Cheap Cloth, Dear Bread: Skewed Growth, Trade and the British Living-Standards Paradox*

Dalia Gutiérrez Valencia† Lucas Llach‡ Pablo Schiaffino§

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Abstract

The Industrial Revolution made Britain one of the richest nations on earth, and its workers ate barely more than their grandparents. Between the 1770s and the 1860s an English wage came to buy more than six times as much cloth and iron, but less than twice as much food, and food per head rose by only an eighth. Cloth got cheap. Bread stayed dear. We show why with a two-region model of England and the rest of the world. Productivity growth in cotton and iron, which only Britain made, lowered their price at home and abroad; the same growth in goods the rest of the world also made would have raised the English wage in bread. The Corn Laws, rebuilt from the statutes, kept foreign grain dear. The model accounts for most of the gap between cloth and bread and four-fifths of the rise in the food wage, though it puts wheat too dear after Waterloo and food per head too low. Part of the puzzle is an artefact of measurement: the standard calorie series leaves out the grain Ireland shipped to Britain free of duty, the back door of the Corn Laws, and adding it back removes a third of the fall in calories of the 1830s. What mattered was not how fast Britain grew but what its growth made cheap. Had productivity growth been spread evenly across sectors, at a pace that left real consumption the same, English workers would have eaten 12 per cent more food by the 1860s (4 to 13 per cent across our variants). Keeping the Corn Laws would have cut food per head by about a tenth.

Keywords: British Industrial Revolution; living standards; food puzzle; skewed technological change; relative prices; Corn Laws; Ireland.
JEL Codes: N13, N33, N53, O14, O41, F14.

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†Department of Economics, Universidad Torcuato Di Tella, Av. Figueroa Alcorta 7350, (1428) Buenos Aires, Argentina; dagutierrezvalencia@mail.utdt.edu

‡Department of History and Social Studies, Universidad Torcuato Di Tella; lllach@gmail.com

§Department of History and Social Studies, Universidad Torcuato Di Tella; pschiaffino@utdt.edu

1 Introduction

Few episodes in economic history have sustained a debate as durable as the standard of living during the British Industrial Revolution. The cliometric record indicates that real wages rose over the century after 1780—substantially by some estimates (Lindert and Williamson, 1983; Clark, 2005), modestly and late by others (Feinstein, 1998; Allen, 2009)—yet the anthropometric evidence points the other way: average heights stagnated and, for the cohorts born between the 1820s and the 1850s, declined (Floud et al., 1990; Komlos, 1998; Cinnirella, 2008). For an economy only beginning to leave the Malthusian world, in which calories were still a binding constraint on welfare, rising real incomes should have meant better nutrition and taller adults. They did not. This is the living-standards paradox.

The paradox is usually stated as one contradiction, between income and welfare. It is more useful to see it as two gaps, each of which calls for a different kind of explanation.

The first gap is between the wage measured in the goods that the Industrial Revolution made cheap and the wage measured in food. Take the day wage of an average English male worker from Clark (2009) and deflate it by the price of cotton cloth: between the 1770s and the 1860s it rises by a factor of seven. Deflate it by a composite of cotton cloth and manufactured iron, the two goods that stand for "modern" industry in the national accounts of Broadberry et al. (2015), and it rises by a factor of 6.3. Deflate it by the food basket of a working-class household and it rises by a factor of 1.9. No one was paid in cloth, and the first number is not a measure of welfare. It is a fact about relative prices, and the kind of fact a general-equilibrium model of production and trade can explain.

The second gap is between the wage in food and the food itself. Between the 1800s and the 1860s the wage in food rose by 91 per cent and national income per head measured in food by 62 per cent. Calories available per head in England, from domestic output and net imports, rose by 13 per cent, all of it in the last decade, after a dip in the 1830s (Broadberry et al., 2015). This is the British food puzzle of Clark et al. (1995), and it is a fact about demand and about measurement: about what households did with income measured in food, and about how the food they ate has been counted.

Our argument is that the first gap, and much of the slow rise of the wage in food, come from the composition of productivity growth, while the second gap comes from demand and partly from how the food supply has been measured. Productivity growth in Britain between 1770 and 1870 was not so much fast as concentrated. Total factor productivity grew at about 0.3 to 0.4 per cent a year in agriculture (+35 to +50% over the century; Clark, 2007, and our own accounts in Section 3) and 0.7 per cent in industry as a whole (+100%),

but inside industry a handful of branches grew several times faster than everything else: cotton at nearly 2 per cent a year (+600%), iron at about 1 (+170%) (Harley, 1999; Crafts, 2004, 2021b). On the output series of Broadberry et al. (2015), British industrial output per head more than doubled between 1800 and 1850, while agricultural output per head fell by about a quarter, on land that was fixed while population doubled.

The Industrial Revolution can therefore be pictured as an outward shift of the production possibility frontier concentrated almost entirely along one axis (Figure 1). On the per-head output series of Broadberry et al. (2015), taking 1800 as the base, production in 1850 was at about 220 in manufactures and 75 in food: more than twice the manufactures and three-quarters of the food. Trade separated consumption from production. Britain turned from a net exporter of grain in the mid-eighteenth century into a country that imported more than a third of its calories by the 1860s, and the consumption point of 1850 lay on a price line through the production point, at about the food per head of 1800 and 70 per cent more manufactures. The picture is a description, not a mechanism. Why the terms on which Britain traded moved as they did, and why consumption ended where it did, is what this paper explains.

The question is older than cliometrics. Adam Smith held that a nation poor in land could prosper by manufacturing and buying its corn abroad, as Holland bought it from Danzig (Smith, 1776, bk. IV, ch. v). Malthus answered, in 1798, that an increase in manufacturing wealth is not an increase in the "funds for the maintenance of labour": higher wages without more provisions would be eaten away by dearer food, faster growth on the land would come slowly, and he doubted that a large country could import its way out of the constraint as Holland had (Malthus, 1798, ch. xvi). To prevent industrialisation from stalling on Malthusian mechanics, a transition "from Malthus to Ohlin" (O'Rourke and Williamson, 2005), through trade and access to overseas land, or the presence of primary-producing peripheries alongside an industrial core (Pomeranz, 2000), becomes indispensable, especially when productivity gains are concentrated in the urban sector.

How much trade can do depends on what kind of open economy England was. It was largely a price taker in food and in what we call old manufactures, and the dominant supplier of the new ones. The point is easiest to see by comparing three economies that receive the same shock: productivity grows in manufactures and nowhere else. In a closed economy the price of manufactures falls at home, and with unit-elastic demand the allocation of labour does not change: the wage rises in manufactures and little or not at all in food. In an open economy that takes world prices as given, the price of manufactures does not fall, however much their productivity grows, and the wage rises in both goods by the full gain. In an open economy that is the dominant supplier of manufactures, their

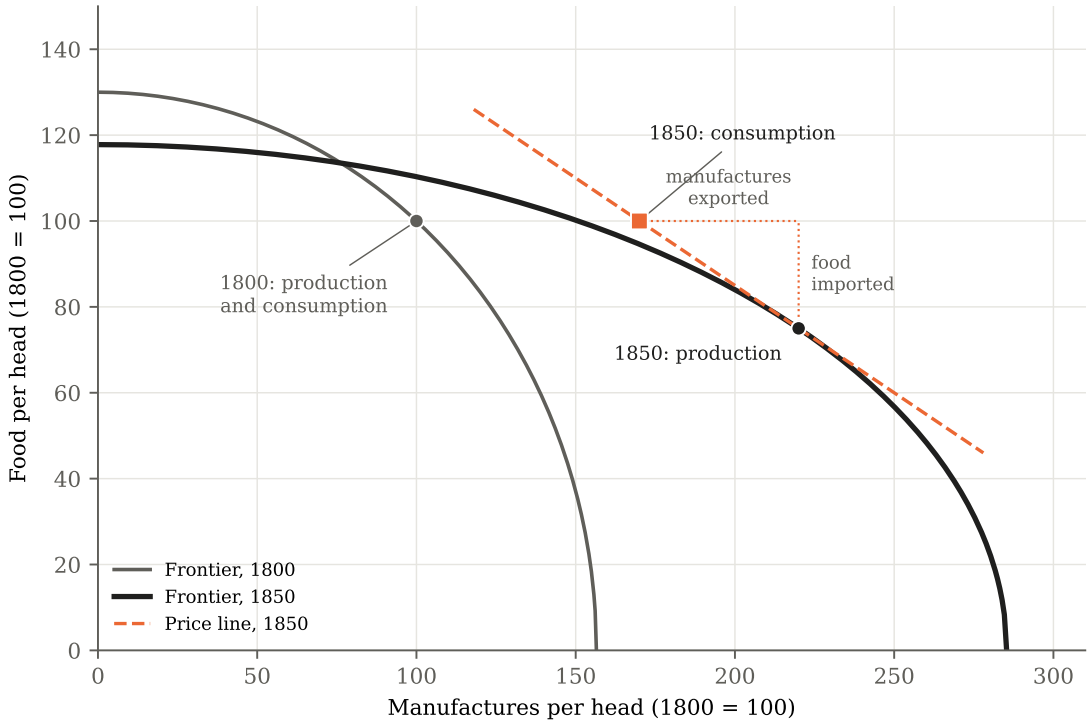


Figure 1: Production and consumption per head, 1800 and 1850. Food and manufactures per head, 1800 = 100. The production points are from the output series of Broadberry et al. (2015). Consumption in 1850 is placed at about the food per head of 1800, on a price line tangent to the 1850 frontier at the production point. The shapes of the frontiers and the slope of the price line are illustrative.

price follows its own costs and falls with them, for every buyer in the world. If it also makes other goods at world prices, as England did, the wage is set in those goods, and the gain in manufactures goes into their price. The result is much as in the closed economy: the wage rises in manufactures, and little or not at all in food. England was the third economy for cotton and iron and the second for old manufactures.

This is the resolution of the paradox we propose. The Industrial Revolution concentrated its productivity growth in goods of the third kind, whose gains went into their price, and left the wage in bread to the slow growth of goods of the second kind. Real wages rose, as the optimists hold, but far more in cloth than in bread, and food per head rose less still: nutrition barely improved, as the heights suggest.

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We build a two-region model of England and the rest of the world. England has four sectors: agriculture on fixed land, "old" manufactures that the rest of the world also makes, "modern" manufactures that only Britain makes and that the rest of the world buys from it,

and services. Modern manufactures use raw cotton imported from America, whose price we take from the record. England can buy grain at the continental price plus freight plus whatever duty the law in force imposes, and the English price of food moves within the band this defines, built, outside the French wars, from the statutes and the cost of freight rather than from English prices. Productivity growth in manufacturing and services comes from growth accounting on quantities (output, capital and labour), not from the fall of prices relative to wages, since those prices are what the model has to explain; prices enter only to divide manufacturing between modern and old. Agricultural productivity is set so that the model reproduces food imports and the farm share of employment.

The model reproduces part of the record and misses part of it. It raises the wage in food by a factor of 1.69 between the 1770s and the 1860s, against 1.88 in the data, about four-fifths of the rise in logarithms. It accounts for three-quarters to four-fifths of the rise in the price of food relative to modern manufactures, a fit that is in part a check on the prices of cloth and iron used to divide manufacturing. It runs too dear on wheat after Waterloo, when the wartime expansion of English agriculture left a glut it does not contain. And it makes food per head rise 6 per cent between the 1800s and the 1860s, against 12 to 13 in the data, largely because a one-food model cannot let wheat become cheaper than potatoes after repeal.

Along the way the model shows that the acceleration in the fall of cotton cloth prices between 1810 and 1840 was in large part the collapse of the price of raw cotton after the war: with raw cotton as an imported input, a constant rate of productivity growth in modern industry reproduces the timing of the fall in their relative price.

The dip in calories per head in the 1830s, the sharpest expression of the food puzzle, is partly an artefact of the series that records it. The calorie series of Broadberry et al. (2015), on which the puzzle now rests, counts as imports only grain from outside the United Kingdom, so it omits the grain Ireland shipped to Britain free of duty, which peaked exactly when foreign grain was kept out. Ireland was the back door of the Corn Laws. That Ireland fed industrial Britain was argued long ago by Thomas (1982). Adding back England's share of the grain that entered Britain removes a third of the dip if half of the oats went to horses.

