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Since the mid nineteenth century, the standard of living in Western Europe and its off shoots has increased steadily. The long lasting rise in living standards indicates a change in the relationship between the human population and the environment way rivalled only by the neolithic adoption of settled agriculture. Modern growth appears to have begun in Britain between 1750 and 1850, when factory industry, the modern industrial city, and an urban industrial proletariate all emerged. New technology in textile and iron production and the development of an efficient steam engine--called by mid century the Industrial Revolution--appeared the obvious source of change. Efforts to understand modern economic growth continue to direct interest to the economic history of Britain in the century that centered on 1800.

I. Conceptions of the Industrial Revolution

Historians have approached the Industrial Revolution from varying points of interest over the years; asking different questions and sketching differing dominant images. David Cannadine [1984] recently categorized the historiography of the Industrial Revolution into four phases by reference to "preoccupations of the present." From the 1880s to the 1920s, historians focused on class division and the distribution of income. From the mid 1920s to the early 1950s, interpretation "was characterized by pessimism about the economy and the future of capitalism" [p. 142] as historians searched for the context of the interwar collapse of western economies. From the mid-1950s to the early 1970s, "the unexpected, unprecedented efflorescence of western

capitalism," [p. 149] led an optimistic search for the roots of success. In the last two decades, inflation, renewed unemployment and environmental concerns have qualified the success of western growth and "the British Industrial Revolution is now depicted in a more negative light, as a limited, restricted, piecemeal phenomenon, in which various things did not happen or where, if they did, they had far less effect than was previously supposed." [p. 162]

Cannadine's taxonomy usefully organized the literature of the British industrial revolution, but failed to characterize the current literature adequately. Recent events in both developed and less developed countries have made us more cautious about inevitability of growth; but other forces also redirected research. For the first time, many historians of the Industrial Revolution were trained as economists. Also, the normal process of scholarship revealed inconsistencies within the literature that led scholars to reexamine previously accepted views.

Explaining extraordinary western growth over the past two centuries remains the central aim of the recent work; Cannadine's characterization "limits to growth" thus somewhat misleads. Although many now reject a sudden Industrial Revolution initiating modern growth, they still try to discover the source of unprecedented growth. Recent demographic work[1] provide perspective. Although data deteriorate as we consider more distant era, a convincing outline of English population and the real wage of workers exists for the last seven centuries. Juxtaposition of population and wages (Figure 1) reveals dramatic change around 1800. In earlier centuries, real wages rose and fell over long periods in inverse relationship to population, but real wages

were without secular trend. The Black Death in the fourteenth century killed about a third of England's population and population remained low until the early sixteenth century. Workers in the smaller population enjoyed nearly twice the real wages of their pre-Plague ancestors. Population grew during the sixteenth and first half of the seventeenth century and wages fell to pre-Plague levels. History conformed to economists' theoretical expectations, first developed by David Ricardo around 1800, that wages in an economy constrained by limited resources vary inversely with population.

Since Ricardo's time population and wages have no longer varied inversely. English population exploded: between 1820 and 1980, it grew from 11.5 million to more than 45 million. From the fourteenth to the seventeenth century, population grew about 14 percent per century and technology and capital stock improved, approximately maintaining the standard of living. Between 1820 and 1950 population grew at a rate of 260 percent per century and real wages increased as fast as population. The statistics are imprecise, but the broad picture is indisputable: the relationship of population to environment has changed radically. The transformation of the European economy is indisputable; but its nature remains unclear. How sudden or protracted was the process? Was change pervasive or localized? What roles did agriculture and foreign trade play? Recent research has reappraised these persistent questions.

Most observers since the nineteenth century have thought that key industrial innovations in the late eighteenth century transformed economy and altered society

rapidly and fundamentally. Friedrich Engles began his 1845 The Condition of the Working Class in England with the following sentences:

> The history of the English working classes begins in the second half of the eighteenth century with the invention of the steam engine and of machines for spinning and weaving cotton. It is well known that these inventions gave the impetus to the genesis of an industrial revolution. This revolution had a social as well as an economic aspect since it changed the entire structure of middle-class society.

In the paragraphs that follow Engles compared an idyllic life of quasi-artisan pre-factory textile workers who controlled their work, with the life of proletarian workers in Manchester in the 1840s. This view quickly become a part of the Marxist historical dialectic. Near the other end of the political spectrum, Benjamin Disraeli, in his novel Sibyl, similarly described the displacement of a humane well-ordered world by a disjoint capitalist society. His views echoed and shaped views of Tory reformers.

Professional historians expressed very similar views. Arnold Toynbee, in his famous 1884 Lectures on the Industrial Revolution in England, pictured society "suddenly broken in pieces by the mighty blows of the steam engine and the power loom." The succeeding generations of historians, particularly those like the Hammonds and the Webbs, associated with the Fabians and concerned with social issues, shared this view. There were other views but social concern dominated. Sir John Clapham wrote his massive history in the interwar years, and presented a gradualist view that without displacing prevailing class-oriented views.

