between North American and rest of world tropical food.

Table 3. Counterfactual results, 1850s

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Elasticities:		TRM=5; TFOOD=5			TRM=2; TFOOD=5			TRM=5; TFOOD=2			TRM=2; TFOOD=2			TRM=100; TFOOD=100		
	BM	No NAM	No ROW	Neither	No NAM	No ROW	Neither	No NAM	No ROW	Neither	No NAM	No ROW	Neither	No NAM	No ROW	Neither
Outputs																
Cotton textiles	100	92	65.8	41.3	85.4	65.7	41.3	90.9	65.8	41.3	82.2	65.7	41.2	98	66.4	41.6
Other textiles	100	90.1	90	74.2	89.5	90	74.2	90	90	74.2	89.2	90	74.2	90.5	90.1	74.3
Iron and steel	100	99.8	115.4	112.8	101.5	115.4	112.9	100.2	115.4	112.8	103	115.4	112.9	98.5	115.4	112.6
Coal	100	101.4	88.1	79.3	101.5	88.1	79.3	101.4	88.1	79.3	101.4	88	79.3	101.4	88.1	79.4
Agriculture	100	104.2	130.7	123.3	104.4	130.7	123.3	104.3	130.7	123.3	104.6	130.7	123.3	103.9	130.7	123.4
Other	100	100.4	87.3	99.1	100.8	87.3	99.1	100.4	87.3	99.1	100.9	87.3	99.1	100	87.3	99
Prices																
Cotton textiles	100	100.4	81.4	61.9	104.4	81.5	62	101	81.4	62	106.7	81.5	62	97.2	80.5	60.5
Other textiles	100	96.8	76.1	31.5	97.4	76.2	31.5	96.9	76.1	31.5	97.8	76.2	31.5	96.5	75.9	30.9
Iron and steel	100	94.5	67.2	20.7	93.9	67.2	20.7	94.4	67.2	20.7	93.7	67.2	20.7	95.1	67.2	20.4
Coal	100	94.2	63	19.8	93.6	63	19.8	94.1	63	19.8	93.3	63	19.8	94.8	63	19.5
Agriculture	100	100.1	101.2	29.6	100	101.2	29.7	100.1	101.2	29.6	100	101.2	29.7	100.1	101.1	29.2
Other	100	94.1	61.7	20.8	93.5	61.7	20.8	94	61.7	20.8	93.4	61.7	20.8	94.6	61.6	20.4
Wages	100	94.3	61.3	19.6	93.7	61.3	19.6	94.1	61.3	19.6	93.4	61.3	19.6	94.8	61.2	19.3
Profits	100	93	60.5	18.7	92.3	60.5	18.7	92.9	60.5	18.7	92.1	60.5	18.7	93.7	60.5	18.4
Rents	100	107.9	167.8	41.3	108.1	167.8	41.3	108	167.8	41.3	108.3	167.8	41.3	107.4	167.6	40.8
Price of utility	100	97.4	79	29.5	97.5	79	29.5	97.5	79	29.5	97.9	79	29.5	97.1	78.8	29
Nominal income	100	95.1	71.0	21.3	94.6	71.0	21.3	95.0	71.0	21.3	94.3	71.0	21.3	95.6	70.9	21.0
Real wage	100	96.8	77.6	66.4	96.1	77.6	66.4	96.5	77.6	66.4	95.4	77.6	66.4	97.6	77.7	66.6
Real profits	100	95.5	76.6	63.4	94.7	76.6	63.4	95.3	76.6	63.4	94.1	76.6	63.4	96.5	76.8	63.4
Real rents	100	110.8	212.4	140.0	110.9	212.4	140.0	110.8	212.4	140.0	110.6	212.4	140.0	110.6	212.7	140.7
Real income	100	97.6	89.9	72.3	97.0	89.9	72.3	97.4	89.9	72.3	96.4	89.9	72.4	98.5	90.0	72.5
Utility	100	97.7	89.8	72.4	97	89.8	72.4	97.4	89.8	72.4	96.4	89.8	72.4	98.4	90	72.6

Notes: BM = Benchmark. No NAM = North American endowments set to 5% of actual. No ROW = rest of world endowments set to 5% of actual. Neither = North American and rest of world endowments set to 5% of actual. TRM = Armington elasticity of substitution between North American and rest of world tropical raw materials. TFOOD = Armington elasticity of substitution between North American and rest of world tropical food.