The main counterfactual keeps the pace of the Industrial Revolution and changes only its composition: every English sector grows at the same rate, the average of the baseline's sectoral rates weighted by value added, so that agriculture and old manufactures grow faster than they did, services slightly more slowly and modern manufactures much more slowly. Everything else is left as it was. In that across-the-board revolution the first gap vanishes: the price of food relative to modern manufactures, which in the baseline rises

more than two-and-a-half-fold, stays flat. Food per head in the 1860s is 17 per cent higher, and real consumption per head 8 per cent higher. With the common rate set instead so that real consumption per head is the same as in the baseline, food per head is 12 per cent higher: the balanced economy is no richer, but better fed. It moves productivity from goods of the third kind to goods of the second. The size of the gain runs from 4 to 13 per cent across our variants, and as little as 1 if old manufactures both grew fast and had a market of their own; it depends above all on how fast productivity grew in old manufactures, the worst-measured part of the record.

The other counterfactuals score the oldest debate on the question. Faster productivity growth in agriculture alone would have raised food per head by about 3 per cent. Keeping the Corn Laws after 1846 would have cut it in the 1860s by about a tenth: 11 per cent with the statutory duty, 9 with the duty actually collected. Never passing the law of 1815 would have raised it in the 1830s by at most two-fifths, the limit that the small-country case of Williamson (1990) implies, and by less than a fifth if British demand had raised Baltic prices as Fairlie (1969) assumed. Smith was right about levels, if by less than a small-country calculation suggests. Malthus was right about the outcome and wrong about its cause. He expected manufacturing growth to raise wages in money but not in provisions, because provisions would grow scarce on fixed land. Bread did grow dear, but against cloth, not against pottery, nails or cutlery: relative to those it was a fifth dearer at the height of protection and only 5 per cent dearer by the 1860s. It was cloth that moved. Trade relaxed the constraint of land, as the Corn Laws showed by tightening it; what held back the wage in bread was where productivity grew.

Related literature. In emphasising the relative price of food we follow Komlos (1998). In explaining it we depart from him. Komlos attributed dear food to diminishing returns and slow capital accumulation in agriculture. We show that the relative price of food against the goods that became cheap is a direct consequence of where productivity grew, that it survives in an economy that imported a third of its calories, and that it is consistent with wage series in which real wages rose even in food. Clark et al. (1995) framed the food puzzle and proposed three partial resolutions: the rising share of processing and distribution in the food bill, a falling income elasticity of food, and substitution towards goods that became cheap. We keep the first, measure it with their own multiplier, and add a fourth, the Irish grain that is missing from the supply series. Like Crafts and Harley (2000) we use a transparent general-equilibrium simulation to discipline narratives about the period, and like Clark et al. (2014) we find that biased technological change and population growth made Britain dependent on trade. Crafts (2021a) argues that the same bias made

growth pro-rich. Our contribution is to put these pieces around the question of living standards, with the level of productivity measured from quantities rather than from the prices to be explained, the barrier to imported grain built from the Corn Laws themselves, and the food supply corrected for Ireland. Like Williamson (1990) we treat the Corn Laws in general equilibrium. Unlike him, we ask what they did to the food of workers rather than to the incomes of classes. On the pessimist side, Mokyr (1988) found little gain in consumption before 1850. On the composition of growth, Crafts and Harley (1992) defend a narrow, slow Industrial Revolution and Temin (1997), from the pattern of trade, a broad one, which in our terms would mean faster growth in old manufactures and a smaller gain from balance.

The rest of the paper proceeds as follows. Section 2 documents the two gaps, the Irish correction and the gap between English and continental grain prices. Section 3 discusses where productivity grew and how we measure it. Section 4 presents the model and its calibration, and Section 5 confronts it with the record. Section 6 presents the across-the-board counterfactual, and Section 7 reads the remaining counterfactuals against Smith and Malthus. Section 8 concludes. The online appendix documents the data and the robustness of the results.

2 The paradox in the data

2.1 The wage in cloth and the wage in bread

Table 1 takes one nominal wage, the decadal average of the male day wage in Clark (2009), and deflates it by five price indices. The choice of deflator moves the "real wage" between the 1770s and the 1860s from a rise of 88 per cent to one of 608 per cent.

Table 1: The wage of an average English male worker under alternative deflators

Deflator	1770s→1840s	1770s→1860s	1800s→1860s
Food			
Workers' food basket (Clark, 2009)	1.56	1.88	1.91
Manufactures bought by households			
Household manufactures (Clark, 2009)	1.87	1.97	1.59
Modern manufactures			
Cotton cloth (Clark, 2009)	8.50	7.08	3.49
Cotton and iron, geometric 0.76/0.24	6.87	6.26	3.46
All consumption			
Workers' cost of living (Clark, 2009)	1.61	1.92	1.83

Note. Ratio of the wage deflated by each index between the decades shown. Nominal wage: decadal average of the male average day wage in Clark (2009). Cotton cloth and manufactured iron (in the composite; the wage in iron alone rises 4.25-fold) are Clark's individual price series (Clark, 2009, Appendix Table A1). The cotton–iron composite weights cotton cloth by 0.76 and iron by 0.24, their relative weights in the industrial price index of Broadberry et al. (2015) (22 and 7 per cent, iron without the hardware we count among old manufactures), which are also the weights of the modern sector in the model. Deflated by the agricultural prices of Broadberry et al. (2015) the wage rises 1.63-fold between the 1770s and the 1860s, and by Clark's clothing and bedding 2.36-fold.

Three things stand out. First, the manufactures a working household actually bought became cheaper, relative to the wage, about as fast as food did: the wage in Clark's household manufactures rose by a factor of 2.0 between the 1770s and the 1860s, and the wage in food by 1.9. Clark's index of manufactured goods is made of the items of a household inventory—pewter, pottery, nails, cutlery, spades, paper—and his clothing index is dominated by woollen cloth and suits, with cotton cloth at 2 to 8 per cent. Second, the divergence is concentrated in the goods the Industrial Revolution made: the wage in cotton cloth rose sevenfold, and the wage in a composite of cotton and iron more than sixfold. Third, the cost of living of a working household rose about as much as the wage in food, because food was most of it.

The two wages are linked by an identity: the wage in food is the wage in cotton and iron times the price of cotton and iron in food. The first rose by a factor of 6.3 between the 1770s and the 1860s; the second fell to less than a third, since the price of food relative to modern manufactures rose 3.3-fold (Section 5); their product is the 1.9 of Table 1. The whole of the first gap is a relative price.

The first gap, stated with care, is therefore between the wage in modern manufactures, which rose by a factor of six to seven, and the wage in food, which rose by a factor of less than two. No one was paid in cloth, and the wage in modern manufactures is not a measure of welfare: it is an index of a relative price, the fall in the price of cotton goods whose size Harley (1998) and Cuenca Esteban (1994, 1997) have debated, and the model

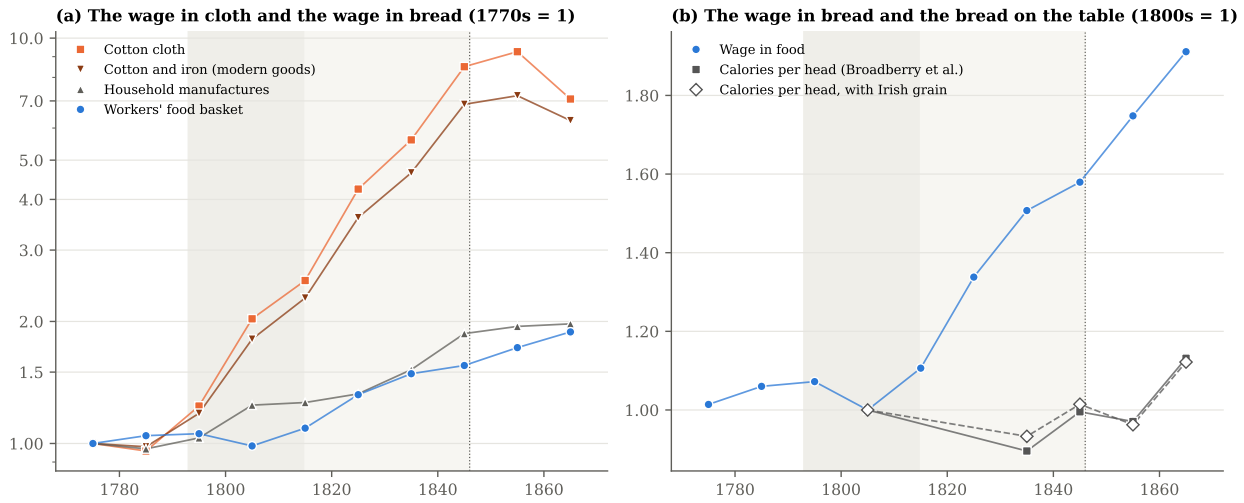


Figure 2: The two gaps. (a) Clark's male day wage deflated by four price indices, 1770s = 1, log scale. (b) The wage in food against calories per head, 1800s = 1. Calories from Broadberry et al. (2015, Table 7.06); the corrected series adds the grain Ireland shipped to Britain (Section 2.3). Shading marks the French wars (1793–1815) and the Corn Law period (1815–1846).

has to explain that relative price together with the price of food. Figure 2(a) shows its chronology: it opens with the war, widens fastest between 1815 and 1845, and narrows slightly in the 1860s, when the American Civil War cut the supply of raw cotton. That is the fact a model of skewed productivity growth has to deliver.

The nominal wage is a male day wage, mostly from the building accounts of institutions, and it is not household income. Days worked rose (Voth, 2001; Humphries and Weisdorf, 2019), the earnings of women and children first rose and then fell (Horrell and Humphries, 1992, 1995), and the rates paid by institutions to contractors may overstate what workers received (Stephenson, 2018). These caveats bear on the level and growth of household income, not on the relative prices that define the first gap, since every deflator in Table 1 divides the same wage. They do bear on the second gap, which compares a wage with consumption; for that comparison the relevant income is national income per head in food, which rose 62 per cent between the 1800s and the 1860s, and it is national income, not the day wage, that drives the demand for food in the model.

2.2 The wage in bread and the bread on the table

The wage in food rose 91 per cent between the 1800s and the 1860s; national income per head, measured in the same food basket, rose 62 per cent (Clark, 2009). Calories available per head, computed by Broadberry et al. (2015) from domestic output and net imports, were 2,176 a day in the 1800s, 1,949 in the 1830s, 2,166 in the 1840s, 2,112 in the 1850s and

2,462 in the 1860s: a rise of 13 per cent at the very end and none before (Figure 2b). With an income elasticity of food expenditure of 0.6, which Clark et al. (1995) estimate from working-class budgets, a 62 per cent rise in income per head in food would predict about a third more food. This is the second gap.

Clark et al. (1995) offered three partial resolutions. The first is that what people ate was increasingly not what farms produced: the ratio of the value of food and drink consumed to the value supplied by agriculture and net imports, which they call the value-added multiplier, rose from 1.27 at the end of the seventeenth century to 1.43 in 1800 and 1.57 in 1850 and 1867, as bread, beer and meat went through mills, breweries, railways and shops. A given rise in food expenditure therefore bought a smaller rise in farm output. The second is that the income elasticity of food falls as income rises; the third, that cheap coal, clothing, sugar and tea substituted for calories. Our model incorporates the first directly, using their multiplier. It does not need the second, which works through a redistribution of income towards the rich that is hard to square with real wages that rose faster than income per head (Clark, 2009). And it adds a fourth, to which we now turn.

