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ABSTRACT

The growing dependence of Britain on trade during the Industrial Revolution*

Many previous studies of the role of trade during the British Industrial Revolution have found little or no role for trade in explaining British living standards or growth rates. We construct a three-region model of the world in which Britain trades with North America and the rest of the world, and calibrate the model to data from the 1760s and 1850s. We find that while trade had only a small impact on British welfare in the 1760s, it had a very large impact in the 1850s. This contrast is robust to a large range of parameter perturbations. Biased technological change and population growth were key in explaining Britain's growing dependence on trade during the Industrial Revolution.

JEL Classification: F11, F14, F43, N10, N70 and O40
Keywords: british industrial revolution, colonies, great divergence, growth, specialization and trade

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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 frequent warfare, 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 lay at its core (e.g., Nicholas F. R. Crafts, 1985, Mokyr, 2005). The fight for world domination, for colonies and markets, was of secondary importance. At least two types of claims have been made by cliometricians downplaying the importance of trade for the British economy during this period. First, causation ran from the Industrial Revolution to growing volumes of trade, and not vice versa. As Robert P. Thomas and Deirdre N. McCloskey (1981, p. 102) memorably noted, "Trade was the child of industry." Second, the static welfare effects of trade on the British economy, as measured by Harberger triangles, were held to be small. For example, according to C. Knick Harley (2004, p. 194), "Self-sufficiency in 1860...would have cost Britain only...about 6 per cent of national income".

This consensus has been 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: trade was crucial for British growth on the supply side, as it were. Ronald Findlay and Kevin Hjortshøj O'Rourke (2007) argue that trade was of critical importance for the leading sectors of the Industrial Revolution, notably cotton textiles, on both the supply side and the demand side, providing elastic supplies of raw materials and large overseas markets with elastic demand. In a counterfactual world without international trade, technological progress in the cotton textiles sector would have led to a much more rapid increase in the cost of raw cotton, and to a much more rapid decline in the price of cotton textiles, than actually occurred.[1] In turn, this would have squeezed profits in that sector, with a negative impact on the incentive to innovate. Robert Allen (2009) argues that trade *before* the Industrial Revolution was critical for the British take-off: mercantilist success led to a prosperous trading economy with high wages. Those high wages, in turn, provided a spur for innovation, with British entrepreneurs seeking ways of replacing relatively expensive British labour with relative cheap British capital and coal.

Authors like McCloskey remain sceptical of such claims. McCloskey (2010) devotes four chapters of her recent book to arguing against the notion that trade was essential for British growth during the Industrial Revolution: it was not an engine of growth in some demand-led sense, the static welfare effects of trade were small, a counterfactually smaller cotton textiles sector would not have had a major impact on British economic welfare in the 19th century, and appealing to trade's dynamic effects is intellectually unconvincing. Mokyr (2009, Chapter 8) gives a balanced and nuanced account of the debate, allowing that trade (and, more generally, openness) was beneficial in several respects, but ending with the conclusion that "It was ingenuity and innovativeness that drove exports and trade, not the other way around" (p.165).

In part the debate has revolved around whether static trade models, and estimates of the static welfare effects of trade, can say anything at all about whether trade caused the Industrial Revolution or not. Findlay and O'Rourke argue that by definition they cannot: if growth was

[1] Or, perhaps more accurately, in a counterfactual world with less trade, since with *no* trade there would have been no cotton textiles at all. Cliometricians who deny the importance of trade during this period typically consider counterfactuals involving less trade, rather than a counterfactual involving autarky: that is to say, a counterfactual world without any raw cotton, sugar, tobacco, Indian textiles, imported grain, and without any exports either (McCloskey 2010, pp. 225-6).

driven by capital accumulation and technological progress, then the issue of whether trade drove the Industrial Revolution or not can only be resolved by thinking about the mechanisms through which it influenced investment and innovation. Comparing the static welfare effects of trade with the total growth experienced over a period, and concluding that these were relatively small, is beside the point.