Data Appendix

The social accounting matrices for the three regions at the two benchmark dates are shown at the end of this appendix, and they were constructed as follows.

Great Britain, 1850s

Cotton textiles: Cotton here includes cotton and linen and jute. The value of output is taken as £67.8 m. based on value of imports of cotton, flax, indigo and other dyestuffs of £31.6 m. (Davis 1979, 109, 124–5) and a markup estimate (Harley 1998, table 5, 64). Labor and capital shares in value added are assumed 50:50 based on Harley (1998), and Harley and Crafts (2000), but modifying for the absence in our model of the non-traded sector. The implied value added in "cottons" is 6.3% of total value added. The employment share of this sector in England and Wales in 1851 was 5.9%, so this figure seems reasonable (Parliamentary Papers, 1852–3).

Other textiles: These are the wool and silk industries. The value of outputs of £60.4 m. and intermediate inputs (£15.8 for wool and £6.3 for silk) are from Deane and Cole (1967, 196–210) and Davis (1979). Labor and capital shares are again taken as 50:50. The implied value added here is 6.6%. That makes the combined value added in all the textile industries 12.9%. The employment share of all textiles in 1851 in England and Wales was 11%, but this is assumed a more capital intensive sector than on average.

Iron and steel: This is here taken to include other metals and metal manufactures such as tin, copper, lead and zinc. Employment in these sectors was 5.5% of all employment in England and Wales in 1851. To account for these other metal sectors output was taken as £69.4, 1.5 times the output for iron alone given by Deane and Cole (1967, 225) figure for iron alone. Coal inputs of £11 m. calculated from coal required per ton given in Hyde (1977, 142, 153). Labor and capital shares are 67:33 based on Harley and Crafts (2000). This implies a value added share of 10.1%. The employment share of the metal industries in England and Wales was just 5.5%, but given the high assumed capital/labor ratio this is reasonable.

Coal: A physical net output of 65 m tons for Great Britain was estimated from Church (1986, 3, 19). This corresponded to a value of £37.1 based on an average price at final consumption of £0.57. There was a domestic farm input of horses, oats, timber, etc., of £0.8 from Church (1986, 502, 521–2). Labor, capital, and land shares of 0.61, 0.27, and 0.12 are based on Clark and Jacks (2007, table 6, 55).

Agriculture: British output of £123.8 estimated by scaling up the estimated English output of £96.2 given in Clark (2002, table 2) by the relative farm areas of Britain and England (1.26:1) in 1866. Inputs of guano, etc. from UK imports given by Davis (1979) assuming all of this went to British agriculture . Labor, capital, and land shares of 0.41, 0.15, and 0.44 are based on Clark (2002), table 2. These outputs are again scaled up to Britain by multiplying by the relative farm areas of Britain and England in 1866.

Rest of the economy: Total nominal GDP for Britain of £576.6 was calculated by scaling up figure of £503.8 for England and Wales from Clark (2001), table 3, by the ratio of British to English and Welsh populations (21.81:18.83). Value added in the rest of the economy is calculated as a residual between this scaled up figure and the sums of output for the above industries. All tropical raw materials not used as inports in other sectors are assumed to be inputs here. In this sector, which includes large amounts of services, the inputs were assumed to be 70% labor and 30% capital.

Imports: Imports are partitioned into those from North America and the Caribbean, and those from the rest of World (including Ireland). For North America and the Caribbean, and the rest

of World, the data are from Davis (1979), pp. 109, 124–5 on imports minus re-exports into the UK, and are the average of the years 1854–6.

The Davis figures include Ireland. We thus need to allocate these imports between Britain and Ireland. Ireland's population was 21.6% of UK population, but since we assume Irish income per person was only 0.6 of that in the UK (comparing wages as in Clark (2005), and Geary and Stark (2004)), Irish income was only 14.2% of UK income. We assume the only imports to the UK going to Ireland were tropical foods (tea, coffee, sugar etc.), and allocate these proportionally to income. This gives Ireland £3.2 m. of such imports, compared to British consumption of £19.0 m.