2.3 Ireland: the back door of the Corn Laws

The calorie series of Broadberry et al. (2015, Table 7.06) is for England—English output, divided by a population of 9.1 million in the 1800s and 20.1 million in the 1860s, which is that of England and Wales—and takes its net imports from the foreign trade statistics of the United Kingdom (Mitchell, 1988), which it attributes wholly to England. For Irish grain, which entered Great Britain, we attribute to England only its share of the British population, 84 per cent (with Wales, as in the population that divides the series), and we treat half of the oats as horse fodder. Broadberry et al. (2015, 283) measure domestic oats net of what farm animals ate and then deduct a fixed allowance for non-farm horses (Table 7.03), whatever the origin of the oats those horses ate; on that accounting Irish oats would count in full, and treating half as fodder is our central case; Table 2 also reports the figures that follow from counting all the oats as food or as fodder. (The agricultural output per head cited in the introduction is, by contrast, British output over British population, from their national accounts.) Ireland was part of the United Kingdom from 1801, and after the customs union was completed in 1826 its trade with Britain left the overseas-trade accounts, although Parliament collected returns of it until 1842 and Bourke (1976) extends them to 1848. In the calorie series Irish grain is therefore counted neither as English output nor as an import: it is simply missing. And Ireland was, in the decades of prohibitive protection, the one source of grain that entered Britain free of duty.

That Ireland fed industrial Britain is not a new observation. Thomas (1982, 1985) made it the centre of an argument about how Britain escaped the Malthusian constraint, Ó Gráda (1994) and Solar (1987) document the pre-Famine growth of Irish farm output and exports, and Kelly and Ó Gráda (2013) and Meredith and Oxley (2014) have reworked British food supply in the period, the latter deducting what went to horses. Those reworkings are for Britain or the United Kingdom, where Irish grain is internal trade; our point is narrower: that the series for England on which the food puzzle has come to rest, Table 7.06 of Broadberry et al. (2015), omits it, and by how much. The correction is a bound on the dip, not a new estimate of supply.

The quantities were large. Mitchell and Deane (1962, Agriculture 9, from Parliamentary Papers 1843, vol. LIII) report the wheat and wheaten flour, barley, and oats and oatmeal imported into Great Britain from Ireland each year between 1800 and 1842. Irish wheat grew tenfold between the 1800s and the 1830s, from 58 to 610 thousand quarters a year; between 1832 and 1836 it was almost all the wheat Britain imported. Irish oats and oatmeal grew from 320 thousand quarters a year in the 1800s to nearly two million in the 1830s. Table 2 converts these quantities to calories per head of the English population, with the extraction rates Broadberry et al. (2015) use for domestic output.

Table 2: Grain imported into Great Britain from Ireland and from abroad, calories per head per day

	1800s	1810s	1820s	1830s	1840–42
From Ireland: wheat	9	19	50	60	17
From Ireland: oats and oatmeal	25	41	75	100	103
From Ireland: all grain	35	62	128	167	123
with England's population share, all of the oats as food	29	52	108	140	103
with half of the oats as fodder	22	41	91	117	72
and England's population share (central case)	18	34	76	98	60
with all of the oats as fodder, England's share	8	18	45	56	17
From abroad, net (Mitchell and Deane)	96	101	76	102	–
Net imports in Broadberry et al. (2015)	154	–	–	139	299[a]

Note. Thousands of quarters from Mitchell and Deane (1962, Agriculture 9 and 10), converted with the calories per bushel and the storage, milling and brewing losses of Broadberry et al. (2015, Tables 7.01–7.03), and divided by the population of England and Wales. The central case attributes to England 84 per cent of the grain entering Great Britain and treats half of the oats as fodder. [a] 1840s.

Two things follow. The first is that Broadberry et al. (2015) exclude Ireland. Their net imports match the overseas grain trade of the United Kingdom converted to calories without deducting losses (151 against their 154 in the 1800s, 157 against 139 in the 1830s), and not the trade of Great Britain including Ireland, which on the same basis would give 215 and 457 (Online Appendix A.3). Our central correction is, if anything, conservative: we deduct losses from Irish grain that they do not deduct from imports, we treat half of

the oats as fodder, and we add nothing for the cattle, pigs, butter and provisions Ireland also sent (Ó Gráda, 1994), which we have not quantified. A higher level of English calories, as Kelly and Ó Gráda (2013) argue for, would leave the Irish correction the same in calories and make it slightly smaller in proportion, without changing the sign or the timing of the dip. The second is that the correction matters exactly where the food puzzle bites. Adding Irish grain, calories per head in the 1830s fall 7 per cent below the 1800s instead of 10 (8 if all the oats were fodder, 5 if none were), and in the 1840s they are 1 per cent above instead of level; counting all the grain as English food, the fall is 4 per cent and the 1840s are 4 per cent above. The share of food from outside England in the 1830s is 12 per cent instead of 7 (15 at most). Part of the food puzzle of the Corn Law decades is an artefact of where the customs frontier ran.

2.4 The Corn Law wedge

The last fact concerns the wedge between the domestic and the world price of grain. We measure it as the percentage gap between the price of wheat in England (the Gazette average) and on the continent (Figure 3). Before 1815 the continental price is that of Danzig, the port that fed Holland in Smith's example, from the Parliamentary Papers as reported by Allen and Unger (2019), which gives it in English money and so avoids the wartime depreciation of the pound. From 1815 it is Hamburg, from the series compiled by the Statistisches Reichsamt (2008). Both are five-year centred means; the Amsterdam series of Allen and Unger (2019) gives a similar path. Online Appendix A.2 describes the construction.

The measured wedge is not the tariff. It includes freight, insurance and the costs of trade, which explains why it stood at 40 to 50 per cent in peacetime before the war, and it includes, in the years of prohibition, the gap between two separate markets rather than the cost of arbitrage between them. That is why it reaches 180 per cent in the mid-1820s, when English prices were held up by the Corn Law and continental prices collapsed in the post-war agricultural depression. It falls with the sliding scale, as Sharp (2010) documents for the statutory duty, and after repeal it converges to the 10 per cent or so of freight and handling that remained in the 1850s and 1860s. The measured wedge describes what separated the price an English household paid for bread from the price at which grain could be had abroad, but it cannot be fed into a model whose task is to explain the English price, because it is computed from that price. The model therefore builds the wedge, outside the French wars, from its components: the duty that each law imposed at each English price, and the cost of bringing grain from the Baltic (Section 4). Whether the

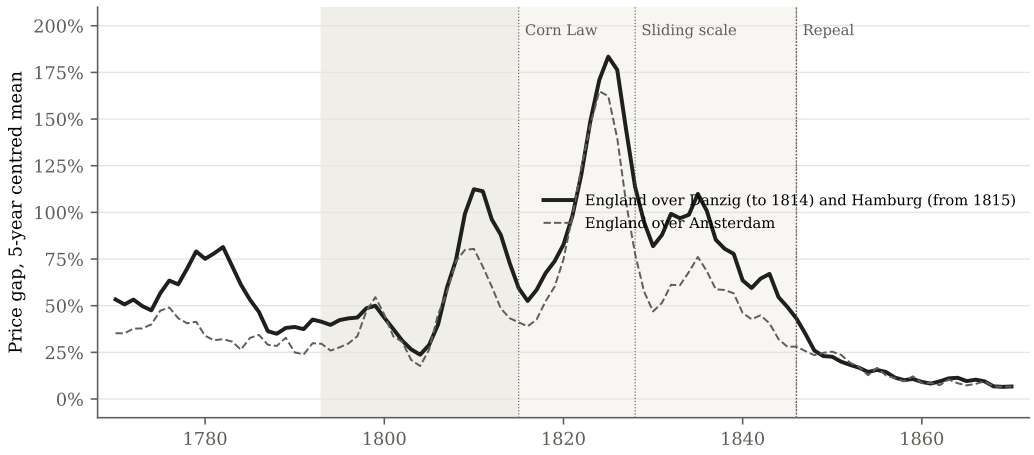


Figure 3: The wedge between the price of wheat in England and on the continent, 1770–1870. Five-year centred means. Vertical lines mark the Corn Law of 1815, the sliding scale of 1828 and repeal in 1846.

English price that results is the one observed is then a test of the model, and Section 5 reports it.

3 Where productivity grew

3.1 Quantities and prices

Sectoral productivity can be measured in two ways that agree in theory and disagree in practice. The primal method measures it from quantities: it subtracts share-weighted input growth from output growth. The dual method, first applied to this period by Antràs and Voth (2003), measures it from prices: it adds share-weighted factor-price growth and subtracts the growth of the output price. For Britain between 1770 and 1860 the dual gives faster productivity growth than the primal: 0.61 against 0.51 per cent a year for the economy as a whole in the most recent estimates (Crafts, 2021b, Table 5). The objects this paper sets out to explain are relative prices and real wages, and a model whose productivity had been recovered from those prices would reproduce them by construction. We therefore take the level of productivity growth in industry and services from the primal, use prices only to distribute it within industry, and, for agriculture, where the estimates diverge most, let the model choose a rate close to the lower published estimates.

The distribution is the difficult part, because primal estimates for individual branches do not exist. The rates for the modern branches in Harley (1999, Table 3.6), which revise those of McCloskey (1981) and which Crafts (2021b, Table 5) updates, are derived largely

from the fall in output prices relative to input prices, and so are dual in origin: 1.9 per cent a year for cotton, 0.95 for woollens and 0.9 for iron over 1780–1860 in Crafts's update. Clark (2007, Table 12.1), by the dual method throughout, finds 2.4 per cent for cotton and 1.4 for iron and steel. Neither gives a rate for the rest of industry: in both it is a residual, and in both it comes out close to zero. Because the division of industry between modern and old manufactures is the choice on which our results depend most, we estimate the dual rates ourselves, for cotton, iron and woollens and for twenty-one goods of the rest of industry, from the prices of Clark (2009) and a single method. Online Appendix E describes the calculation and the other choices this section summarises.

3.2 The rates

Table 3 collects the estimates and our choices. Our own primal accounts for 1800–1870, on the output series of Broadberry et al. (2015), the capital stock of Feinstein (1988), labour by sector from the census and social-table benchmarks, and the factor shares of Clark (2009), give 0.66 per cent a year for industry as a whole and 0.58 for services. The model, however, has no mines, and in it buildings are produced by the service sector. We therefore take mining and building out of industry: removing coal and construction from Broadberry's industrial output index with the weights of his industrial price index, and their capital and labour from the inputs, leaves manufacturing growing at 0.78 per cent a year, and adding building to services lowers their rate to 0.57. Mining and building absorbed much labour with little gain in productivity, so manufacturing grew faster than industry as a whole. The model applies these rates from 1770, although the same accounts give manufacturing only about 0.1 per cent a year over 1770–1800, when the output index weights the new trades least (Berg and Hudson, 1992); Online Appendix H reports the model with rates measured over 1770–1860. Our dual estimates reproduce those of Clark for the modern branches, 2.3 per cent a year for cotton cloth and 1.3 for bar iron in gross output, but give woollen cloth 0.3 rather than Crafts's 0.95, and the rest of manufacturing a small positive rate rather than zero, with silk, linen, hardware and paper above the average and pottery and cutlery below it. Because the primal total is a rate for value added, we express the dual rates in value added too, dividing each by the share of value added in the value of output. The rest of manufacturing is a weighted average of its trades, with the weights of the industrial price index of Broadberry et al. (2015), so that clothing and hardware count for more than candles or glass; it leaves out the goods whose prices fell with the repeal of excise duties. The branches are then weighted with the value-added shares of Crafts (2021b, Table 5) for 1820: cotton 7 per cent of national income, iron 2, woollens 5, and the rest of manufacturing

9, which is Crafts's 16 for the rest of industry less mining and building. So weighted, the dual rates imply productivity growth in manufacturing of about 1.5 per cent a year, nearly twice the primal. Scaling them down in the same proportion until they add up to the primal total gives cotton 1.7 per cent a year and iron 1.2, and modern manufactures, cotton and iron, 1.6 per cent a year in value added, or 1.23 in gross output once raw cotton is counted as an input; old manufactures, woollens and everything else, grow at 0.26.