This paper does not engage with the issue of whether trade drove technological change during the Industrial Revolution. Rather, it takes that change as given, and asks what this implied for the dependence of the British economy on trade. More precisely, we use a formal, static, computable general equilibrium (CGE) model to assess the role of trade in explaining British income levels at either end of the first Industrial Revolution. We find, consistent with other authors, that trade had only a small impact on British living standards in the 1760s. Assuming plausible values for key elasticities yields a welfare loss of only three or four per cent, consequent on shutting off Britain from trade with the rest of the world. However, an identical exercise produces welfare losses of 25-30 per cent in the 1850s: a very large number indeed, given that this is a standard CGE model without any non-convexities or dynamic effects of the sort that might be expected to boost the welfare effects of trade. Studies of the role of trade during the British Industrial Revolution which focus on the 18th century are thus missing a major part of the picture: Britain was becoming dramatically more dependent on trade during this period. While this does not directly address the issue of what were the dynamic effects of trade during this period, the results strongly suggest that Britain's growing interactions with the rest of the world were becoming increasingly important in maintaining living standards as the Industrial Revolution progressed.

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 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 of local production (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. There are three primary factors of production: land, labour, and capital. All three primary factors are region-specific but mobile across sectors. (However, 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 constant elasticity of substitution (CES) aggregate of the three 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 so-called “Armington aggregates”, one for each sector and region, are again CES combinations of the three regional varieties of the relevant commodity. The elasticities of substitution used to combine the different regional varieties into Armington aggregates, which we will refer to as “Armington elasticities”, are close to those used by Harley and Crafts: we use 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 turn out to be 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 (2010). 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 cost 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 that 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.[2] 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 reacts. Our interest is in evaluating the hypothesis that British economic welfare 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. However, these endowment shocks provide a reasonable estimate of the gains from trade to the British economy that would have been sacrificed had the opportunities for trade with other regions been almost vanishingly small.

[2] In the 1760s case, we assume that 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 that its export pattern to the Rest of the World was similar to its export pattern to Britain.

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 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 discuss 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 rest of the world have provided the raw cotton required for the growing cotton textile industry. 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. (The higher the elasticity, the easier it would have been to substitute between goods coming from different regions, and the smaller would have been the welfare impact of abolishing trade with either region.) 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. The benchmark values of all variables, reflecting the actual British level of trade with the rest of the world in that decade, are set equal to 100 (in column 1). Columns 2 through 4 present the results when each of our three counterfactual shocks is imposed on the model, setting the Armington elasticities of substitution for tropical foods and raw materials equal to 5. The remaining columns show how the impact of the three shocks changes when these Armington elasticities take on different values.

For each of our three counterfactual scenarios, the model generated outputs in each sector; prices in each sector (here expressed relative to the price of output in the British "rest of the economy" sector, which is thus taken to be the *numéraire*); 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 (column 2), 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 (column 3). 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 even 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 10.7% 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 (column 4). 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 (columns 5 through 16).

Table 3 shows that the results are very different for the 1850s. Cutting off trade with North America in the benchmark case (column 2) 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: when the elasticity of substitution between tropical raw materials from North America and the rest of the world is lowered from its benchmark value of 5 to 2 (columns 5 and 11), 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 (column 14), 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 (column 3). 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.

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 (column 4; again, this result is 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. Cotton textiles output would have declined by almost three-fifths, 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).

We stress that the difference between the 1760s and 1850s results is solely due to the way in which the model, which is identical in both cases, has been calibrated. That is, our finding that the British economy was becoming increasingly dependent on trade during this period depends not on changing the theoretical structure of the model, or the elasticities embedded within it, but on the changing structure of the British economy of this period. We will return to the issue of what the key structural changes driving these changing results might have been below. First, however, we note that this changing structure would have had different implications for the dependence of the British economy on trade, had elasticities of substitution been different. In particular, if Armington elasticities of substitution between domestic and foreign goods, or elasticities of substitution in consumption, had been higher, then an inability to trade with the rest of the world would have been less costly in either period. By how much would the large dependence on foreign trade in the mid-nineteenth century which we have uncovered here have been reduced as a result?