After the Second World War, historians shifted their interest to economic development. They shared a prevailing belief, or at least hope, that industrialization would quickly eliminate the poverty prevalent in most of the world. They sought a model of growth in European industrialization. Walt Rostow developed an emphatic and popular model in his Stages of Economic Growth. For Rostow, a dynamic leading sector and markedly increased investment led to "take-off into self-sustained growth" over a couple of decades; Britain "took-off" between 1783 and 1802. Such precise dating inevitably drew challenge. Nonetheless, much of the historical literature looked for a brief period with lessons for development planning in contemporary low income countries.

In the last thirty years, economic historians have increasing relied on quantitative evidence. The pioneering quantitative studies--Walter Hoffmann's [1955] index of industrial production and Phyllis Deane and Arthur Cole's [1962] indices of national income--have had enormous influence. In the 1950s, historians trained in formal economics (the "New Economic Historians") began to influence the writing of economic history. These historians attempted to unite formal model building with quantification. They looked for quantitative data and turned to Hoffmann and Deane and Cole.

Hoffmann's index appeared in German in the interwar years and in English in 1955. Although the index received considerable criticism, it became widely quoted. Deane and Cole rejected Hoffmann's index for the eighteenth century as "too narrowly based to be conclusive" and produced an independent estimate of industrial growth as well as estimates of national income. Hoffmann's and Deane and Cole's different

procedures yielded similar estimates of growth. Both confirmed the long held view of a major structural change in British industry in the fifty years before 1830. Both indices showed that industrial output grew less than one percent per year form 1700 to about 1770 and then jumped to a rate of two and a half per cent per year over the next half century and accelerated a bit more in the following decades.

Deane and Cole's national income estimates remained the unquestioned backdrop of research until recently. Quantitative research into individual industries[2] showed that Deane and Cole's aggregate growth could not have result from only the famous technological change in textiles, iron and steam, even with very free assessment of linkages to the rest of economy. A synthesis emerged that married Clapham's gradualist view with Deane and Cole's quantitative estimates. Max Hartwell began to articulate this view in the mid 1960[3] and it has remained dominant until very recently. Donald McCloskey, for example, summarized a view of growth emerging from widespread, but uneven, technological advance with a meterological metaphor: "The gadgets came more like a gentle (though unprecedented) rain, gathering here and there in puddles. By 1860 the ground was wet, but by no means soaked, even at the wetter spots." [1981, p. 106]

Research and synthesis in the Hartwell-McCloskey spirit had changed the general impression of the Industrial Revolution by the early 1980s. The study of individual industries had revealed gradual, often incremental change. Innovations in textiles, iron and power could have had only modest impact on the standard of living. David Cannadine caught the changed mood in a 1982 review. A familiar picture of

Manchester at mid century graced the dust jacket of Floud and McCloskey [1981], a text book which presented a gradualistic description of change:

> "The...views of Manchester, the 'shock city' of early nineteenth-century England...embody a familiar picture of the Industrial Revolution: of factories pouring out goods, and chimneys belching forth smoke; of burgeoning exports, spiralling output and rising productivity; and of improved land, unceasing labour, accumulating capital and inspired enterprise. Here is epic drama: Coketown in the making, the workshop of the world in operation, and the factors of production in fertile fusion. Taken together, these...illustrations project an image of the Industrial Revolution as an heroic happening, characterized by vigour, energy, inventiveness and courage, or (depending on your point of view) by exploitation, cruelty, avarice and shame. [1989, p. 147]
>
> But recently the solitary scholar-gladiator of old, replete with lance and trident, was replaced by a new model army of research assistants, computer experts and applied economists who, under the guidance of a lab-coated field-marshal, launched massive bombardments with all the scholarly firepower (and some of the strategic futility) of a Somme offensive. [1989, p. 149]
>
> The idea of the Industrial Revolution as an heroic happening, as conventionally embodied in the picture on the dust-jacket, is seen as at best atypical and at worst a myth. [1989, p. 152]

Since Cannadine reviewed Floud and McCloskey, reassessment of the aggregate growth has again changed the idea of the industrial revolution. The sharp increase of industrial production and income growth during the last quarter of the eighteenth century now appears to have been an artifact of inappropriate index construction by Hoffmann and Deane and Cole. In industry, change was confined to the famous industry, agriculture contributed much and growth accelerated gradually over many decades.

II. New Aggregate Estimates

Particular industries can expand at the expense of other activities, so to understand growth we need estimates of aggregate economic performance. Prior to the mid nineteenth century statistical information is extremely spotty. Even in modern industrial societies construction of national income statistics presents theoretical and data problems; national income estimates for eighteenth century Britain are only controlled conjectures. Nonetheless growth cannot be understood without them. Factors of production move between alternate uses and some sectors can grow even in a static economy. Aggregation is necessary to strike the balance between growing and contracting sectors.

Ideally national income estimates summarize complete enumerations of economic life. Factor incomes, the value of final output, the sum of values added and the value of final sales each sum to national income. Modern statistical

bureaucracies collect all these data to construct national income statistics. Prior to the mid twentieth century, when modern national income accounting began, national income estimates requires creative use of population censuses, tax returns and other available quantitative data. For Britain, Phyllis Deane and Arthur Cole used available date to construct historical national income estimates in the 1950s. These estimates remain the foundation on which all others have built. Over the last decade, though, N. F. R. Crafts has crucially modified Deane and Cole's estimates.