Table 3: Sectoral productivity growth, per cent a year

		Modern		Old manufactures			
	Period	Cotton	Iron	Woollens	Rest	Agriculture	Services
Own primal	1800–70	0.78 (manufacturing); 0.66 (industry)				0.43	0.57
Harley (1999)	1780–1860	1.9	0.9	0.02[a]		0.7	–
Crafts (2021b)	1780–1860	1.9	0.9	0.95	0.25[b]	–	–
Clark (2007), dual	1760s–1860s	2.4	1.4	c. 0		0.3	–
Own dual, gross output	1780s–1850s	2.3	1.3	0.3	0.2	–	–
This paper, value added		1.69	1.18	0.32	0.23	0.29	0.57
by sector		1.58		0.26			

Note. Own primal: growth accounting on the output series of Broadberry et al. (2015), the capital stock of Feinstein (1988), labour shares by sector and the factor shares of Clark (2009); manufacturing excludes mining and building, and services include building. Harley (1999), Table 3.6; his agricultural rate is Crafts's older estimate. Crafts (2021b), Table 5; trade and transport 0.9. Clark, Table 12.1. The own dual estimates are described in Online Appendix E. [a] All sectors outside the modernised ones and agriculture. [b] The whole economy outside the four modernised sectors, by the primal method (0.39 by the dual). In the model the rate of modern manufactures applies to gross output, with raw cotton as an input, and is 1.23.

Agriculture is the sector on which the estimates disagree most: the older primal estimates of Crafts, which Harley adopts, give 0.7 per cent a year, Clark's dual 0.3, our own primal accounts 0.43, while Crafts (2021b) gives no rate for agriculture but 0.25 for the whole economy outside the modernised sectors; Clark (1999) argues that much of what looks like technical progress in agriculture was costly investment in soil fertility. Here the model helps, because given the rates of the other sectors it pins agriculture down with two quantities: food imports and the farm share of employment. With old manufactures at 0.26, an agricultural rate of 0.43 would leave England importing only 19 per cent of its food in the 1860s and keeping 29 per cent of its labour on the land; 0.29 brings imports to the record, 37 per cent, and the farm share to 25 per cent, against 24. We use 0.29, close to Clark's dual 0.3 and at the low end of the published estimates for agriculture. The price of this choice is that imports and farm employment are no longer tests of the model.

Two consequences should be stated at the outset. The first is that the relative size of the rates in industry comes from prices, including the prices of cotton cloth and iron against

which Section 5 measures the first gap, so the model's success in reproducing the price of food relative to modern manufactures is in part a check on the consistency of our own dual estimates, not a prediction. The genuine tests are on the side of food: its price, the wage measured in it and the food on the table. The second is that the level of productivity growth is primal, and slower than the dual would make it, in modern industry as well as outside it. With manufacturing and services primal and agriculture close to Clark's dual, the whole economy grows at about 0.51 per cent a year, the primal total of Crafts (2021b), and well below his dual total (0.61). Online Appendix H reports the model with faster rates outside modern industry, which bring the economy-wide total close to the dual.

3.3 Manchester and Georgia

The cheapening of cotton cloth was not all British. Raw cotton was a large part of its cost, and its price fell steeply once cotton growing, made practical by the gin of 1793, spread after the war into Alabama and Mississippi. Harley (2012) decomposes the price of a piece of grey printing cloth: in the early 1780s it sold for 49 shillings (at constant prices), of which 11 were raw cotton; in the early 1820s for 11 shillings, of which 4 were raw cotton. Raw cotton's share in the price rose from about a quarter to about a third, and Harley (1999) puts it at 25 per cent of the value of cotton output in 1815 and 31 per cent in 1841. The British value added in a piece of cloth fell to a fifth in forty years; raw cotton accounts for about a fifth of the fall in its price.

The timing of the two components differs. Relative to Clark's price of consumer manufactures, raw cotton fell little before 1810 and then by more than half between the 1810s and the 1820s, and again in the 1840s (Mitchell and Deane, 1962, Prices 11); the price of cloth fell steadily. A model without raw cotton would have to credit Manchester with what happened in Georgia, and would need a burst of British productivity growth between 1815 and 1840 to reproduce the path of cloth prices. With raw cotton as an imported input, 22 per cent of the cost of modern manufactures (the cotton share of their output times Harley's raw-cotton share, held constant in the model where Harley's rises from 25 to 31 per cent), a constant rate of productivity growth in modern industry does the job.

4 The model

The model is built to answer one question: given where productivity grew, how many people there were, how much land they had, and what the Corn Laws and the cost of shipping grain from the Baltic allowed, what happens to the wage measured in different

goods and to the food on the table? It is deliberately simple. There are two regions, England and the rest of the world. Time is annual, from 1770 to 1870. The object is England: its population, wages, prices and food supply. Productivity growth, for want of English accounts, is measured for Great Britain; foreign grain follows the convention of Broadberry et al. (2015), who attribute to England all the grain imported into the United Kingdom, and Irish grain is attributed by population. Each year is a static general equilibrium; the years are linked by population, which is exogenous, by the capital stocks, which accumulate out of saving, and by the allocation of labour between farm and town, which adjusts slowly.

4.1 Production

England has four sectors. Agriculture (A) produces food with labour, capital and a fixed quantity of land T:

$$Y_{A,t} = Z_{A,t}\, L_{A,t}^{0.50}\, K_{A,t}^{0.14}\, T^{0.36}, \tag{1}$$

with factor shares from Clark's accounts of farm income (Clark, 2009). Old manufactures (O), modern manufactures (N) and services (S) use labour and capital with a labour share of 0.73, the share of labour in non-farm income. Modern manufactures, which stand for cotton and iron, also use raw cotton, C, bought abroad at a price $p_{C,t}$:

$$Y_{N,t} = Z_{N,t} \left(L_{N,t}^{0.73} K_{N,t}^{0.27}\right)^{1-\kappa} C_t^{\kappa}, \qquad \kappa = 0.22. \tag{2}$$

Old manufactures are a homogeneous good, produced in both regions, traded freely and used as the numeraire; they stand for woollens, leather, hardware and the many crafts in which productivity grew slowly. Modern manufactures are produced only in Britain and sold at home and abroad at an endogenous price $p_{N,t}$. For iron this is an anachronism before 1800, when Britain still imported bar iron from Sweden and Russia; cotton, three-quarters of the sector, is not affected. Services are not traded. Productivity grows at constant sectoral rates: 0.29 per cent a year in agriculture, 0.26 in old manufactures, 0.57 in services and 1.23 in the gross output of modern manufactures, which is 1.6 in their value added (Section 3).

Capital is mobile across sectors within a year, but not across regions (drainage and enclosure are part of land, not of capital), and accumulates as $K_{t+1} = (1-\delta)K_t + sI_t/P_{I,t}$, where $s = 0.16$ is the saving rate (Online Appendix H reports a rate rising from 0.08 to 0.14), I_t national income, $\delta = 0.02$, and investment goods are a composite of manufactures (35 per cent) and structures produced by services (65 per cent). Labour is the English population of Clark (2009), which grows by a factor of 2.8 between 1770 and 1860.

4.2 The labour market

Non-farm sectors pay a common wage w_t. The farm wage $w_{A,t}$ is lower: in Clark's national accounts the average non-farm male wage exceeded the farm wage by 52 per cent in the 1770s, and the gap widened to 85 per cent by the 1860s. We model the gap in two parts. A permanent differential $\mu = 0.52$, which reflects the higher cost of urban life and the skill premium of the average non-farm worker, defines the allocation $\ell^*_{A,t}$ at which $w_t = (1+\mu)\, w_{A,t}$. Since Clark's gap compares the average non-farm worker, craftsmen included, with farm labourers whose wages omit food and lodging, 0.52 is an upper bound on the differential that would leave an identical worker indifferent between farm and town; Online Appendix H reports the model with $\mu = 0.20$. The actual farm share of employment moves only part of the way towards it each year,

$$\ell_{A,t} = \ell_{A,t-1} + \lambda\,(\ell^*_{A,t} - \ell_{A,t-1}), \qquad \lambda = 0.05, \tag{3}$$

so that the gap widens when labour is being pushed out of agriculture faster than it can move. We set the initial farm share at 45 per cent of employment, between the 48 per cent of the 1760s in Clark (1999) and the lower estimates of Shaw-Taylor and Wrigley (2008).

4.3 Demand

A fixed fraction $1 - s$ of national income is spent on consumption. Households split it between food and everything else with the price-independent generalised linear preferences of Boppart (2014). The share of food in consumption expenditure E_t is

$$\omega_t = \nu \left(\frac{p_{A,t}}{P_{X,t}}\right)^{\gamma} \left(\frac{E_t / L_t}{P_{X,t}}\right)^{-\varepsilon}, \tag{4}$$

where $P_{X,t}$ is the price of non-food consumption. With $\varepsilon = 0.40$ the income elasticity of food expenditure is 0.6, the value Clark et al. (1995) estimate from working-class budgets, and it does not drift with income. With $\gamma = 0.3$ the price elasticity of food demand is -0.7; Online Appendix H reports the case of a unit elasticity, $\gamma = 0$. With two goods the preferences are well defined as long as the food share does not exceed $(1-\gamma)/(1-\varepsilon) = 1.17$, which holds at every income reached in the simulations; since $\varepsilon > \gamma$, the restriction of Boppart (2014) holds locally rather than globally.

Food bought by households is not food produced by farms. Following Clark et al. (1995), a share ϕ_t of the food bill pays for milling, baking, brewing, transport and retailing, which services supply; the rest buys farm output. We set $\phi_t = 1 - 1/m_t$, where m_t is their

value-added multiplier, interpolated between 1.27 in 1695, 1.43 in 1800, 1.57 in 1850 and 1.57 in 1867. Farm food consumed per head is therefore $c_{A,t} = (1 - \phi_t)\,\omega_t E_t / (p_{A,t} L_t)$.

Non-food expenditure is split between manufactures and services with fixed shares, and manufactures are a CES composite of old and modern goods with elasticity of substitution σ:

$$P_{Q,t} = \left[a\, p_{N,t}^{1-\sigma} + (1 - a) \right]^{\frac{1}{1-\sigma}}. \tag{5}$$

We set $\sigma = 2.48$, the value at which modern goods reach 38 per cent of manufacturing value added in 1866–70, their weight in the industrial output index of Broadberry et al. (2015) once mining and building are left out: cotton has 22 per cent of the index, iron and steel other than the hardware we count among old manufactures 7, and mining and building 24.

4.4 The rest of the world

The rest of the world has agriculture, old manufactures and services, with the same technologies and factor shares as England, the same preferences, and the same slow reallocation of labour between farm and town ($\lambda = 0.05$). It does not produce modern manufactures; it buys them from Britain out of its own spending on manufactures, with the same elasticity σ, and the weight of modern goods in its basket is set so that Britain exports 40 per cent of its modern output in 1770. Its population grows at 0.65 per cent a year, the rate of European population between 1750 and 1850, and its productivity in old manufactures and services grows at the English rates. Its size is the one parameter for which the historical record gives only a range. In the baseline its labour force is six times England's: on the estimates of Bairoch (1982, Table 10), the United Kingdom produced 4.3 per cent of world manufactures around 1800 and Europe as a whole 28.1 per cent, so that Britain made about a sixth of Europe's manufactures, and the rest of Europe was the market in which its old manufactures competed and from which its grain came. Table 7 and Section 7 report the results for a rest of the world twice England's size, roughly the grain-exporting Baltic, and eighteen times, roughly the world.

One series is left free. The productivity of agriculture in the rest of the world is chosen, year by year, so that the continental price of grain in the baseline is the one observed at Danzig and Hamburg. The continental price of grain is thus an input, not a result: the model explains what England did given the price at which the rest of the world sold grain, not that price. It absorbs everything the model does not otherwise contain: harvests, the wars, the post-war glut that Fairlie (1965) describes, the opening of the Black Sea and of America. In the counterfactuals it is held at its baseline path, and the world price of grain,

relative to old manufactures, is then determined by what England does as well as by what the rest of the world produces. England is not assumed to be small in either market.