Table 4 gives some answers. In column (1) it presents the benchmark levels of our key variables, set equal to 100: these are the actual levels observed in the 1850s, given that Britain was in fact trading with the rest of the world as it actually did. Column (2) gives the estimated impact of moving to autarky (i.e. reducing non-British endowments by a factor of 20) assuming that all elasticities are set equal to their benchmark level: this is identical to the estimates in column (4) of Table 3. Columns (3)-(9) repeat the exercise, but increase all the relevant elasticities of substitution, one at a time. In columns (3)-(7) the Armington elasticities of substitution between British and foreign goods are increased, one at a time, to twenty, a very high value indeed. In columns (8) and (9) the elasticity of substitution in aggregate British consumption is increased to one, and then two.

Our key interest here is in the overall welfare effect of moving to autarky, which is presented in the last row of the table. As can be seen, there is only one elasticity of substitution that is really decisive for the finding that autarky would have been very costly in the 1850s, and that is the Armington elasticity of substitution for the "rest of the economy" sector. If this elasticity is increased to 20 (column 7), then eliminating trade reduces British welfare by only 6.7%, much less than the baseline 27.5% welfare loss presented in column 2. Since the "rest of the economy" sector's output was largely non-traded, and since twenty is a very high elasticity anyway, we can safely dismiss this case as irrelevant. The other elasticities that seem to matter are the Armington elasticity for "other textiles" (column 7), and the overall elasticity of substitution in consumption (columns 8 and 9). However, even when these elasticities are raised to unreasonably high levels, as in Table 4, the costs of autarky in the 1850s remain very high (of the order of 15-20 per cent).

IV. What caused the increase in Britain's dependence on trade?

As stressed above, the difference between our results for the 1760s and 1850s are driven entirely by the changing structure of the British economy during this period, as reflected in the calibration of our models. Which changes in particular made Britain so much more dependent on trade?

We can think of two obvious candidates. The first is technological change associated with the Industrial Revolution, which was uneven across sectors. Uneven technological change meant that the technological gap between Britain and the rest of the world was increasing more rapidly in some sectors than in others. This in turn meant a greater basis for Ricardian gains from trade between Britain and the rest of the world. The second is population growth. Increasing the population of a small island with limited land resources inevitably meant (given diminishing returns in agriculture) a growing need to import food and raw materials, and thus a growing need to export manufactured goods in order to pay for these (Harley and Crafts 2000, Clark 2007).

How important were these respective forces in explaining Britain's growing dependence on trade? For this we need quantitative estimates of total factor productivity (TFP) growth by sector, and factor endowment growth, and these are provided in Table 5. The TFP growth rates are from Clark (2010). The land endowment is assumed to be constant; population growth for England and Wales is taken from Wrigley and Schofield; and the capital endowment is calculated by multiplying the capital income in the social accounting matrices provided in the data appendix by twenty (i.e. assuming a 5% return), and using the GDP deflator provided in Clark (2010). As can be seen, while all sectors experienced technological progress, TFP growth was highest in the cotton textiles sector, and was also relatively high in the iron and steel and "other textiles" sectors. Population growth was more than matched by capital accumulation, but while the capital-labour ratio was therefore rising rapidly, the land-labour ratio was declining.

Table 6 looks at the impact of increased productivity and larger factor endowments on the British economy after 1760. It does so by imposing a series of shocks on the 1760s benchmark equilibrium, and seeing how the endogenous variables in the model adjust. Column (2) increases sectoral productivity levels in line with the actual increases listed in Table 5. As can be seen, even though all sectors experienced higher productivity, the unbalanced nature of the productivity growth meant that some sectors expanded – in particular cotton textiles and iron and steel – while others contracted – in particular other textiles and agriculture. The decline in agricultural output is not surprising, since TFP growth in agriculture was comparatively low, but TFP growth in other textiles was high, and yet output in the sector fell by over 15 per cent. This can be explained by the over seven-fold increase in cotton textiles, which necessarily implied falling output in other sectors; with iron and steel also experiencing rapid productivity and output growth, and coal-mining increasing in response to this, something had to give in an economy with limited resources, and falling output in the traditional textile sectors was one way in which the economy adjusted to higher cotton textiles output. Higher productivity in the ninety years following the 1760s implied a growth in British welfare of the order of 50 per cent.