Estimates of British national income prior to the mid nineteenth century involve projection backward into periods of less and less adequate data. Britain began decennial censuses of population in 1801. Deane and Cole based their estimates national income from 1801 on these data. The early censuses were of poor quality but gradually became more comprehensive. By mid century the census contained useful occupational information. The census of 1841, although judged to be somewhat incomplete, contains the earliest reliable labor force data from which to construct labor income estimates [Deane and Cole, 1962, pp. 139-40]. Sir Robert Peel's reimposition of the income tax in 1842 provides a contemporary source for property income [Deane and Cole, 1962, p. 164 ff.]. Reasonable reliable national income estimates, based on factor incomes, thus exists from the 1840s. The quality of the estimates for subsequent dates improves as the state collected more extensive data. Comprehensive agricultural output data began in the 1880s and the first census of industrial production occurred in 1907. Estimates of national income prior to 1840 consist of projections from the 1840s benchmark. Estimates are based on population (from censuses and earlier

estimated), incomplete output series, and inferences of various sorts.

Industrial Production

Traditional interpretations place a transformation of industrial technology at the center of growth that began in the late eighteenth century. Cotton and then other textiles were transformed, Watt radically improved the steam engine and various advances led to the smelting of iron with coke. How much did these improvements lead to growth in industrial output as a whole and in national income?

Underlying data for industrial production comes from several sources. Since Britain imported raw cotton, trade figures reveal the general trend of the cotton textile industry. Excise tax records reveal the histories of some other industries, particularly leather, paper and printing, and beer production. For other industries various scholars have estimated output from more fragmentary sources [Harley, 1982, pp. 272-5]. Table 1 presents indices of output (with 1841 outputs set to 100) for various industries in 1815 and 1770. Cotton textiles' very rapid growth stands out; output in 1770 was just 0.8 percent its 1841 level. By contrast, other industries grew slowly. Metal production, the second fastest growing industry, stood at nearly 7 percent its 1841 level; other large industrial sectors--the other textiles, leather and food and drink only slightly more than doubled over the period. The growth of aggregate industrial output was an appropriately weighted average of the experiences of sectors with very different histories. Its rate of growth depends crucially on the weight assigned to the fast growing cotton

industry.

Output indices are sensitive to the aggregation procedure used in their construction. Appropriate aggregation sums quantities of various commodities valued at their prices in some base date. The first need is to identify appropriate prices and quantities for various base dates. In this historical period in which the relative prices of various commodities change rapidly, so the value of the index will depend on the choice of base.[4]

Quantifying the structure of the industrial sector to provide appropriate weights for aggregation presents the greatest challenge to constructing an index of industrial production for Britain prior to the 1840s. Hoffmann, in his pioneering index, gave inadequate consideration to this issue and overweighed the cotton sector, yielding an exaggerated rate of aggregate growth. An ideal base rests on a comprehensive census of industrial production but the first such census occurred only in 1907. The earliest reasonably comprehensive alternative comes from the occupational classifications in the population census of 1841. Harley [1982] chose to base calculations of industrial production explicitly on these data. Weights for 1841 were assigned to sectors in proportion to their 1841 labor force (with women, children and handloom weavers given half the weight of adult males). Projection of 1841 employment shares backward using industry output indices and making adjustment for the change in relative price of cotton textiles and iron provided consistent shares for 1815 and 1770. The relative price of cottons was 1.8 times as high in 1815 as in 1841 and three times as high in 1770 as in 1841. The relative price of iron was 1.2 times its 1841 level in 1815 and

1.8 times its 1841 level in 1770. The industrial structures implied by these calculations are presented in Table 2.

N. F. R. Crafts also reestimated industrial production. His data on sectoral growth were mostly the same as Harley's, although there were some minor differences. Crafts approached the crucial issue of weighting somewhat differently. While Harley attempted to maintain consistency by projecting back from a comprehensive 1841 labor enumeration, making explicit adjustments for relative price changes, Crafts employed separate estimates of industrial output at current prices for 1770, 1801 and 1831. Crafts' shares differ somewhat from those derived from the census employment data. Most importantly cotton has nearly twice the weight in his calculations as in Harley's and so his aggregate growth rate is higher.

Hoffmann and Deane and Cole overestimated the growth of industrial output and so understate the level of eighteenth century industrial output. Hoffmann's overstatement arose from the industry weights he used for the late eighteenth century. He constructed a 1783 base to weight sectors in the late eighteenth century. He estimated that cotton textiles constituted 6.7 percent of industrial output--just about Crafts' weight but larger than Harley's. Hoffmann estimated that the industrial output series he had available covered 56.4 percent of total industrial output. To construct an index, he had to estimate the growth of the remaining 43.6 percent, either explicitly or implicitly. He proceeded by raising the weight of each included industry in proportion by a factor of 1.79 (= 1/0.564). This raised the weight of cotton textiles to 12 percent of the index. Hoffmann's procedure implicitly, but incorrectly, assumed

that other industry, 79 percent the size of cotton, shared cotton's growth.