4.5 Trade in food

The world price of food, in units of old manufactures, is $p^*_{A,t}$, the price of grain in the rest of the world; in the baseline it equals the price of wheat at Danzig until 1814 and at Hamburg from 1815, divided by Clark's price of consumer manufactures. England can import at $p^*_{A,t}$ plus freight plus whatever duty the law in force imposes, and export at $p^*_{A,t}$ less freight. The domestic price $p_{A,t}$ therefore lies in a band,

$$p^*_{A,t} - f_t \;\le\; p_{A,t} \;\le\; \bar{p}_{A,t}, \qquad \bar{p}_{A,t} = \min\{\, p : p - d_t(p) \ge p^*_{A,t} + f_t \,\}, \tag{6}$$

where f_t is the cost of freight and handling and $d_t(p)$ is the duty payable, per quarter, when the English price is p. Food is imported only when the upper bound binds and exported only when the lower one does; within the band England, with Ireland, is self-sufficient, and the domestic price is whatever clears the domestic market. What England imports, the rest of the world exports, and the duty and freight are treated as a real cost of trade. Treating the duty as a cost rather than as revenue returned to households overstates the cost of protection, but not by much: in the baseline and in the Corn Law counterfactuals, the Malthusian one included, the duty collected averages at most about 1 per cent of national income in a decade and 2 per cent in a single year, so that returning it to households would raise food per head by less than 1 per cent. (It reaches nearly 4 per cent of income only in the 1830s of the economy balanced outside agriculture, which imports far more grain through the sliding scale.) The upper bound is built from the statutes, not from English prices (Online Appendix B). Until 1791 imports paid a nominal duty once the English price reached 48 shillings a quarter and a prohibitive one below it. From 1815 to 1827 they were prohibited below 80 shillings and free above it. From 1828 the duty followed the sliding scales of 1828, 1842 and 1846 as tabulated by Sharp (2010), and from 1849 it was a registration duty of one shilling. Freight and handling are 7.5 shillings a quarter to 1846, the figure Sharp (2010) and Fairlie (1969) use for the Baltic trade (the regression of Williamson (1990) implies about 10), falling to 4.5 shillings by 1856, which is what remained of the gap between English and continental prices once the duty was nominal. During the French wars, when freight and insurance rates are not known and the laws of 1791 and 1804 hardly bound, the band is set by the measured gap between English and Danzig prices. Apart from fixing the unit of the price of food in 1770, setting post-repeal freight and converting wheat to the farm basket (below), these are the only years in which

English food prices enter the model. The model works in units of old manufactures; its price of wheat in shillings is its relative price of food times Clark's price of manufactures, scaled to the English price of 1770, and when the upper bound binds that price is simply the continental price plus freight and duty. The price of wheat is therefore a test of the model only when England is inside the band, which the statutes allow before 1792 and between 1816 and 1848; Section 5 says in which of those years it was.

Two further features complete the food market. Ireland shipped grain to Britain free of duty throughout; we treat it as a supply outside the band, equal each year to the Irish grain of Section 2.3 attributed to England, with half of the oats as fodder, as a share of English output, from 1800 to the famine. And the model has a single food, while the wheat that England imported became cheaper after 1846 than the potatoes, hay and oats that it did not; we therefore carry the continental price of wheat over to the farm basket with the observed English ratio of arable prices to wheat, a price within the food basket that the one-good model cannot explain but that does not involve the level of food prices relative to anything else (Online Appendix C).

4.6 Equilibrium and calibration

Given the capital stocks, the populations, the farm labour shares, productivity, the laws in force, freight, Irish grain and the price of raw cotton, an equilibrium in year t is a set of prices—the English and the world price of food, the price of modern manufactures, the prices of services and the wages in each region—and allocations such that firms maximise profits, households spend as above, the world markets for grain and modern manufactures and the domestic markets for services clear, food trade respects the band, and each region's trade is balanced through old manufactures. We solve it year by year. Table 4 lists the parameters and their sources.

5 The baseline against the record

Table 5 separates what the calibration targets from what the model has to predict. Two things in the second column are only partly free: the relative price of modern manufactures and the wage measured in them depend on dual rates computed from the prices of cloth and iron.

Table 4: Parameters

Parameter	Value	Source or target
Taken from the literature		
Productivity growth: manufacturing, services	0.78, 0.57%	Primal accounts on Broadberry et al. (2015) and Feinstein (1988); mining left out, building in services
Division of manufacturing: modern (value added; gross), old	1.6 (1.23), 0.26%	Own dual rates by branch, prices of Clark (2009); weights of Crafts (2021b, Table 5) and Broadberry et al. (2015) (Online Appendix E)
Raw cotton share in modern manufactures	0.22	Harley (1999, 2012)
Factor shares in agriculture (labour, capital, land)	0.50, 0.14, 0.36	Clark (2009)
Labour share outside agriculture	0.73	Clark (2009)
Income elasticity of food expenditure	0.6	Clark et al. (1995)
Food value-added multiplier	1.38 (1770) to 1.57 (1860s)	Clark et al. (1995)
Saving rate, depreciation	0.16, 0.02	Constant; a rising rate in Online Appendix H
Population	7.0 (1770) to 19.7 million (1860)	Clark (2009)
Rest of the world: size, population growth	6 times England, 0.65%	Bairoch (1982); European population
Taken from series		
World price of food, baseline		Danzig to 1814, Hamburg from 1815 (Allen and Unger, 2019; Statistisches Reichsamt, 2008), over Clark's manufactures; matched by the path of agricultural productivity in the rest of the world
Duties on imported wheat		Statutes of 1773, 1791, 1804, 1815, 1828, 1842 and 1846 (1s. from 1849) (Sharp, 2010)
Freight and handling	7.5s to 1846, 4.5s from 1856	Sharp (2010), Fairlie (1969)
Band during the French wars		England over Danzig, measured
Irish grain	0 to 7% of English output (annual)	Mitchell and Deane (1962, Agriculture 9)
Price of raw cotton $p_{C,t}$		Mitchell and Deane (1962, Prices 11) over Clark's manufactures
Calibrated		
Farm share of employment, 1770	0.45	Clark (1999), Shaw-Taylor and Wrigley (2008)
Manufacturing and services shares of employment, 1770	0.27, 0.28	Broadberry et al. (2015), building in services, mining left out
Non-farm/farm wage differential μ	0.52	Clark's wages, 1770s
Speed of farm labour adjustment λ	0.05	Farm share of employment, 1800–1860
Agricultural productivity growth	0.29%	Food imports and farm employment, 1860s (Section 3)
Elasticity of substitution, old/modern σ	2.48	Modern share of manufacturing, 1866–70
Price elasticity parameter γ	0.3	Price elasticity of food -0.7
Exports of modern goods, 1770	40% of output	Assumed; cotton exported most of its output, iron much less
Food trade, 1770	none	English price inside the band

Table 5: What the calibration targets and what the model predicts

Targeted	Not targeted
Farm share of employment, 1770, and its path 1800–1860 (λ)	Price of wheat, 1770–91 and 1819–27
Non-farm/farm wage gap, 1770s (μ)	Wage in food
Food imports, 1860s (agricultural productivity)	Food per head, and its dip in the 1830s
Modern share of manufacturing, 1866–70 (σ)	Food imports before the 1860s
Continental price of grain (agricultural productivity abroad)	Wage in old manufactures and in all manufactures
English price over Danzig, 1793–1814 (the band)	Land rents in national income
Freight after repeal (English over Hamburg, 1850s)	Widening of the wage gap after 1770
Arable over wheat prices in England (farm basket)	
Exports of modern goods, 1770	Agriculture's share of output and relative productivity
Prices of cloth and iron relative to wages (division of manufacturing, partly)	Price of food relative to modern manufactures, wage in modern manufactures (partly)

The price of food. Figure 4 shows the price of wheat in shillings a quarter: the Gazette average, the price in the model, the continental price, and the price at which importing paid under the law in force. By construction the model's price is a prediction only when England is inside the band. In practice that means most years of 1770–91 and 1819–27; in 1816–18 and from 1828 to 1848 the model's price sits at the ceiling of the statutory band, so what is tested there is the band itself. In the first window it passes: 46 shillings on average in 1770–91, against 45 in the data. In the second it fails. From 1815 to 1827 the ceiling was 80 shillings; the English price approached or passed it in 1816–18 and then fell far below it, to an average of 59 shillings in the 1820s, when England and Ireland fed themselves. The resumption of cash payments in 1819–21 lowered all money prices, and through Clark's price of manufactures it lowers the model's price in shillings too; what the model misses is that grain fell further than manufactures, the relative price that the glut and the harvests explain. The model follows the first movement but not the second: its price is 11 shillings above the Gazette in the 1820s, 7 in the 1830s (and up to 12 in the cheap years 1833–36) and 2 in the 1840s. The miss of the 1820s is a failure of the model; that of the 1830s, when the model is at the ceiling, reflects the statutory duty, which was higher than the duty actually collected on grain released from bond (Online Appendix H). After 1849 the band is narrow

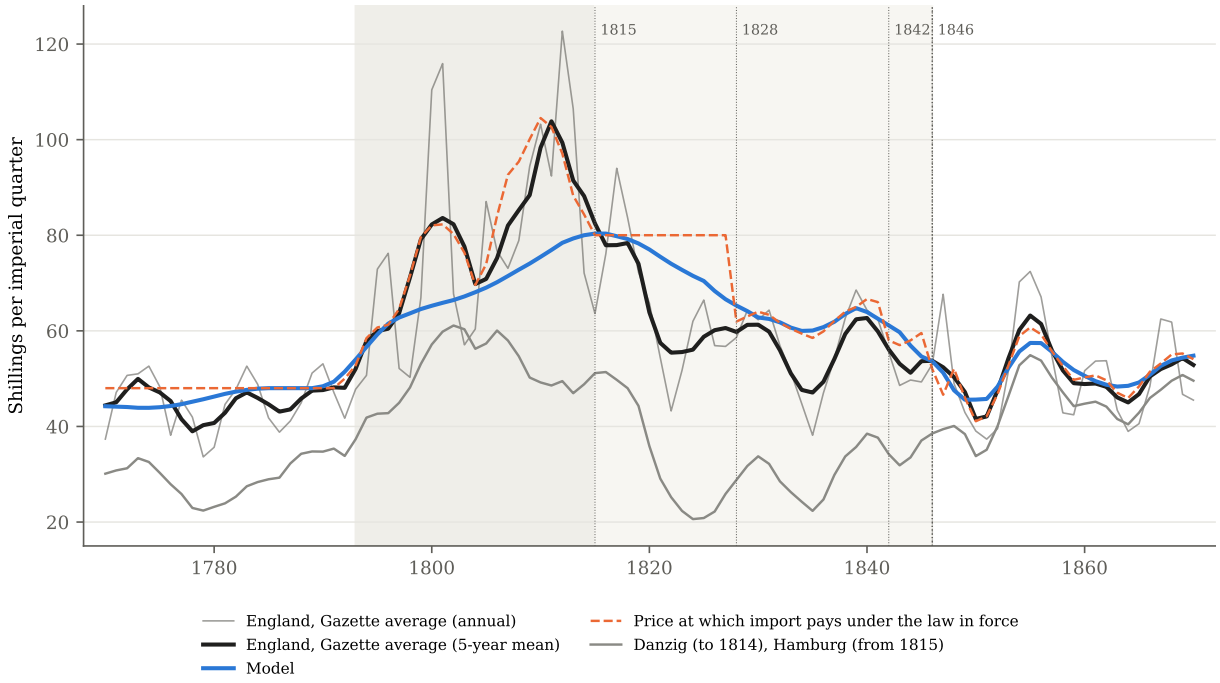


Figure 4: The price of wheat, 1770–1870, shillings per imperial quarter. The model's price is a five-year centred mean. The price at which import pays is the lowest English price p at which p less the duty then in force covers the continental price plus freight; during the French wars it is the measured English price. Vertical lines mark the laws of 1815, 1828, 1842 and 1846.

and the model's price follows the continental one, as the English price did, but that is no test.

The failure has a historical reading. Fairlie (1965, pp. 564–567) describes the post-war years as a glut: English farmers "who had increased their overheads and invested heavily in marginal lands in response to wartime prices" faced floods of cheap imports once the blockades were lifted (Fairlie, 1965, p. 564, n. 4), and prices collapsed. The model captures the continental side of the glut, through the path of agricultural productivity abroad that reproduces the collapse of Baltic prices, but not the English side: it has no wartime investment in English land to unwind, and no harvests. The same absence explains the war, when the model's price rises smoothly from 53 to 82 shillings while the English price reached 80 to 100 in years of harvest failure and blockade. The miss of the 1820s and 1830s matters for what follows: it raises the model's price of food in the decades of protection, lowers its wage in food then, and enlarges the gain from never passing the law of 1815 (Section 7).