Column (3) lets all sectors of the economy experience the same productivity growth, namely the economy-wide TFP growth experienced between the 1760s and 1850s. As expected, the impact on overall British welfare was almost identical to that in column (2), but outputs in the individual sectors barely move in this simulation: the increased productivity is entirely reflected in higher payments to the three factors of production. A comparison of columns (2) and (3) make it clear how profound were the implications for the structure of the British economy of the unbalanced nature of productivity growth over this period.

Column (4) lets the labour and capital endowments expand as they actually did between the 1760s and 1850s. Since the endowment of capital expanded twice as fast as that of labour, it is not surprising that the big beneficiary in terms of relative output was the capital-intensive iron and steel sector, with coal expanding in response. Agricultural output also increases, but by less than 40%, reflecting the fixed land endowment; as a result, all the manufacturing sectors expand in order to earn the foreign exchange needed to pay for the extra food imports. While capital-labour ratios increase in this simulation, the land-labour ratio falls, and the latter effect is dominant in the sense that per capita welfare falls by almost 20%: the population growth of this period, had it not been matched by the productivity advances of the Industrial Revolution, would have immiserised the population (with real wages falling by almost 30 per cent), in time-honoured Malthusian fashion.

This population growth, however, *was* accompanied by productivity growth, and the impact of both is given in column (5). Wages and per capita utility both increase by 45 per cent: the Industrial Revolution did indeed break the link between population and wages. On the other hand, the big winner under this scenario (as in an old-fashioned Malthusian economy) was land, with real land rents more than doubling: it would take the move to free trade, and the decline in global transportation costs of the late 19th century, before rising population would coincide with falling land rents. In this scenario, the output of cotton textiles and iron and steel explodes, increasing as a result of both increased relative productivity, and population growth pressing on a fixed land endowment generating a need to pay for food imports.

Column (6) goes one step further, and imposes autarky (i.e. a cut of 95% in the endowments on North America and the rest of the world) on this larger, higher-productivity economy. The impact of autarky on the British economy, given that productivity and endowments have both been allowed to increase from their 1760s to their 1850s levels, is given in column (7), and is obtained by expressing the values of all variables in column (6) relative to their free trade values in column (5). As can be seen, autarky in this situation reduced cotton textile output by over 80%, and lowers British welfare by a third: the latter effect is very close to (although slightly bigger than) the effect of imposing autarky on the economy calibrated to 1850s data shown in Table 3. It seems as though productivity growth and factor endowment growth can jointly explain the increase in the welfare costs of autarky between the 1760s and 1850s, apparent in a comparison of Tables 2 and 3.

Which of these two forces has a bigger effect in explaining the increased dependence of the British economy on trade? The answer is provided in Table 7. This gives, in column (1), the impact of moving to autarky in the 1760s, given benchmark elasticity values: this is identical to column (4) in Table 2. Successive columns then show how scaling up sectoral productivities and factor endowments to their 1850s levels changes the effects of moving to autarky. Column (5) is identical to column (7) in Table 6: it shows what the impact of moving to autarky in the 1760s would have been if sectoral productivities and factor endowments in the 1760s had been at their 1850s levels. Recall from Table 6 that this is derived by comparing the effects of two counterfactual equilibria: the equilibrium that would have obtained if British sectoral TFPs and factor endowments had increased as they actually did between the 1760s and 1850s (column 5 of Table 6); and the equilibrium that would have obtained if British sectoral TFPs and factor endowments had increased as they actually did between the 1760s and 1850s, *and* non-British endowments had been reduced by 95% (column 6 of Table 6). Columns (2)-(4) of Table 7 are all derived in an identical manner.