Deane and Cole proceeded differently and their procedures differed for the eighteenth and nineteenth century. For the nineteenth century, they constructed estimates of current incomes by sectors. These calculations combined estimates of labor income based on the census and property income estimates from the income tax assessments.[5] They then deflated these current income estimates with Rousseaux's index of industrial product prices to estimate output volumes. Unfortunately, Rousseaux's index inadequately represented industrial prices and declined too fast in the early nineteenth century [Crafts, 1985, pp. 30-1]. For the eighteenth century, Deane and Cole divided the industrial sector into two parts: a domestic portion and an export portion. The output of 'domestic industry' (one third of the whole in 1700) was estimated from excise series [Deane and Cole, 1962, p. 76]. They felt that the direct statistical base for the export industries was inadequate. They decided, after a extensive discussion [pp. 50-61] that "it seems fair to assume that the volume of imports and exports may provide us with a reasonably accurate index of the growth of those industries which entered largely into overseas trade." Eighteenth century growth of trade provided the statistical basis of their estimated growth of industrial output, but the procedure has no sound theoretical basis. In addition the procedure is undermined because much of the late century growth of trade occurred with the Americas where population grew more rapidly than elsewhere and where the war temporarily closed markets to non-British exporters.

The data do not permit precise conclusions but Harley's and Crafts' critical

evaluations of industrial production, although differing considerably, point to a common conclusion: industrial growth, particularly growth per capita, in the decades after 1770 was much slower than had generally been assumed. Harley estimated industrial growth from 1770 to 1815 at 1.6 percent per year or 0.6 per cent per year per capita. Craft estimated faster growth: about two percent per year in aggregate and 1 percent per capita. Both these estimates are well below Hoffmann's 2.6 total and 1.6 per capita. The extent of the differences can best be appreciated by comparing the levels of industrial output per capita in 1770 to levels in 1815. My calculation implies per capita output of 76 percent of the 1815 level, Crafts' of 64 percent and Hoffmann's of 49 percent. Although there is considerable difference between Crafts' and my estimate, we both feel that they tell the same story: industrial growth was much slower than has usually been assumed. With industry's share of national income at just under a third [Crafts, 1985, p. 45], industrial growth generated per capita income growth of two or three tenths of a percent per year.[6] At that rate, income would double only in two hundred to three hundred and fifty years--not the stuff of sudden transformation.

As all the authors have emphasized, these calculations are little more than controlled conjectures and can claim no great precision. The weight of cotton textile production in the aggregation constitutes the greatest potential source of error. My weight may fail to account adequately for the value added in chemical and other industries involved in finishing of cotton cloth and so be a bit low. Crafts, on the other hand, probably overweighs cotton and textiles generally. His weights for the textile sectors in 1831 add to 46 percent of total industrial output while textiles and

clothing accounted for 38 percent of employment in 1841. In addition, cotton amounts to half his textile sector but employs only 40 percent of labor in 1841. Although probably less important than appropriate weighting, many indices of sectoral output growth are crude approximations. The errors in individual series are unlikely to be strongly correlated so we may hope that the error in the aggregate is less than the error in individual series. Nonetheless, estimates of industrial production are highly approximate.[7]

National Income

Assessing British growth requires accounting of the entire range of economic activities. Unhappily, data for the rest of the British economy before the mid nineteenth century are even worse than those for industrial production. Industry never much exceeded a third of national income and its experience need neither have represented nor lead the economy as a whole. An effort must be made to assess the primary sector of the economy--mainly agriculture--that was larger than industry until the second quarter of the nineteenth century and various services that in total generated more income than either industry or agriculture [Crafts, 1985, pp. 62-3]. N. F. R. Crafts has recently re-estimated the growth of these sectors. He built on Deane and Cole's pioneering estimates but he comes to new conclusions.

Deane and Cole estimated eighteenth century agricultural growth by assuming that per capita consumption remained unchanged [1962, pp. 65, 74]. Their index of

output was population adjusted for net imports of grain. Crafts pointed out [1976 and 1985, pp. 38-44] that demand for food in low income societies has considerable price and income elasticity that Deane and Cole's procedure overlooked. Since relative agricultural prices were the same in 1760 as in 1700, only income effects needed to be considered to compare these dates. Crafts modified Deane and Cole's estimate by allowing for an income elasticity of 0.7. This yielded agricultural growth of 0.6 percent per year, about 0.2 percent above the growth rate of population.[8] After 1760 agricultural price rose relative to other prices complicating analysis. Craft used two independent procedures for this period. Fortunately, each yielded a similar estimate. Crafts' first deflated estimates of current values of output by Patrick O'Brien's agricultural price index [O'Brien, 1985]. For 1760, Peter Lindert and Jeffrey Williamson [1982 and 1983] estimated the value of agricultural output from Joseph Mashie's contemporary estimate. Deane and Cole provided estimates for nineteenth century census years. In his second procedure, Crafts constructed demand estimates using a price elasticity of -0.8 and the income elasticity of 0.7 and solved simultaneously for national income and agricultural output. The two procedures generated very similar estimates for 1760 to 1800: growth rates of 0.44 and 0.50 percent per year respectively. A greater discrepancy appeared between 1801 and 1831; deflation yielded 1.18 percent annual growth and while demand estimates produced a 1.88 percent. Crafts has used the lower estimate in subsequent work.