Ireland is assumed to export just linen textiles and food to England. We assume linen imports to Britain from Ireland equal British cotton textiles exports from Britain to Ireland. We assume consumption of each good in Ireland is 16.55% of British consumption based on the estimated relative incomes above (and implicitly assuming that preferences are identical and homothetic in Ireland and Britain). That makes Irish cotton textile consumption £4.7 m., and hence linen exports £4.7 m. also.

Agricultural output in Ireland is assumed to be the same per acre as in Britain. Based on 1866 acreages this makes it £56.0, compared to £123.8 in Britain. Since final UK consumption is £218.5 this makes Irish agricultural exports to Britain £25 m.

Total final use: Sum of all the above. (Final use here means total supply to the market net of intermediate use.)

Exports: Exports to Ireland, North America and the Caribbean, and the rest of World are calculated separately. For North America and the Caribbean, and the rest of World the data is from Davis (1979), p. 101, and is the average of 1854–6.

Exports of cotton, iron and steel and coal to Ireland are based on the assumption that Britain produces the entire UK output, and Irish consumption is 0.142 of the UK total. To balance trade between Britain and Ireland we assume Britain exports £10.25 m. of "rest of the economy goods to Ireland." This makes total British exports to Ireland £29.7 m.

A balancing factor of £38.2 is added to rest of the economy exports to the rest of the world to assure overall trade balance in the UK as well as in Britain.

Rest of the World, 1850s

Production: In each sector, output is total final use minus imports plus intermediate uses. All intermediate input shares are as in Britain, except coal is replaced by wood produced in the agricultural sector. Labor and capital shares are assumed at 70:30 for cotton textiles, other textiles, iron and steel, coal and the rest of the economy, reflecting less mechanization (lower capital shares) than in Britain. The labor, capital and rent shares in agriculture, tropical raw materials and tropical food are set at 40%, 20%, and 40% as in British agriculture.

Production plus net imports is set to final consumption.

Imports: Imports from the UK are based on Davis's export data for the UK to the rest of the world for 1854–6, adding in British exports to Ireland. Exports from North America and the Caribbean to the rest of the world are assumed to have same composition as UK imports from this region. The level of exports from US to the rest of the world is estimated from Doug Irwin's U.S. Historical Statistics exports estimate of $144 million total exports from the US compared to $71 million going to the UK in 1850 (Irwin, 2006a).

Exports: Exports to the UK are based on Davis's import data for the UK from the rest of the world. Exports from the rest of the world to North America and the Caribbean are assumed to have same composition. The level of exports from the rest of the world to North America and the Caribbean is computed from Irwin's U.S. Historical Statistics total US imports estimate of $174 million, with $75 million coming from the UK, in 1850 (Irwin, 2006b). A balancing factor of £22.8 m. is added to rest of the economy exports from the rest of the world to North America to assure overall trade balance in both the rest of the world and North America and the Caribbean.

Consumption: We assume the rest of the world total consumption expenditure is £13,118.4 m., given by British consumption times 22.75. This ratio is based on an assumed rest of world:British population ratio of 1,240:21.8 and a consumption per person ratio of 40%. This assumes a total world population of 1,300 in the 1850s based on the estimates of Durand (1977), Haub (1995) and McElready and Jones (1978). We assume consumption weights in the rest of the world are: cotton textiles 2%, other textiles 4%, iron and steel 1%, coal 0.1 %, temperate agriculture 37.5%, tropical raw materials 0%, tropical food 37.5%, and the balance for rest of the economy. These shares are adjusted from those of Britain to reflect lower incomes and higher textile prices, based in part on Clark (2007), 40–70. Thus in Britain cotton textiles were 4.9% and other textiles 8.8%.

Total final use: For each sector this is consumption plus exports minus imports.

North America and Caribbean, 1850

Production: In each sector, output is total final use minus imports plus intermediate uses. Coal output and input use is set to zero (forcing imports to go to consumption). All intermediate input shares are as in Britain, except coal is replaced by wood from agriculture. Labor and capital shares are assumed at 50:50 for cotton textiles, and other textiles; at 33:67 for iron and steel, and 70:30 for the rest of the economy, reflecting assumed similar mechanization levels to Britain. Labor, capital and rent shares in agriculture, tropical raw materials and tropical food are set at 40%, 20% and 40% as in British agriculture.