Recall that if the British economy of the 1760s had been barred from trading with the rest of the world, cotton textiles output would have expanded (since Britain was still importing cotton textiles, net), and utility would have declined by a modest 3.3% (column 1). The impact of moving to autarky would have been almost identical if all sectors had experienced the same, economy-wide TFP growth rate (column 3). However, the fact that TFP growth was so unbalanced meant that moving to autarky would have been much more costly, reducing welfare by 9.4% (column 2). Furthermore, the Ricardian comparative advantage in cotton textiles provided by this unbalanced productivity growth not only increased Britain's overall gains from trade, but influenced the sectoral effects of trade. Instead of expanding as a result of autarky, the British cotton textile industry would now have declined dramatically, by over 60 per cent.

Column (4) shows that the gains from trade (or, more precisely, the welfare costs of autarky) were increased even more as a result of factor endowment growth: increasing British factor endowments to their 1850s levels increases the welfare cost of autarky to 18.3%, or almost twice as much as in column (2). Factor endowment growth on its own also meant that the capital-intensive iron and steel industry was a major beneficiary of trade: it would have contracted by almost 80% had Britain moved to autarky. All other manufacturing sectors would also have contracted, as agriculture expanded: population growth meant a large increase in the desirability of importing food, and of exporting manufactures to pay for these imports. The big losers from a move to autarky, given this population growth, would have been labour and, especially, capital: they would have lost anyway as a result of diminishing returns (column 4 of Table 6), but absent trade their losses would have been much greater.

Why did Britain become more dependent on trade during the Industrial Revolution? The answer lies partly with the unbalanced nature of technological change during the period, but endowment changes were almost twice as important in explaining the increased welfare cost of autarky between the 1760s and 1850s.

IV. Conclusion

We have been able to reproduce the standard finding that international trade was not very important to overall British welfare in the 1760s, in the context of an equally standard, convex general equilibrium model of the sort that rules out by assumption the kinds of mechanisms that can heighten the importance of trade. What is striking about our results is that the same, standard, convex general equilibrium model also finds that by the 1850s, the welfare costs of Britain no longer being able to trade with the rest of the world would have been very substantial – of the order of thirty per cent. It is worth emphasising once again 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 increasingly 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 2007). In the words of Brinley Thomas, “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” (Thomas 1985, p. 731).