Measuring the service sector, which presents problems even in modern economies, is nearly impossible in the late eighteenth century. Deane and Cole

divided eighteenth century services into "Government and Defence" and "rents and services." Reported government expenditures were deflated by the Schumpeter-Gilboy price index. Rents and services were assumed grow with population growth. Crafts retained these procedures. For the early nineteenth century, Deane and Cole estimated current value of output primarily from census employment. They deflated current value by Rousseaux's price index to obtain constant price estimates. Crafts rejected this one of Deane and Cole's procedures; the price deflator was inappropriate and the results were highly implausible. He constructed alternate estimates based primarily on employment estimates [1985, pp. 34-37].

Crafts' re-evaluation altered the picture of aggregate growth. Crafts' and Deane and Cole's indices of national income are presented in both aggregate and per capita terms in Table 4 and Figure 3. Deane and Cole showed a shift to high growth of per capita income coinciding with the textile innovations of the late eighteenth century. Crafts' data showed no such shift. Per capita growth increased slightly around 1780 or 1800 but if there was a break in the trend, instead of an acceleration over perhaps as much as two centuries, it occurred with the railway age in the 1840s [Crafts et al, 1989].

III. A Coherent New View of British Growth

A coherent picture of growth in Britain emerged with the new indicators of aggregate income. Industrial change appears largely confined to the famous sectors

of the industrial revolution. The main growth occurred in cotton textiles. Cheaper cottons displaced competing textiles that had not shared rapid technological change. Part of the industry's growth came from British consumers buying cotton textiles but even more came from the British industry's capture of foreign textile markets. The British economy became increasingly industrial and urban as the 'modern' textile sector grew. Large urban concentrations of industry occurred because the steam engine freed textile mills from water power and because the British economy redistributed labor and capital from rural agriculture to urban industry with considerable facility. The income gains from the growth of urban industry were modest, however. British agriculture played an important role in growth. Agricultural technology advanced, much less, to be sure, than the leading industrial sectors, but more than other industrial and service sectors. Also, British agriculture, probably because of its class structure, released labor and capital easily, by comparison to the history of industrialization elsewhere, to growing sectors. During this industrialization period real income grew modestly and the standard of living improved only slowly.

A general view of British growth inevitably involves projection backward from the relatively reliable data that becomes available in the mid nineteenth century. By 1840, Britain had achieved a notable economic leadership. Growth was clearly different after 1840 than it had been in previous centuries. From 1840 to 1910 British income per capita grew at 1.2 per cent per year. The level of per capita income in 1840 approximated that of the Congo in 1970. Income growing at 1.2 percent doubles every 58 years; simple back projection shows early growth at late nineteenth century

rates implies impossibly low per capita income in 1700.

Contemporary observers and historians broadly agree on the extent of Britain's economic lead at the middle of the nineteenth century. Britain's industrial sector, in per capita terms, produced some 4 times as much as its French equivalent and 5 times as much as its German; even Belgium and Switzerland, the most industrialized continental economies, produced only about a third of British industrial output [Bairoch, 1989, p. 37]. There is no question that during the previous century a revolution in British textile production had made British firms industry leaders. Britain had also become leaders in iron by pioneered technological change [Allen, 1979]. In other industrial sectors the British had little technological advantage over continental rivals and undoubtedly lagged in some areas. British agricultural achieved high levels of productivity. Bairoch [1989, p. 37] calculated the caloric net output per male worker in European agriculture for 1860; these figures show that only the Danes (at 87%) approached British productivity. The French and Germans output per worker was about half the British level with Belgium and the Netherlands slightly behind.

The economic change in Britain in the late eighteenth century and early nineteenth century marked the beginnings of modern economic growth. The basic character of the economy changed from one governed by the balance of land and population to one dominated by technological change and capital accumulation. Robert Solow's [1956] procedure of estimating the contributions of factor inputs to output growth and identifying a "residual" growth due to "technological change" constitutes the first step in "explaining growth" within an aggregate neoclassical

framework. The procedure assumes that national output can be adequately represented as an aggregate produced by a well specified production function. Also competition is assumed to result in factor prices that equal real marginal product. In these circumstances, the growth rate of output due to a factor's growth equals the growth rate of the factor times its share of total income. The "residual," or "Total Factor Productivity Growth," is the difference between measured output growth rate and the growth predicted by the growth of inputs.

Crafts [1987, p. 251] performed these calculations and calculated total factor productivity growth in subaggregates of industry and agriculture. These results are reproduced in Table 5. Some sixty percent of the acceleration in output growth between the early eighteenth century and the mid nineteenth century was due to increased rates of factor growth. Historians have long known that population growth accelerated in the final decades of the eighteenth century. Savings and investment maintained the capital stock per capita at approximately the 1760 level. Productivity growth occurred in both industry and agriculture. If Crafts somewhat speculative calculations can be believed, productivity advanced somewhat faster in agriculture than in the economy as a whole.