The first gap. Figure 5 sets the baseline against eight panels of data from Clark (2009) and Broadberry et al. (2015). The price of food relative to modern manufactures rises

to 2.18 times its level of the 1770s by the 1820s, 2.98 by the 1840s and 2.66 by the 1860s, against 2.55, 4.34 and 3.30 in the data: the model accounts for three-quarters of the rise to the 1840s and four-fifths of the rise to the 1860s, in logarithms. The record depends on how cotton and iron are weighted: we weight them, as in Table 1, by their weights in the industrial price index of Broadberry et al. (2015), 0.76 and 0.24; with weights of 0.55 and 0.45 the record is 3.6 by the 1840s and 3.0 by the 1860s, and the model accounts for between five-sixths and nine-tenths of it. As Section 3 explained, the relative size of the productivity rates in manufacturing comes from our dual estimates, which use Clark's prices of cloth and iron, so this is partly a check of consistency. With the weights of Table 1, Harley's branch rates applied to gross output would fit the first gap better than our baseline in the 1840s (Online Appendix E); we prefer the baseline for its consistency with a primal total in value added and for its fit on the side of food, not for its fit on the first gap. The wage in modern manufactures, which combines that relative price with the wage in food, rises by a factor of 3.7 between the 1770s and the 1860s, against 6.3 in the data, and falls behind from the 1810s.

Raw cotton matters here. Without it, and with the same productivity growth, the price of food relative to modern manufactures in the 1840s would be 2.4 instead of 3.0: the collapse of the price of raw cotton between the end of the war and the 1830s, as cotton growing spread into Alabama and Mississippi, accounts for much of the acceleration of cheap cloth between 1810 and 1840 (Online Appendix H). British productivity growth in modern industry can be constant and still produce it.

The wage in food. The wage in food rises by a factor of 1.69 between the 1770s and the 1860s, against 1.88 in the data: with primal productivity the model accounts for about four-fifths of the rise, in logarithms. When England imports at the margin, the price of food is set abroad, and the wage in food is the wage in old manufactures divided by a world price that the model takes from the record. The shortfall is therefore a shortfall of the wage in old manufactures, which rises by 1.59 in the model and by 1.97 in Clark's index of household manufactures, and its source is the slow growth of productivity in old manufactures and services and of capital per worker. With agriculture and old manufactures growing at 0.43 and 0.38 per cent, which puts the economy-wide total close to the dual, the wage in food rises by 1.81 (Online Appendix H), and with the whole gap between primal and dual attributed to modern industry, by 1.98 (Online Appendix E). Productivity closer to the dual thus closes the shortfall, but we cannot claim more than that: the dual is itself inferred from wages, and the variants that close it do worse elsewhere, one on imports and the other on the first gap. Capital deepening cuts the other way: with a saving rate rising from

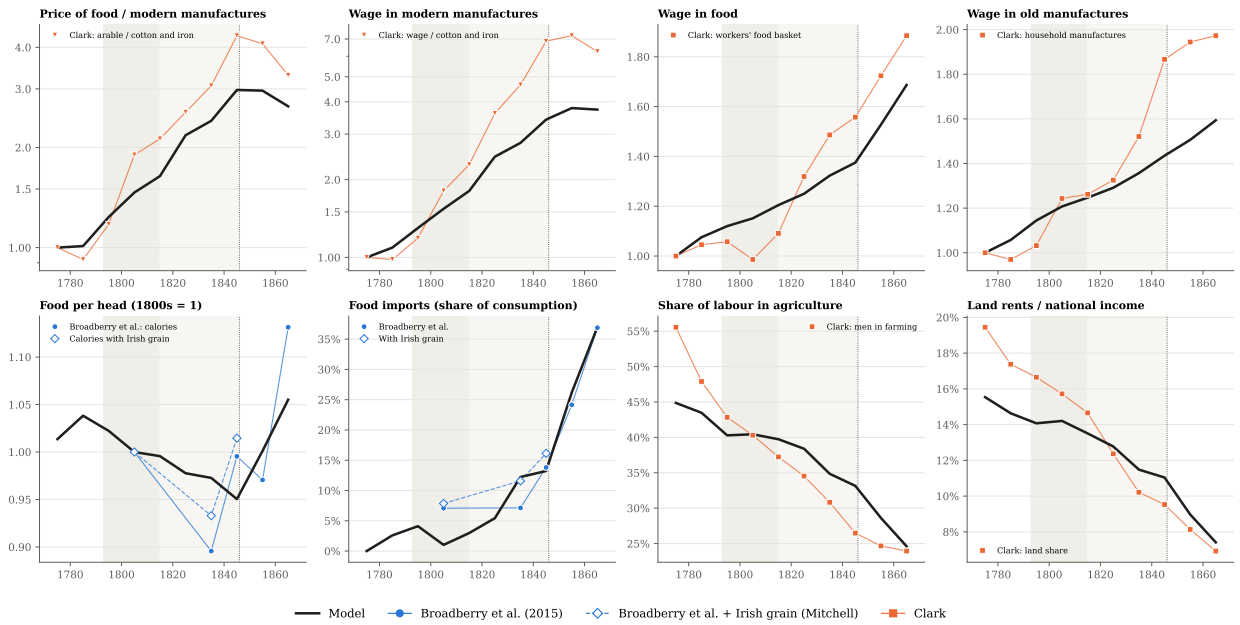


Figure 5: The baseline model against the record, decadal averages. Price and wage panels are indexed to the 1770s. The wage in food of the model is the average of farm and non-farm wages over the price of final food, which includes processing and distribution, and is compared with Clark's working-class food basket. Old manufactures in the model are compared with Clark's index of household manufactures. Modern manufactures in the data are the cotton–iron composite of Table 1. Food imports in the model include Irish grain. Calories with Irish grain add the central-case row of Table 2. Shading marks the French wars and the Corn Law period.

0.08 to 0.14, closer to the record of the eighteenth century, the wage in food rises by only 1.59. The model's wage in all manufactures rises by 1.96, against 2.36 in Clark's clothing index.

The second gap. Food per head in the model rises 6 per cent between the 1800s and the 1860s, against 13 in the calorie record and 12 when Irish grain is added. In the 1830s it is 3 per cent below the 1800s, against 10 per cent below in the uncorrected series and 7 with Irish grain; in the 1840s, 5 per cent below, against zero and 1 per cent above. Food from outside England, Irish grain included, is 12 per cent of consumption in the 1830s, as in the corrected record, and 37 per cent in the 1860s. The model's wage in food and its income per head in food rise far more than food per head, as in the data, for three reasons: an income elasticity of food expenditure of 0.6; a food bill in which processing and distribution take a growing share; and a price of food that stays high relative to everything except services. The second gap comes from the first two, which the model takes from Clark et al. (1995): with a unit income elasticity food per head would rise 28 per cent, and with the share of processing and distribution held at its level of 1770, 18 per cent (Online Appendix H).

Irish grain, which enters the model as an exogenous supply free of duty, matters for the measured record rather than for the model's food per head: from 1828, when the model's price sits at the ceiling of the band, it displaces foreign grain one for one; in 1819–27 it lowers the English price instead.

The model makes food per head more stagnant than it was, and most of the difference after 1846 comes from its single food. To carry the continental price of wheat over to the farm basket we multiply it by the English ratio of arable prices to wheat, which had risen by a sixth by the 1860s as potatoes, hay and oats, which were not traded, became dearer relative to wheat, which was. In a one-food model this makes all food dearer. Without the adjustment, food per head rises 17 per cent and the wage in food by 1.86, both close to the record, but imports reach half of consumption (Online Appendix C). The truth lies between: a model with a traded grain and non-traded other food would let wheat become cheaper without making potatoes cheaper. We do not build it, because the across-the-board and Corn Law counterfactuals compare economies with the same food basket, and the adjustment moves them together: removing it changes none of them by more than about a point (Online Appendix C). But the reader should read the model's shortfall in food per head as partly an artefact of it.

The structure of the economy. The share of labour in agriculture falls from 45 per cent in 1770 to 25 per cent in the 1860s, against 24 in Clark's series, a path the calibration targets. The share of land rents in national income, which it does not target, falls from 16 per cent in the 1770s to 7 in the 1860s, against 19 and 7 in Clark's accounts. The gap between non-farm and farm wages, set at Clark's 52 per cent in 1770, widens to 84 per cent in the 1860s, against Clark's 85; with the smaller permanent differential of Online Appendix H it widens much less. Online Appendix G compares the model's agricultural sector with the two readings of the record in Clark (1999); it is closer to Clark's than to Crafts's.

6 An across-the-board revolution

Suppose the Industrial Revolution had not been skewed. Keep everything as it was—population, land, capital accumulation, the Corn Laws and the cost of freight, the rest of the world, the price of raw cotton, preferences—but let productivity in England grow at the same rate in every sector. Which rate is a matter of definition, and we use two. The first is the average of the baseline sectoral rates weighted by the value added of each sector in 1780–1860, 0.51 per cent a year, so that the aggregate rate of productivity growth is the same in both economies. The second chooses the common rate, 0.45 per cent, so that real

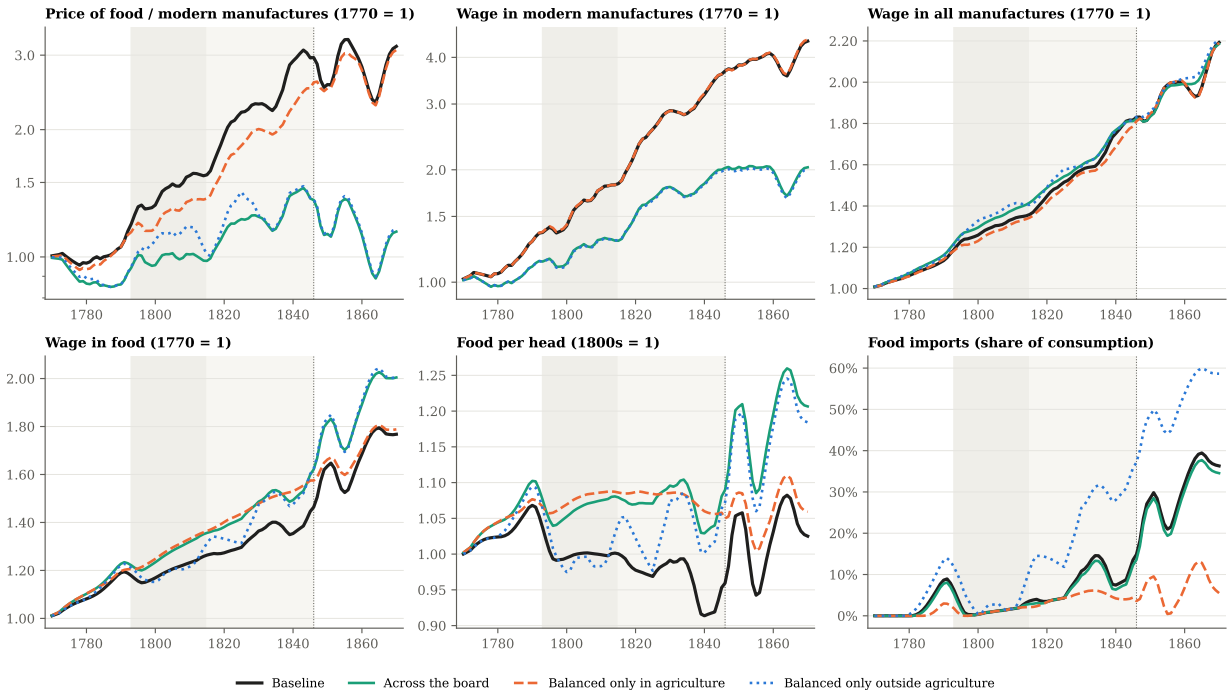


Figure 6: The baseline and three balanced revolutions: productivity growth at the same aggregate rate in every English sector, only in agriculture, and only outside agriculture. Five-year centred means of annual model output.

consumption per head in the 1860s is the same as in the baseline, measured with a Fisher index of the prices of food and of everything else; it isolates the composition of growth from its effect on income. In both, agriculture and old manufactures grow faster than in the baseline, services slightly more slowly and modern manufactures much more slowly. The rest of the world keeps its baseline path of productivity, but the world prices of grain and of modern manufactures now respond to what England does. Figure 6 and Table 6 compare the economies.