Our results suggest that it was the second of these forces that played the greater role in heightening Britain’s dependence on international trade, although unbalanced productivity growth played an important role as well. Analyses that conclude that trade was irrelevant to the Industrial Revolution because it did not have a major aggregate welfare impact on the British economy prior to this great transformation ignore the crucial role of trade, and trade policy, on the key sectors involved in it. Our results show that they also miss the point that the Industrial Revolution itself, as well as the population growth that coincided with it, made Britain far more dependent on trade in aggregate terms than it had been hitherto. In that context, by the mid 19^{th} 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)	(16)
		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
Output																
Cotton textiles	100	98.9	133.4	125.6	98.6	133.3	125.4	101.6	133.3	128.0	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	74.0	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	101.0	92.3	93.0
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	91.0
Relative prices																
Cotton textiles	100	101.3	102.6	104.8	101.5	102.5	104.9	101.4	102.7	104.9	102.2	102.7	105.6	100.9	102.4	104.2
Other textiles	100	101.8	104.5	108.0	101.9	104.4	108.0	101.9	104.5	108.0	102.3	104.6	108.3	101.6	104.2	107.7
Iron and steel	100	99.7	99.1	98.0	99.6	99.1	98.0	99.6	99.2	98.0	99.6	99.2	98.2	99.6	99.1	98.0
Coal	100	100.4	101.0	101.4	100.4	100.9	101.3	100.3	101.0	101.3	100.4	101.0	101.4	100.3	100.9	101.3
Agriculture	100	107.0	117.6	131.7	107.0	117.6	131.7	107.0	117.7	131.7	107.1	117.7	131.9	106.7	117.2	131.5
Other	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Tropical raw materia	100	111.0	122.6	143.0	112.5	122.6	144.4	112.4	122.6	144.7	117.3	122.8	149.2	107.6	121.2	139.2
Tropical food	100	129.1	118.7	161.9	130.1	118.6	163.0	164.1	118.7	192.2	167.6	118.7	196.8	108.9	119.6	140.3
Real factor prices																
Real wage	100	95.7	92.1	86.1	95.6	92.0	86.1	94.2	92.1	85.2	94.0	92.1	84.8	96.8	92.1	87.0
Real profits	100	94.3	89.3	80.6	94.3	89.2	80.6	92.8	89.3	79.7	92.7	89.3	79.6	95.4	89.4	81.5
Real land rents	100	109.4	126.4	144.9	109.4	126.3	144.9	107.9	126.4	143.3	107.8	126.4	143.0	110.0	125.6	146.0
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 (the world as it actually was, with trade flows set to their actual levels). 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)	(16)
		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
Output																
Cotton textiles	100	92.0	65.8	41.3	85.3	65.7	41.3	90.9	65.8	41.3	82.2	65.7	41.3	98.0	66.4	41.6
Other textiles	100	90.2	90.0	74.3	90.3	90.0	74.3	89.9	90.0	74.3	89.7	90.0	74.3	90.5	90.1	74.3
Iron and steel	100	99.8	115.4	112.8	101.4	115.5	112.8	100.2	115.5	112.8	102.9	115.5	112.8	98.5	115.4	112.6
Coal	100	101.4	88.1	79.3	101.4	88.1	79.3	101.4	88.1	79.3	101.3	88.0	79.3	101.4	88.1	79.4
Agriculture	100	104.2	130.7	123.3	104.5	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	100.7	87.3	99	100.4	87.3	99	100.8	87.3	99.1	100	87.3	99
Relative prices																
Cotton textiles	100	106.7	131.9	297.4	111.4	132.1	297.4	107.5	131.9	297.4	114.1	132.1	297.4	102.7	130.7	295.5
Other textiles	100	102.8	123.4	151.3	103.1	123.4	151.3	103.2	123.4	151.3	104.2	123.4	151.3	101.9	123.2	150.6
Iron and steel	100	100.4	109.0	99.4	100.4	109.0	99.4	100.4	109.0	99.4	100.3	109.0	99.4	100.4	109.0	100.0
Coal	100	100.1	102.2	94.9	100.1	102.2	94.9	100.1	102.2	94.9	100.0	102.2	94.9	100.2	102.2	95.5
Agriculture	100.0	106.4	164.2	142.3	106.7	164.0	142.3	106.5	164.2	142.3	107.1	164.0	142.3	105.7	164.1	142.9
Other	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Tropical raw materia	100	114.9	170.1	532.7	125.3	170.3	533.3	116.6	170.1	532.7	131.2	170.3	533.3	106.3	167.3	528.8
Tropical food	100	113.1	170.8	532.1	116.3	170.8	532.1	117.4	171.0	532.1	126.0	171.0	532.1	106.2	167.6	528.8
Real factor prices																
Real wage	100	96.8	77.5	66.5	96.0	77.5	66.5	96.5	77.5	66.5	95.4	77.5	66.5	97.6	77.7	66.5
Real profits	100	95.5	76.6	63.3	94.7	76.4	63.3	95.3	76.6	63.3	94.1	76.4	63.3	96.5	76.8	63.3
Real land rents	100	110.9	212.2	139.8	111.0	212.2	139.8	110.8	212.2	139.8	110.7	212.1	139.8	110.6	212.7	140.7
Utility	100	97.7	89.8	72.5	97.0	89.8	72.5	97.4	89.8	72.5	96.4	89.8	72.4	98.4	90.0	72.6