Donald McCloskey brought together information pertaining to various industries and sectors in an interesting attempt to find "the location of ingenuity." He produced "crude approximations to annual productivity change by sectors" [1981, p. 114]. He then computed the contributions of various modernized sectors and agriculture to the aggregate productivity growth implied in Deane and Cole's national income estimates.

The residual technological change he attributed to "all other sectors." McCloskey concluded from this exercise that "ordinary inventiveness was widespread in the British economy 1780 to 1860" [1981, p.117]. Unfortunately, the conclusion rests on the residual estimate of productivity growth in "all other sectors." When Deane and Cole's aggregate with its implied rate of technological change of 1.19 per cent annually is replaced by the total factor productivity growth of 0.55 per cent annually implied by Crafts' revisions of national income, McCloskey's enumerated modern sectors and agriculture completely exhaust the aggregate [Crafts, 1987, p. 250, 1985, p. 86].

McCloskey's exercise, although a precarious and uncertain process of identifying residuals of residuals, is extremely interesting and bares reconsideration. Not only did McCloskey's original calculation depend on Deane and Cole's income estimates, his estimates of individual sector contributions to total factor productivity growth contain several errors.[9] He exaggerated productivity change in cotton textiles by overstated the decline in cotton cloth prices (he compared the price of a fancy muslin--a velveret--in the 1780s with an ordinary printing grey cloth calico 1860).[10] Grey calico sold in the 1760s and 1770s for about three (not 15) times its price in the mid nineteenth century. For worsteds and woolens, McCloskey attributed the rate of productivity growth between 1805 and 1860 to the entire period. History of the industry indicates little technological advance before the early nineteenth century so the appropriate rate of change for the entire period needs to be lowered. Finally, McCloskey uses North's [1968] estimate of productivity change in North Atlantic shipping as an estimate of technological change in coastal and ocean shipping. Recent work [Harley, 1988] has

shown much slower technological change in shipping. McCloskey's estimate of agricultural productivity growth lies well below Crafts'. Table 6 presents revised sectoral growth rates (with McCloskey's original calculations for comparison). Productivity growth in the modernized sectors was only two thirds the rate McCloskey calculated. Nonetheless, the contributions of these sectors and a dynamic agriculture practically exhaust estimated aggregate total factor productivity change.

Revolutionary changes in industry were largely confined to the famous sectors of textiles, iron and transportation. Even in combination their technological change contributed only modestly to growth of aggregate output. A contribution of 0.34 percent growth per year would require two centuries to double income. To be sure, industrial change helped to change social structure, demographic behaviour and savings habits, all of which may have stimulated growth. Nonetheless, it seems impossible to sustain the view that British growth was revolutionized in a generation by cotton spinning innovations.

The new estimates of national income identify a long period of transition. Growth probably began to accelerate in the last years of the seventeenth or the early years of the eighteenth century. In the late eighteenth century, important innovations occurred in some industries but per capita national income growth accelerated only modestly. Accelerating agricultural change contributed about as much as industrial innovation. Modern economic growth became fully established in Britain only in the railway age.

Despite the moderate impact of industrial technology on aggregate growth,

changes in economic activity greatly altered the social structure of Britain. By the 1830s, a combination of the rapid growth of the urban based textile industries and British agriculture's rapid release of labor produced the first urban industrial economy. Both industrial technology and the mobility out of agriculture were important. Britain's lead in both textile and iron technology led to dramatic price decline that resulted in British producers supplied a large portion of world demand in these industries.[11] In the 1840s, British cotton producers exported some sixty percent of their production [Ellison, 1886, p. 60]. The iron industry exported a quarter of its output and the woollen industry about twenty percent.

Britain's transformation also required a ready movement of labor, and other factors of production, from agriculture to industry. By historical standards, the British adjusted very rapidly. The labor force in the primary sector of the economy, although it increased from 1801 to 1851, fell dramatically as a proportion of the labor force. Primary production employed 40 percent in 1801 but only 25 percent in the 1840s [Crafts 1987, p. 257]. Other European economies did not reach this low a share of primary sector employment for another century. During the early stages of industrialization in most countries, labor left the primary sector very slowly and a large gap opened between labor productivity in agriculture and industry. No such gap appeared in Britain. Deane and Cole's estimate for 1840 shows 25 percent of the labor force engaged in the primary sector essentially equal to the share of income in the sector (24.9). The average European economy ("European norm") at that level of income had a labor share in the primary sector that exceeded the sector's income

share by some forty percent. Later in the nineteenth century, cheap imported American food became available and the share of income in the British primary sector fell more rapidly than the share of labor. By the eve of the First World War, 15 percent of the labor force remained in the primary sectors while only 10 percent of the income originated in these activities. Britain remained unlike the European norm, where at a similar level of income, primary production employed 29 percent of labor and produced 15 percent of income.