Imports: Imports from the UK are based on Davis's export data for Britain to North America and the Caribbean. Imports from the rest of the world to this region are assumed to equal exports by the rest of the world to North America.

Exports: Exports to the UK are based on Davis import data for Britain from the rest of the world. Exports to the rest of the world are assumed to equal imports by the rest of the world from North America.

Consumption: We assume total consumption expenditure in North America and the Caribbean was £1101.6, given by British consumption times 1.91. This ratio is based on an assumed North America and the Caribbean: British population ratio of 41.7:21.8 (Mitchell, 2003), and a North American and Caribbean consumption per person equal to that of Britain per person. We assume homothetic identical preferences in Britain and North America and the Caribbean.

Total final use: For each sector, consumption plus exports minus imports.

England, 1760.

Cotton textiles: Cotton again includes cotton and linen and jute. The value of output is taken as £1.4 m. based on value of imports of cotton, flax, indigo and other dyestuffs of £0.19 m.

(Davis, 1962, 300) and markup estimate (Harley, 1998, table 5, p. 64). Labor and capital shares are assumed 50:50 as in the 1850s.

Other textiles: Represents wool and silk. The value of outputs £14.88 and intermediate inputs of wool and flax (£3.15) are from Deane and Cole, 1967, 196, 210. Raw and thrown silk inputs (£0.75) are from Davis (1962), 300. Labor and capital shares are assumed 50:50 based on the 1850s shares.

Iron and steel: The output of £1.57 m. is from Deane and Cole (1967, 221). The coal input of £0.19 m. is calculated from the input:output ratios given in Hyde and coal prices calculated from Clark and Jacks (2007, 67). Labor and capital shares are 67:33 based on Harley and Crafts (2000).

Coal: Output of £3.41 m. from Flinn (1984) estimate of output of 6 m. tons and final consumption price of £0.57. Agricultural input of horses, oats, timber, etc., of £0.04 m. from Church (1986, 502, 521–2). Labor, capital, and land shares of 0.61, 0.27, and 0.12 are based on Clark and Jacks (2007, table 6, 55) as in 1850.

Agriculture: Output of £38.9 m. and labor, capital, and land shares of 0.38, 0.14 and 0.48 from Clark (2002, table 2).

Rest of the economy: Nominal GDP of £95.3 m. from Clark (2001), table 3. Value added based on residual GDP not accounted for by other sectors. Labor and capital shares are 70:30 as in 1850.

Imports: Imports from North America and the Caribbean, and the rest of world are from Davis (1962), pp. 300–1. Since Davis only gives data for 1752–4 and 1772–4, the figures for 1772–4 were used.

Total final use: This is the sum of production and imports minus intermediate uses for each sector. Final use here means total supply to the market net of intermediate use.

Exports: Exports to North America and the Caribbean, and to the rest of world are from Davis (1962), pp. 302–3. Since Davis only gives data for 1752–4 and 1772–4, the figures for 1772–4 were used. A balancing factor of £2.88 is added to rest of the economy exports to the rest of the world to assure overall trade balance for England.

Rest of the World, 1760

Production: In each sector, output is total final use minus imports plus intermediate use. All intermediate input shares are as in England, except coal is replaced by lumber (agriculture). Labor and capital shares are assumed at 70:30 for cotton textiles, other textiles, iron and steel, coal and rest of the economy, reflecting less mechanization (lower capital shares) than England. Labor, capital and rent shares in agriculture, tropical raw materials and tropical food are set at 40:20:40 as in England agriculture.

Imports: Imports from England are based on Davis export data for England to the rest of the world. Imports from North America are assumed to be England's reexports to rest of the world.

Exports: Exports to England are based on Davis import data for England from the rest of the world. Exports to North America are assumed to be England's reexports to North America.