Table 6: Skewed and balanced productivity growth, 1860s

	Baseline	Across the board		Balanced only	
		same real consumption	same aggregate rate	in agriculture	outside agriculture
Common rate (% a year)		0.45	0.51	0.51	0.51
Price of food / modern manufactures (1770s = 1)	2.66	1.02	1.02	2.61	1.03
Wage in modern manufactures (1770s = 1)	3.73	1.65	1.78	3.76	1.75
Wage in all manufactures (1770s = 1)	1.96	1.84	1.99	1.95	2.02
Wage in food (1770s = 1)	1.69	1.76	1.90	1.70	1.91
Food per head (baseline 1800s = 1)	1.06	1.18	1.23	1.09	1.21
Food per head (baseline = 1)	1	1.12	1.17	1.03	1.15
the same, diverging from the baseline only in 1800	1		1.11	1.02	1.10
Real consumption per head (baseline = 1)	1	1	1.08	1.03	1.06
Food from outside England (% of consumption)	37	36	35	10	58
Share of labour in agriculture (%)	25	24	24	31	17

Note. "Same real consumption": every English sector grows at the rate that leaves real consumption per head in the 1860s equal to the baseline's, measured with a Fisher index of the price of final food and of non-food consumption, with each economy's budget shares. "Same aggregate rate": every sector grows at the average of the baseline rates weighted by value added in 1780–1860. "Balanced only in agriculture" and "outside agriculture": the sectors named grow at that rate, the others as in the baseline. Modern manufactures' rate refers to value added. The rest of the world is held at its baseline path of productivity; world prices are endogenous. The balanced economies diverge from the baseline from 1770, except in the row marked "diverging only in 1800".

The first gap disappears. The price of food relative to modern manufactures, which rises more than two-and-a-half-fold in the baseline, ends the century where it began, and the wage in modern manufactures rises about as much as the wage in food: by a factor of 1.7 or 1.8 rather than 3.7. Cheap cloth was the product of where productivity grew, not of how fast.

The wage in food and food per head both rise. At the same real consumption, food per head in the 1860s is 12 per cent higher than in the baseline and the wage in food 4 per cent higher, while the wage in all manufactures is 6 per cent lower: the balanced economy is no richer, but it is better fed. Compensation is imposed in the 1860s; in earlier decades the balanced economy is up to 2 per cent richer, and the Laspeyres and Paasche indices of real consumption in the 1860s differ by less than a tenth of a point. With a saving rate rising from 0.08 to 0.14 instead of a constant 0.16, the gain at the same real consumption is again 12 per cent. At the same aggregate rate it is also richer, by 8 per cent in real consumption, and food per head is 17 per cent higher. The second gap, between the wage in food and food per head, is about as wide in every column, because it comes from the demand for food, not from the composition of productivity growth. Two-fifths of the gain at the same aggregate rate is already in place by the 1800s—food per head is 7 per cent above the baseline in that decade—because the common rate exceeds the baseline's rate in agriculture from 1770, before the modern sector had grown much; if the balanced economy diverges from the baseline only in 1800, food per head ends 11 per cent higher.

The size of England in world markets matters little: with a rest of the world twice or eighteen times England's size the gain at the same aggregate rate is 16 or 17 per cent, and at the same real consumption 11 or 12. How easily households substituted old for modern manufactures matters more at the same aggregate rate, between 13 and 22 per cent with σ between 1.9 and 3.1, mostly because the elasticity changes the weight of the fast-growing sector and so the common rate; at the same real consumption the range narrows to 10–13. The weights of the common rate matter in the same way: with the value-added shares of the 1780s it is 0.43 per cent and the gain 10 per cent, with those of the 1850s 0.60 and 24 per cent. That is why we put the compensated experiment first.

It is natural to object that England was a large exporter of woollens and hardware, not only of cotton, and that faster growth in those goods too would have driven down their price. In the model the rest of the world also makes old manufactures, and when England makes more of them the rest of the world makes fewer and grows more of its own food; the world price of old manufactures relative to grain hardly moves. Modern manufactures are different because no one else made them. Online Appendix F gives English old manufactures a price of their own and a finite elasticity of demand. The objection is right in direction and moderate in size: with elasticities between 10 and 2 the gain at the same real consumption is 7 to 9 per cent instead of 12, because faster growth in English old manufactures then also lowers their price and passes part of its gain abroad.

The other uncertainty is the division of productivity growth within manufacturing (Figure 7). The more of the primal total one attributes to old manufactures, the better the model does on the side of food, the worse on the first gap, and the smaller the gain from balanced growth: at the same real consumption, 10 to 12 per cent with the other ways of combining the trades of old manufactures, and 4 per cent when the whole gap between primal and dual is placed in modern industry. The two uncertainties compound: with the whole gap in modern industry and English old manufactures a variety of their own, the gain is 1 or 2 per cent at the same real consumption and 2 to 4 at the same aggregate rate. Table 7 collects every variant. Productivity growth in old manufactures is the worst-measured part of the period's record, and our central number inherits that uncertainty.

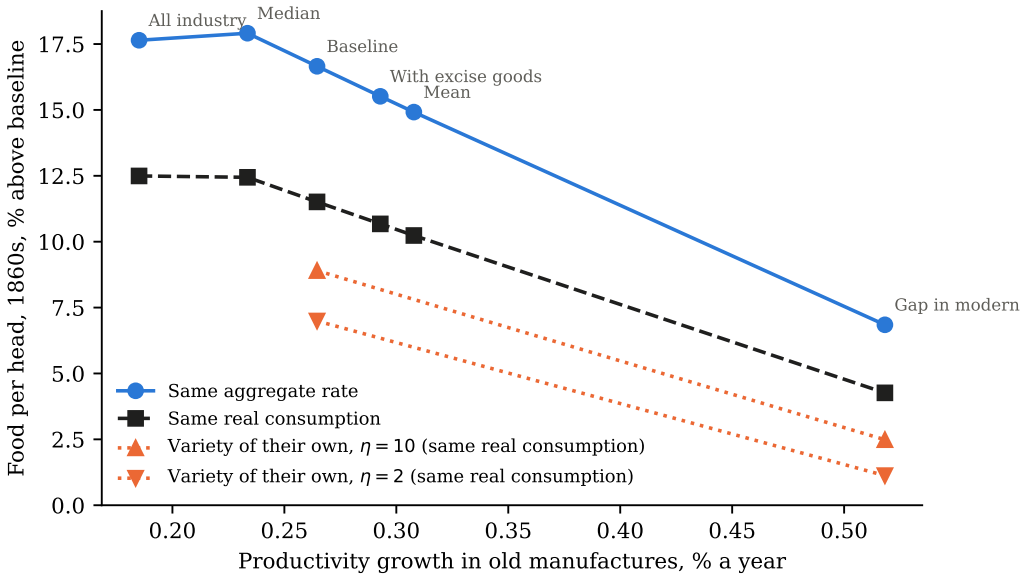


Figure 7: The gain from balanced growth against productivity growth in old manufactures, for the divisions of manufacturing of Online Appendix E. Food per head in the 1860s, per cent above each division's own baseline, at the same aggregate rate and at the same real consumption; the triangles give English old manufactures a variety of their own (Online Appendix F), at the same real consumption. Productivity growth in old manufactures, per cent a year: all industry 0.19, median 0.23, baseline 0.26, with the excise goods 0.29, mean 0.31, gap in modern industry 0.52.

Table 7: The gain from balanced growth under each variant: food per head and real consumption per head in the 1860s, per cent above each variant's baseline

	Same aggregate rate			Same real consumption
	Food, from 1770	Food, from 1800	Real consumption	Food, from 1770
Baseline	17	11	8	12
World market				
Rest of the world twice / eighteen times England's size	16 / 17	11 / 11	7 / 8	11 / 12
English old manufactures a variety of their own ($\eta = 10, 5, 2$)	13, 11, 10	8, 7, 6	6, 5, 5	9, 8, 7
Preferences, labour market and saving				
$\sigma = 1.9$ / $\sigma = 3.1$	13 / 22	9 / 14	5 / 12	10 / 13
Farm/non-farm wage differential $\mu = 0.20$	15	10	7	10
Saving rate rising from 0.08 to 0.14	16	11	6	12
Productivity in manufacturing				
Rest of manufacturing: with the excise goods / median / mean	16 / 18 / 15	10 / 12 / 10	7 / 8 / 7	11 / 12 / 10
Old manufactures as all of industry	18	12	8	12
Whole primal–dual gap in modern industry	7	5	4	4
and English old manufactures a variety of their own ($\eta = 10, 5, 2$)	4, 3, 2	3, 2, 1	3, 2, 2	2, 2, 1
Rates measured over 1770–1860	14	10	6	10
Agriculture and trade				
Imports attributed to England by population share	17	11	9	11
Agriculture 0.43, old manufactures 0.38 (reference)	14	10	8	9

Note. Each variant has its own baseline and its own common rate. Real consumption: Fisher index, 1860s, per cent above the variant's baseline. Agriculture held at its homogeneous-case rate in the Armington rows (Online Appendix F, panel A).

The last two columns of Table 6 ask where the gain comes from. Balancing growth in agriculture alone raises food per head in the 1860s by 3 per cent; faster growth of domestic

farm output mostly replaces imports, which fall from 37 to 10 per cent of consumption. The gain is larger earlier, 8 per cent in the 1800s, when England was nearly self-sufficient and its price was set at home; once it imported at the margin, and above all after repeal, the price of food was set abroad and more English grain mostly displaced foreign grain. Balancing growth outside agriculture raises food per head by 15 per cent. Slowing modern manufactures to the common rate, with every other sector as in the baseline, lowers real consumption by 8 per cent and raises food per head by less than 1: modern growth made England richer, but none of it reached food. The wage in food of an open economy is set largely by the productivity of the goods it sells at prices that do not fall as it sells more. Old manufactures are such goods: productivity growth there raises the wage in the numeraire and, at a nearly given world price of grain, the wage in bread. Modern manufactures are not: Britain was their only supplier, and faster productivity growth there lowered their price, at home and abroad. As Harley (1999) puts it, the competitive structure of the cotton industry passed the benefits of technical change to consumers, two-thirds of whom were foreign. The case recalls the immiserising growth of Bhagwati (1958), without its extreme: foreign demand for British modern goods in the model is elastic, with an elasticity of about σ, and growth in them does not make Britain worse off, but it turns the terms of trade against it. In the model Britain exports 41 to 47 per cent of its modern output in every decade, cotton and iron together, less than Harley's two-thirds because iron was sold mostly at home. Its terms of trade, with fixed weights for exports of modern and old manufactures and imports of grain, raw cotton and other goods (the last priced as old manufactures), fall by 28 per cent between the 1800s and the 1860s, against 35 per cent in the Bank of England series (Thomas and Dimsdale, 2017), which rests on Imlah (1958). The model's index is not its own terms of trade but an index of model prices at rough historical weights: modern goods 0.55 of exports, grain 0.15 and raw cotton 0.20 of imports, and old manufactures, the numeraire, the rest of both; with 0.45, 0.10 and 0.15 the fall is 24 per cent instead of 28. It is a check on the price of modern goods, not a target. The timing differs: the record falls sharply during the French wars, which the model's trade does not feel, and the model falls faster afterwards, by a third between the 1820s and the 1860s against a quarter in the record. The difference is on the side of imports. Relative to Clark's price of manufactures, the model's export price falls between the 1820s and the 1860s by about as much as the record's (13 and 14 per cent), but its import price rises by 30 per cent against 14, because its imports are only grain and raw cotton, both cheap in the glut of the 1820s and dear in the 1860s, the decade of the cotton famine, whereas the record's import price covers everything Britain bought.

This is the sense in which the composition of productivity growth, given its pace,

accounts for the first gap and for much of the slow rise of the wage in food. The skew of the Industrial Revolution made modern manufactures cheap, which opened the first gap. It concentrated productivity growth in goods whose gains were passed on through lower prices, which kept the wage in food from rising as fast as the wage in cloth. And it left the food wage to be carried by the slow productivity growth of farming and of everything else.