Notes: BM = Benchmark (the world as it actually was, with trade flows set to their actual levels). 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 4. Impact of autarky, 1850s: further robustness checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	BM	Baseline	CTX=20	OTX=20	MET=20	COAL=20	OTHER=20	ELASC=1	ELASC=2
Output									
Cotton textiles	100	41.3	54.4	43.7	41.1	41.3	43.0	38.3	33.1
Other textiles	100	74.3	74.1	153.5	74.6	74.3	70.0	70.3	64.3
Iron and steel	100	112.8	111.8	92.4	104.2	112.8	74.8	122.5	125.8
Coal	100	79.3	79.6	86.5	78.8	78.9	85.8	98.0	117.3
Agriculture	100	123.3	123.6	134.8	122.1	123.3	121.1	124.5	119.2
Other	100	99	97.4	83.5	101.5	99.1	107.4	94.9	96.3
Relative prices									
Cotton textiles	100	297.4	290.7	184.2	311.0	299.4	118.3	216.4	170.1
Other textiles	100	151.3	149.7	137.3	153.4	151.6	112.7	135.8	123.3
Iron and steel	100	99.4	100.0	109.0	98.6	100.0	101.9	103.1	103.0
Coal	100	94.9	95.7	100.6	94.5	95.5	100.5	98.2	99.4
Agriculture	100.0	142.3	143.5	176.7	140.4	143.2	138.8	146.0	134.9
Other	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Tropical raw materials	100	532.7	517.4	284.8	563.0	536.1	142.6	355.3	253.7
Tropical food	100	532.1	516.1	284.2	561.6	535.5	142.3	354.9	253.2
Real factor prices									
Real wage	100	66.5	67.0	70.7	66.3	66.5	89.0	73.6	81.4
Real profits	100	63.3	64.3	68.5	62.0	63.3	78.6	72.0	79.8
Real land rents	100	139.8	142.7	221.3	134.1	139.8	171.2	163.5	153.6
Utility	100	72.5	73.1	84.0	71.4	72.4	93.3	81.4	87.6

Notes: BM = Benchmark (the world as it actually was, with trade flows set to their actual levels). Baseline = estimate of effects, relative to the benchmark, of setting non-British endowments equal to 5% of their benchmark level, assuming baseline elasticities; this is identical to column (4) of Table 3. Subsequent columns show the effect of changing elasticities, one at a time, on this estimate of the impact of autarky. CTX=20 shows the impact of autarky, assuming that the Armington elasticity of substitution in cotton textiles equals 20, and that other elasticities are at their baseline levels; OTX=20 does the same, assuming that the Armington elasticity of substitution in other textiles equals 20, and that other elasticities are at their baseline levels; MET =20 does the same, assuming that the Armington elasticity of substitution in iron and steel equals 20, and that other elasticities are at their baseline levels; COAL = 20 does the same, assuming that the Armington elasticity of substitution in coal equals 20, and that other elasticities are at their baseline levels; OTHER=20 does the same, assuming that the Armington elasticity of substitution in the rest of the economy equals 20, and that other elasticities are at their baseline levels.

Table 5. Growth in total factor productivity and endowments, 1760s-1850s (per cent per annum)

TFP growth	
Cotton	2.4
Other textiles	1.1
Iron and steel	1.4
Coal	0.2
Agriculture	0.3
Rest of economy	0.32
Total economy	0.486
Factor endowment growth	
Labour	1.2
Capital	2.1

Source: see text.