Consumption: We assume the Rest of the World total consumption expenditure is £13,118, given by England's consumption times 50, minus North America's consumption. This ratio is based on a world population of 770 million versus England and Wales 7 million and Scotland

1.26 m (Clark, 2007, 139, Mitchell and Deane, 1971, 5). We assume the Rest of the World living standards were approximately 50% of England levels based on Clark 2007, 40–70.

We assume consumption weights in the rest of the world are different as follows: cotton textiles 3%, other textiles 3%, iron and steel as England, coal as needed to absorb imports, agriculture 37.5%, tropical raw materials 0%, tropical food 37.5%, and the balance for rest of the economy. This is to reflect the Engel curves which show foodstuffs at higher levels of consumption when incomes are lower.

Total final use: For each sector, consumption plus exports minus imports.

North America and Caribbean, 1760

Production: In each sector, output is total final use minus imports plus intermediate use. Coal output and input use is set to zero (forcing imports to go to consumption). All intermediate input shares are as in England, except coal is replaced by lumber (agriculture). Labor and capital shares are assumed at 70:30 for cotton textiles, other textiles, iron and steel, and for the rest of the economy, reflecting lower mechanization levels than England. Labor, capital and rent shares in agriculture, tropical raw materials and tropical food are set at 40:20:40 as in English agriculture.

Imports: Imports from England are based on Davis export data for England to North America. Imports from the rest of the world are assumed to equal England reexports to North America.

Exports: Exports to England are based on Davis import data for England from North America. Exports to the rest of the world are assumed to equal England re-exports to the rest of the world.

Consumption: Assume North America total consumption expenditure is assumed as £91, given by England consumption times 1. This ratio is based on an assumed North America:England population ratio of 1 based on the various population estimates for the Americas in Mitchell 2003. We assume homothetic identical preferences in England and North America.

Total final use: For each sector, consumption plus exports minus imports.

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Data Appendix: The Social Accounting Matrices

A. For the 1760s

ENGLAND	Cotton textiles	Other textiles	Iron & Steel	Coal	Agricul-ture	Rest of Economy	Tropical raw mat.	Tropical food	Labour L	Capital K	Rent R
Cotton tex	1.4						-0.19		-0.605	-0.605	0
Other tex		14.88			-3.15		-0.751		-5.4895	-5.4895	0
Iron + Steel			1.57	-0.19					-0.4554	-0.9246	0
Coal				3.41	-0.04				-1.78	-1.47	-0.12
Agriculture					38.9				-14.7	-5.7	-18.5
Rest of economy						35.101			-24.571	-10.53	0
Import	0.697	1.766	0.481	0	3.331	0.118	1.394	4.948			
Total final	2.097	16.646	2.051	3.22	39.041	35.219	0.453	4.948			
Cons	1.876	11.631	0.853	2.887	38.469	29.823	0.453	4.948			
Exports	0.221	5.015	1.198	0.333	0.572	5.396	0	0			

REST OF WORLD	Cotton textiles	Other textiles	Iron & Steel	Coal	Agricul-ture	Rest of Economy	Tropical raw mat.	Tropical food	Labour L	Capital K	Rent R
Cotton tex	134.4						-18.2426		-81.323	-34.853	0
Other tex		132.89			-28.132		-6.70701		-68.636	-29.415	0
Iron + Steel			41.44		-5.0152				-25.498	-10.928	0
Coal				0					0	0	0
Agriculture					1706.64				-682.66	-341.33	-683
Rest of economy						800.7743			-560.54	-240.23	0
Trop raw material							26.06929		-10.428	-5.2139	-10.4
Trop food								1671.92	-668.77	-334.38	-669
Import	0.045	3.053	0.827	0.321	0.46984	3.892079	0.020265	0.31002			
Total final	134.5	135.94	42.27	0.321	1673.96	804.6664	1.14	1672.23			
Cons	133.7	133.68	41.8	0.321	1671.02	804.5334	0	1671.02			
Exports	0.782	2.261	0.471	0	2.939	0.133	1.14	1.212			