The unusually rapid transfer of labor from British agriculture to industry was a striking features of the two generations spanning 1800. Agriculture's high level of technological accomplishment, the rapid growth of productivity and the transfer of labor probably arose from the social structure of rural Britain. A large portion of both agricultural entrepreneurship and labor was separated from control of land. This separation of labor from the means of production made labor much more responsive to market signals than it would otherwise have been.[12]

The size of the new industrial sector, particularly cotton, was greatly enlarged by Britain's exports to the rest of the world. The cotton industry, freed from rural water power by the steam engine, created the industrial city. By 1840, the populations of both Manchester and Liverpool approached half a million; about the same number lived in the other textile towns of Lancashire. Similar, although somewhat less intense, cotton based urbanization had occurred in the western Scottish lowlands. Iron had a lesser effect. Birmingham, the center of metal fabrication had grown rapidly but was still some twenty five percent smaller than Liverpool or Manchester. The social

change and urbanization occurred in response to growing factory production, particularly of textiles. Many of the goods produced in urban Britain were exported to the rest of the world.

Most new industry was located in Britain and it is common to talk of Britain possessing a monopoly, or near monopoly of production in the new industries of the early nineteenth century. The term--monopoly--produces an incorrect image, however. Production of the new goods took place under conditions of competitive capitalism. No firm was able rise price above the cost of production. The benefits of technological change passed to consumers as lower prices. Nearly two thirds of the cotton textile consumers lived abroad and shared the benefits. Competition in the cotton textile industry meant that the British, although not the world, gained little from technological change in the exported portion of cotton production.

Britain exported cottons in return for raw materials and foodstuffs. In the twenty five years after the Napoleonic War, technological change reduced the resources needed to product a given piece of cotton cloth by forty to fifty percent. Competitive pressure drove textile prices down; a given piece of textiles could purchase only half as much food as previously. The deterioration in the terms of trade between Britain's textiles and her imports was caused by the same technological change that generated industry growth.

The price changes that transferred the benefits of technological change to foreign consumers mean that conventional aggregation of national income overstates the benefits to Britain of increased cotton production. The orders of magnitude

involved are illustrated by calculations in Table 7. In 1841 Britain produced 5.2 times as much cotton textiles as it produced in 1815. About sixty percent of output was exported in both years. Think of part of these exports paying for the industry's imported raw cotton with the remainder purchasing a representative bundle of other imports for consumption. In 1815, the raw cotton cost about a quarter of the total value of output; in 1841 the proportion was somewhat higher at 31 percent. About thirty percent of the output in 1815 was exported for foreign consumption goods. In 1841 about 29 percent of output was exported, or 4.3 times as many textiles as in 1815. But the relative price of British cotton textiles had deteriorated markedly between 1815 and 1841. A unit of cotton textile exports could purchase only half as many units of imports. The quantity of cotton produced increased 5.2 times, but the bundle of consumption (cotton goods and imports) it purchased increased only 3.8 times, if the cotton and imports are valued at 1815 prices, or 3.3 times, if they are valued at 1841 prices.

IV. Jeffrey Williamson's Critique

Jeffrey Williamson, who has contributed greatly to the recent discussion of the Industrial Revolution, presented a different picture of late eighteenth and early nineteenth century British economic history. Williamson and Peter Lindert collected and analyzed information about occupational structure and income distribution in eighteenth and nineteenth century Britain that has been valuable to the ongoing

reassessment of the period. Williamson agreed that growth was slow in the late eighteenth and early nineteenth century but differed from Crafts in several important ways. Two features underlay Williamson's view the British Industrial Revolution. First, he believed there is a general pattern of the emergence of modern growth. Second, he focused on the distribution of income.

Investigators inevitably bring models of industrialization to their interpretation of the industrial revolution and, because direct evidence is scarce, these models have strong influence. Williamson's model of early industrialization reflected recent Third World experience, from Japan and from the United States. He felt that Britain followed a similar path, except when exceptionally deflected. [1987, p. 269-70, 272-3; 1985, pp. 87-90, 183] In his model, disequilibrium created by technology provided opportunities for the rapid expansion of industry characterizes the early phase of modern economic growth:

> Unbalanced productivity advance has always been viewed as the primary supply-side force driving industrialization and urbanization. Since the rate of technological change has always been viewed as far higher in modern than in traditional sectors, industry 'leads' and agriculture 'lags' in capital formation, output expansion and job creation. So said the qualitative accounts of the British industrial revolution, and now there are some tentative numbers documenting the process.[13] [1985, p. 89]

Williamson found this view of unbalance British growth particularly satisfactory. It presented industrialization as a consistent experience and explained increasing income

inequality in the first half of the nineteenth century.