Table 6. Impact of changing endowments and TFP on the 1760s economy

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Benchmark	Actual TFP	Balanced TFP	Factor endowments	TFP & Factor endowments	TFP & FE & autarky	Impact of autarky (trade=100)
Output							
Cotton textiles	100	787.6	100.0	720.8	6492.2	1062.2	16.4
Other textiles	100	84.1	104.5	298.1	266.6	176.0	66.0
Iron and steel	100	278.2	99.0	4351.1	2360.1	511.4	21.7
Coal	100	111.5	98.5	512.4	411.8	359.1	87.2
Agriculture	100	78.9	98.9	138.7	114.3	168.1	147.1
Other	100	92.3	100.0	336.8	290.4	351.1	120.9
Relative prices							
Cotton textiles	100	15.3	95.2	109.4	14.5	25.0	172.4
Other textiles	100	45.0	90.6	129.5	46.7	100.0	214.1
Iron and steel	100	39.5	95.9	82.4	31.4	25.0	79.7
Coal	100	110.4	99.6	98.6	105.5	108.3	102.7
Agriculture	100	72.4	98.0	245.2	139.9	700.0	500.4
Other	100	100.0	100.0	100.0	100.0	100.0	100.0
Tropical raw materia	100	71.2	98.3	241.3	136.7	775.0	567.0
Tropical food	100	71.9	98.3	244.0	139.9	958.3	685.0
Real factor prices							
Real wage	100	166.0	158.3	71.3	145.3	52.5	36.1
Real profits	100	196.5	159.4	39.2	86.5	20.0	23.1
Real land rents	100	78.8	152.2	281.0	226.5	770.0	340.0
Utility	100	156.4	157.2	230.3	410.5	273.0	66.5
Per capita utility	100	156.4	157.2	81.6	145.4	96.7	66.5

Notes: BM = Benchmark (the world as it actually was, with trade flows set to their actual levels). Columns (2)-(6) express all variables relative to their values in Column (1). Column (2) increases sectoral TFP's in line with Table 5. Column (3) increases all sectors' TFP equally, in line with the total economy entry in Table 5. Column (4) increases the capital and labour endowments in line with Table 5. Column (5) increases sectoral TFP's and the labour and capital endowments in line with Table 5. Column (6) increases sectoral TFP's and the labour and capital endowments in line with Table 5, and also reduces non-British factor endowments to 5% of their benchmark level. Column (7) expresses all variables in column (6) relative to their values in column (5).

Table 7. Impact of increasing TFP and factor endowments on cost of autarky in 1760s

	(1)	(2)	(3)	(4)	(5)
	Impact of autarky, 1760				
	Actual	TFP	BTFP	FE	TFP&FE
Output					
Cotton textiles	125.6	37.3	130.2	82.3	16.4
Other textiles	73.9	75.0	75.6	64.2	66.0
Iron and steel	65.3	43.3	64.9	22.2	21.7
Coal	92.7	91.2	93.2	69.5	87.2
Agriculture	114.5	138.9	114.6	121.3	147.1
Other	90.9	100.0	91.0	103.0	120.9
Relative prices					
Cotton textiles	104.8	102.7	102.5	162.2	172.4
Other textiles	108.0	108.0	104.8	193.1	214.1
Iron and steel	98.0	93.8	98.0	88.0	79.7
Coal	101.4	101.7	101.2	104.0	102.7
Agriculture	131.7	168.1	131.2	290.6	500.4
Other	100.0	100.0	100.0	100.0	100.0
Tropical raw materia	143.0	184.4	141.9	322.2	567.0
Tropical food	161.9	219.6	161.0	380.2	685.0
Real factor prices					
Real wage	86.1	79.1	86.5	52.1	36.1
Real profits	80.6	65.2	81.1	34.5	23.1
Real land rents	144.9	236.6	145.1	191.6	340.0
Utility	96.7	90.6	96.7	81.7	66.5

Notes: Column (1) gives the impact (relative to a free trade benchmark of 100) of autarky in the 1760s (i.e. of reducing non-British endowments by 95%), i.e. it is identical to column (4) of Table 2. Column (2) shows what the impact of moving to autarky in the 1760s would have been if sectoral TFPs in 1760 had been at their 1850s levels. Column (3) shows what the impact of autarky in the 1760s would have been if sectoral TFPs had all increased proportionally in line with economy-wide TFP growth between the 1760s and 1850s. Column (4) shows what the impact of autarky in the 1760s would have been if factor endowments had been at their 1850s levels. Column (5) shows what the impact of autarky in the 1760s would have been if factor endowments and sectoral TFPs had been at their 1850s levels.

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 imports 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 re-exports 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 re-exports 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 re-exports 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	Agriculture	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	Agriculture	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	Agriculture	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).