NORTH AMERICA	Cotton textiles	Other textiles	Iron & Steel	Coal	Agricul-ture	Rest of Economy	Tropical raw mat.	Tropical food	Labour L	Capital K	Rent R
Cotton tex	1.615						-0.21918		-0.9771	-0.4187	0
Other tex		9.174			-1.9421		-0.46302		-4.7382	-2.0307	0
Iron + Steel			0.492						-0.3443	-0.1475	0
Coal				0					0	0	0
Agriculture					43.5759				-17.43	-8.7152	-17.4
Rest of economy						28.30408			-19.813	-8.4912	0
Trop raw material							1.40946		-0.5638	-0.2819	-0.56
Trop food								8.99402	-3.5976	-1.7988	-3.6
Import	0.261	2.457	0.372	0.012	0.36	1.52	0.001	0.165			
Total final	1.876	11.631	0.864	0.012	41.9938	29.82408	0.728265	9.15902			
Cons	1.876	11.631	0.853	0.012	41.344	29.823	0.453	4.948			
Exports	0	0	0.011	0	0.64984	0.001079	0.275265	4.21102			

Note: Negative entries denote inputs.
Source: See text.

B. For the 1850s

BRITAIN	Cotton textiles	Other textiles	Iron & Steel	Coal	Agricul-ture	Rest of Economy	Tropical raw mat.	Tropical food	Labour	Capital	Rent
Cotton tex	67.81						-31.6		-18.105	-18.105	0
Other tex		60.413			-15.822		-6.261		-19.165	-19.165	0
Iron + Steel			69.38	-11					-19.265	-39.114	0
Coal				37.13	-0.7798				-21.054	-14.11	-1.19
Agriculture					123.792		-2.58		-49.392	-18.9	-52.9
Rest of economy						290.673	-4.524		-200.3	-85.845	0
Imports	0	8.7031	0	0	80.282	19.382	44.965	23.9562			
Total final	67.81	69.116	69.38	26.13	187.472	310.055	0	23.9562			
Cons	28.23	50.816	49.8	20.31	187.472	216.0481	0	23.9562			
Exports	39.58	18.3	19.58	5.825	0	94.00694	0	0			

REST OF WORLD	Cotton textiles	Other textiles	Iron & Steel	Coal	Agricul-ture	Rest of Economy	Tropical raw mat.	Tropical food	Labour	Capital	Rent
Cotton tex	228.5						-106.473		-85.404	-36.602	0
Other tex		523.39			-137.08		-54.2427		-232.45	-99.621	0
Iron + Steel			116.5		-18.467				-68.605	-29.402	0
Coal				7.585					-5.3092	-2.2754	0
Agriculture					5143.8				-2057.5	-1028.8	-2058
Rest of economy						2308.156			-1615.7	-692.45	0
Trop raw material							174.1781		-69.671	-34.836	-69.7
Trop food								4932.57	-1973	-986.51	-1973
Imports	33.89	11.479	14.71	5.534	13.5452	85.49235	20.655	9.01243			
Total final	262.4	534.87	131.2	13.12	5001.8	2393.648	34.1176	4941.59			
Cons	262.4	524.73	131.2	13.12	4919.39	2348.189	0	4919.39			
Exports	0	10.136	0	0	82.4078	45.45945	34.1176	22.1966			

NORTH AMERICA	Cotton textiles	Other textiles	Iron & Steel	Coal	Agricul-ture	Rest of Economy	Tropical raw mat.	Tropical food	Labour	Capital	Rent
Cotton tex	48.24						-22.4799		-12.88	-12.88	0
Other tex		88.825			-23.264		-9.20553		-28.178	-28.178	0
Iron + Steel			90.28		-14.313				-25.068	-50.896	0
Coal				0					0	0	0
Agriculture					407.142				-162.86	-81.428	-163
Rest of economy						378.1452			-264.7	-113.44	0
Trop raw material							63.18783		-25.275	-12.638	-25.3
Trop food								56.5379	-22.615	-11.308	-22.6
Imports	5.691	8.27	4.866	0.291	15.1398	40.11245	8.997602	6.89936			
Total final	53.93	97.095	95.14	0.291	384.705	418.2577	40.5	63.4373			
Cons	53.93	97.078	95.14	38.79	358.145	412.7373	0	45.7659			
Export	0	0.0163	0	0	26.5592	5.520408	40.5	17.6714			

Note: Negative entries denote inputs.
Source: See text and Clark, O'Rourke, and Taylor (2008).