7 Smith and Malthus

The question this paper asks is older than cliometrics. Adam Smith held that a nation poor in land could prosper by specialising in manufactures and trade, as Holland did with corn from Danzig (Smith, 1776, bk. IV, ch. v). Malthus answered, in the chapter of the *Essay* on "the probable error of Dr. Adam Smith", that not every increase in a nation's wealth is an increase in the "funds for the maintenance of labour" (Malthus, 1798, ch. xvi). He did not deny growth: he conceded that a nation accumulating manufacturing capital would grow richer, that wages would rise, and that "improvements in manufacturing machinery" would greatly increase the annual produce. His point was about incidence: "any general rise in the price of labour, the stock of provisions remaining the same, can only be a nominal rise, as it must very shortly be followed by a proportional rise in the price of provisions." And he anticipated the two escapes a modern economist would propose, doubting both: that dearer food would pull capital back to the land, which "may take place very slowly", and that trade would bring provisions from abroad, which a small maritime country such as Holland could manage but which in "large countries less advantageously circumstanced" would require a very high price of provisions.

7.1 The first escape: productivity on the land

Section 6 has already asked what faster productivity growth in English agriculture would have done, holding everything else as it was. It would have raised food per head in the 1860s by 3 per cent over the baseline, and by 4 per cent if the rest of the world had been only twice England's size, so that English farm output also lowered the price of the grain England bought abroad. Malthus was right that a large country is not Holland and that its food depended in part on its own land. But the agricultural revolution alone does about a fifth of what the balanced one does at the same aggregate rate, and a quarter of what it does at the same real consumption (Table 6).

7.2 The second escape: trade, and the Corn Laws

By 1815 the question of trade had become a matter of law. Malthus weighed the arguments in his *Observations* of 1814 and came down for restriction in the *Grounds* of 1815, on grounds of security and stability of supply, warning that free importation would "greatly lower" the money wages of the labouring classes (Malthus, 1814, 1815). Ricardo's *Essay*, written in reply to both, turned on distribution: protection pushed cultivation onto poorer land, raised rents and lowered profits (Ricardo, 1815).

The two positions define our remaining counterfactuals. In the *Malthusian* one the Corn Laws are not repealed: the sliding scale of 1842 remains in force from 1846. In the *Ricardian* one the law of 1815 is never passed: from 1815 grain enters free of duty, paying only freight. In both, the price of grain in the rest of the world responds to British purchases. How much it responds was the point on which the historiography divided. Williamson (1990) treats Britain as small in the grain market; Fairlie (1969, Table 3) assumes that half of the gap between English and Prussian prices, net of freight, would have been closed by a rise in the Prussian price. In the model, with a rest of the world six times England's size, the continental price rises by 4 per cent in the 1830s, and with one twice its size, by 10 per cent. We report Williamson's and Fairlie's cases alongside, both in the model with England small in both markets, the latter by letting the continental price rise with British imports at the rate ($\psi = 0.75$, Online Appendix B.5) at which it closes about half the gap; these two columns are therefore bounds rather than nested variants of the structural model.

Table 8: The Corn Laws kept and the Corn Laws never passed

	Baseline	Malthus:	Ricardo: no Corn Law from 1815			
		1842 law kept	Model	Model, rest of world 2×	Williamson	Fairlie
1820s						
Food per head (baseline 1800s = 1)	0.98	0.98	1.49	1.43	1.53	1.28
1830s						
Price of wheat (shillings a quarter)	62	62	38	39	37	47
Continental price (baseline = 1)	1	1	1.04	1.10	1	1.28
Wage in food (1770s = 1)	1.32	1.32	1.84	1.79	1.87	1.59
Food per head (baseline 1800s = 1)	0.97	0.97	1.34	1.30	1.36	1.16
Food from outside England (%)	12	12	59	57	60	44
Labour in agriculture (%)	35	35	19	19	19	24
Land rents in national income (%)	11.5	11.5	4.7	5.0	4.5	6.9
1860s						
Price of wheat (shillings a quarter)	51	62	50	50	50	52
Wage in food (1770s = 1)	1.69	1.49	1.76	1.75	1.76	1.70
Food per head (baseline 1800s = 1)	1.06	0.93	1.08	1.08	1.08	1.05
Food from outside England (%)	37	14	50	49	50	43
Labour in agriculture (%)	25	32	17	18	17	20
Land rents in national income (%)	7.4	10.6	5.8	5.9	5.8	6.7
Growth of food per head, 1800s to 1860s (%)						
	6	−7	8	8	8	5

Note. Malthus: the sliding scale of 1842 stays in force from 1846. Ricardo: from 1815 grain pays only freight. Model: the rest of the world six times England's size; in the next column, twice England's size, roughly the grain-exporting Baltic. Williamson: the continental price is the one observed. Fairlie: the continental price rises with British imports of foreign grain above their baseline level, $\psi = 0.75$, in the model with England small in both markets. Prices of wheat are model prices of the farm basket converted to wheat at the observed ratio, averaged by decade. Food from outside England includes Irish grain.

Keeping the Corn Laws would have cost a good deal (Table 8; Online Appendix I plots the paths). By the 1860s the price of food would have been a fifth higher than it was, the wage in food and food per head both more than a tenth lower, and food per head 7 per cent lower than in the 1800s rather than 6 per cent higher. England would have remained largely self-sufficient, with nearly a third of its labour force on the land instead of a quarter, and landowners would have kept a tenth of national income instead of 7.4 per cent. The statutory scale overstates the barrier somewhat: with the duty at the rate actually collected under the scale of 1842 (two-thirds of the statutory one; Sharp, 2010), food per head in the 1860s is 9 per cent below the baseline rather than 11. The two are bounds, since the average ratio of collected to statutory duty, applied in every year, understates the barrier (Online Appendix H). This is the counterfactual closest to the record and to the exercise of Williamson (1990), and in it Malthus's prediction of 1798 holds: manufacturing growth continues, the wage in modern goods rises as fast as in the baseline, and the food on the table falls.

Never passing the law of 1815 would have done the opposite, and quickly. In the 1830s

the price of wheat would have been 38 shillings instead of 62, grain from outside England would have supplied three-fifths of consumption, food per head would have been 38 per cent above the baseline and land rents would have taken under 5 per cent of national income instead of 11.5. These are upper bounds. The baseline overpredicts the English price, by 7 shillings in the 1830s and 11 in the 1820s: measured against the observed price of 55 shillings, the fall of the 1830s is about a third rather than two-fifths, and the larger gain of the 1820s, about a half, mostly measures the baseline's error. The rest of the world in the model can shift labour into grain and export it on a scale that the historical Baltic could not. With a rest of the world twice England's size the gain falls to 34 per cent; Fairlie (1965, p. 565, n. 5) took British wheat imports of 1838–42 from Prussia (Poland), the rest of Germany and Denmark, about 1.3 million quarters a year, as a fair guide to their normal surplus, less than a tenth of English wheat consumption, while the model imports more than half of English food; and on her assumption about prices the gain falls to 19 per cent. Williamson's small-country case (40 per cent) is a limit, not a feasible outcome, and his large-country variant makes the prices of manufactures, not of grain, respond to Britain. And the model has no invisible earnings or capital flows, so the imported grain is paid for with manufactures alone. The slow movement of labour off the land, by contrast, does not hold the gain down: with farm labour free to move within the year the farm workforce would fall to 5 to 7 per cent of employment, which no economy of the period approached, and the gain in the 1830s would be about the same, 43 per cent. By the 1860s, when the actual duty had fallen to a shilling, food per head is about the same in every version (1.05 to 1.08 against 1.06): from 1849 the Ricardian and the historical economies have the same trade regime, and with exogenous productivity trade can move the level of consumption but not its long-run growth.

Read in that light, Smith and Malthus were talking about different things. Smith's optimism about trade was about levels, and the Ricardian counterfactual vindicates him on that ground, if by less than a small-country calculation suggests. Malthus was concerned with dynamics: manufacturing growth, however vigorous, could not by itself make a nation better fed. He was right about the outcome and wrong about its cause. He expected wages to rise in money but not in provisions, because provisions would grow scarce on fixed land and bread dear against manufactures. Bread did grow dear, but against cloth, not against pottery, nails or cutlery: relative to those it was a fifth dearer at the height of protection and only 5 per cent dearer by the 1860s. It was cloth that moved. Trade relaxed the constraint of land, as the Corn Laws showed by tightening it, and faster growth of farm productivity would have done only part of the work. What held back the food of English workers was the kind of growth the Industrial Revolution brought. It put its

productivity growth into cotton, whose price fell as fast as its cost, and so made England richer, as Malthus conceded it would, without making it much better fed; and it left the goods whose price did not fall, above all the old manufactures, to grow slowly.

8 Conclusion

The living-standards paradox of the British Industrial Revolution is two gaps. The first, between the wage measured in the goods the period made cheap and the wage measured in food, is a fact about relative prices, and it follows from where productivity grew: in cotton above all, in iron, in a few other branches, and slowly almost everywhere else. The second, between the wage in food and the food on the table, is partly a fact about demand—an income elasticity of food well below one and a food bill in which bread and beer carried a growing charge for milling, brewing and distribution—and partly a fact about measurement: in the decades of the Corn Laws, much of the grain that fed England came from Ireland, and the standard series does not count it.

A two-region model that takes productivity growth from quantities, using prices only to divide it among branches of manufacturing, the barrier to imported grain from the Corn Laws and the cost of freight, and the price of raw cotton and of continental grain from the record, reproduces the structure of the English economy, accounts for three-quarters to four-fifths of the rise in the price of food relative to modern manufactures and about four-fifths of the rise in the wage in food. It misses the price of wheat in the decade after Waterloo, runs above it at the statutory ceiling in the 1830s, and it makes food per head more stagnant than it was. Its counterfactuals say what mattered. Had productivity growth been spread evenly across sectors, cloth would not have become cheap relative to bread, and English workers would have eaten about 12 per cent more by the 1860s at the same real consumption—17 per cent more, with real consumption 8 per cent higher, at the same aggregate rate of productivity growth. How much more depends above all on how fast productivity grew in old manufactures and on whether they had a market of their own; across our variants, the gain at the same real consumption runs from 4 to 13 per cent, and to as little as 1 if old manufactures both grew fast and had a market of their own. Had the Corn Laws been kept, English workers would have eaten about a tenth less in the 1860s (9 to 11 per cent, depending on the duty); had the law of 1815 never been passed, they would have eaten more in the 1820s and 1830s—in the 1830s by at most two-fifths, and by less than a fifth if British demand had raised Baltic prices as Fairlie assumed—and about the same by the 1860s. Malthus was right about the outcome and wrong about its cause: bread grew dear against cloth, not against ordinary manufactures. Real wages rose,

as the optimists hold, but far more in cloth than in bread, and nutrition barely improved, as the heights suggest.

The episode is an early and clean case of a general phenomenon. When technological progress is concentrated in goods whose price follows the producer's own costs, goods it makes alone or whose market it dominates, their price falls with their cost and the gains go to whoever buys them, wherever they live. Measured income rises, but the goods that matter most for welfare can become dearer relative to the goods whose productivity surges, and the purchasing power of wages over them depends on the productivity of the rest of the economy. In nineteenth-century England the good left behind was food, which was most of what a worker bought.

Several things remain to be done. The model has no harvests, which is why it misses the price spikes of the French wars; nor does it have the wartime investment in land whose unwinding depressed prices after 1815. It has one food, and a model with a traded grain and non-traded other food would let wheat become cheaper without making potatoes cheaper. Except in the bounds of Section 7, it applies the statutory duties, not the lower duties paid on grain taken out of bond, and its terms of trade fall later than the record's. Productivity outside agriculture rests on primal totals divided with dual estimates computed with assumed cost shares; the wage is a male day wage, not household income; and the market for English old manufactures, on which the size of the central result depends, is modelled with an assumed rather than an estimated elasticity. Above all, the model explains why food per head rose so little, not why the heights of those born between the 1820s and the 1850s fell; the decline requires what the model leaves out: the disease environment of the industrial towns, the intensity of factory work and the distribution of income within the working class. What the model says is that the composition of the Industrial Revolution explains why wages measured in cloth rose so much more than wages measured in bread, and a good part of why the latter rose so little.

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