Williamson formally modelled the British economy as a multisectoral general equilibrium. The economy possessed four primary inputs--farm land, capital, unskilled labor and skilled labor. Williamson, following a long literature, conceived these factors as class based with immobility between classes. Primary inputs, plus a produced domestic intermediate product--resources from mining--and imported raw materials produced three final goods--agriculture, manufacturing, and services. Agriculture employed unskilled labor, capital and land but no intermediate products. Domestic resources used only unskilled labor and capital. Manufacturing used skilled and unskilled labor, capital and imported and domestic intermediate goods. Services were produced with skilled and unskilled labor, capital and domestic intermediate goods. Agricultural goods, manufactured goods and imported intermediate goods were traded internationally. Williamson modelled Britain as a small country facing international prices in these traded goods. Equilibrium of the model determined output quantities, factor prices and the price of services and domestic resources. The general equilibrium solution depended on the parameters on the model's production and consumption relationships, initial conditions and exogenous factor supplies and international prices. [1985, Ch. 8]

Williamson examined change in the economy from 1821 to 1861 (and from 1861 to 1911). The exogenous labor force growth (essentially the same in for skilled and unskilled labor), capital formation and technological advance determined change. Technological progress occurred most rapidly, at just over one percent, in industry,

and more slowly elsewhere, three tenths of a percent, in agriculture, services and intermediate goods. More rapid technological advance drew mobile capital and unskilled labor to industry. Capital formation occurred at a considerably higher rate than labor force growth, stimulating more rapid growth in the capital intensive industrial sector.[14] The stimulus to manufacturing from differential technological change and rapid capital formation was partially, but only partially, offset by exogenous deterioration of manufactured goods' prices--caused by international factors. [1985, Appendix E] In response, the industrial sector grew about 3.2 percent per year while agricultural output grew about 1.4 percent per year. The higher growth of industry differentially increased the demand for skilled labor and widened the premium on skilled workers wages at a rate of a little more than three quarters of a percent annually. [1985, pp. 130-131; 151-160, cf. Table 10.6]

Williamson found Britain's economic history prior to the 1820s puzzling. In particular, he wondered "why was British growth so slow?" [1985, Ch. 11; 1984] He commented [1985, p. 162] that "[e]ven during productivity slow down, OPEC fuel--crunch, Malthusian burdens, and capital scarcity abroad, the Third World managed per capita income growth rates around 3.2 per cent per annum in the 1970s, ten times that of Britain prior to the 1820s!" Also, "the rate of [British] industrialization was unimpressive." In addition, "Britain was a low saver...the rate of capital accumulation was so modest that hardly any capital-deepening took place at all."

Williamson followed his list of puzzles, with possible solutions. The first, "that the conventional dating of the first industrial revolution is just plain wrong," he quickly

rejected. Instead he proposed the hypothesis "that Britain tried to do two things at once--industrialize and fight expensive wars--and she simply did not have the resources to do both effectively." Williamson's concentration on the effects of war highlights a major difficulty in analyzing this period. The eighteenth century wars and particularly the Wars of the French Revolution and Napoleon complicate the economic history of the late eighteenth and early nineteenth century in ways that are poorly understood. To Williamson the major impact came from government's wartime demands on the capital market. He felt that capital formation in Britain was abnormally low for a period of industrialization and that state borrowing displaced investment. The shortfall of investment occurred primarily in urban infrastructure. Williamson saw the British industrial revolution beginning in the 1760s. In the absence of war, he believed that capital formation, structural shift and growth would have been more rapid, following a normal pattern of early industrialization.

Crafts' and Williamson's views of the British industrialization are basically different. Williamson saw a generally applicable industrialization process as beginning modern economic growth. He characterized the process by reference to experiences of contemporary Third World economies, the nineteenth century United States and twentieth century Japan [1985, p. 183; 1987, p. 272-3]. These models lead him to expect modernization to begin with rapid growth, led by industry. Typically, in the initial spurt, productivity increased rapidly in the modern sectors but not in the traditional sectors. A rapid increase in capital formation helped uneven technological improvement in driving the spurt. Crafts worked from a different underlying vision.

His research has found and emphasized significant differences between Britain and the later industrializing economies of Europe [1985, Ch. 3]. In this framework, Williamson's analogies to the United States, Japan and the contemporary world are unpersuasive; these economies differed much more from Britain than had Continental economies. Britain pioneered industrialization along a path inevitably different from that taken by economies that followed.

Crafts and Williamson disagree on the balance of dynamic sectors of the British economy. Crafts worked extensively on the evidence for growth in various sectors of the British economy in the decades between 1760 and 1830 and evolved a view of the dynamics of various industries. Within industrial production, revolutionary change occurred but was confined to a few industries. Arkwright and Crompton and others revolutionized cotton spinning during the last third of the eighteenth century. Unprecedented change continued in cotton textiles and spread to the other textile industries in the following generation. Well-known innovations led to the use of coke in iron production also with revolutionary impact. But much of the production of final metal products, and most other industrial processes were largely unchanged.

Crafts and Williamson also differ on the history of agriculture. Crafts' calculations indicated that agricultural output and productivity grew rapidly. The evidence is weak since overall statistics do not exist but detailed studies of British agriculture [Jones, 1974; Allen, 1988] support this view. Williamson rejected a vision with agricultural advance of similar magnitude to industrial advance. His argument drew on analogies to industrialization elsewhere: "Central to all industrialization

accounts past and present has been the view that modern sectors exhibit much faster rates of productivity advance while traditional sectors lag behind." [1987, p. 273] He also suggested that Crafts' productivity estimates cannot fit into a consistent macro-economics of the industrial revolution:

> "Crafts' revisionist view of unbalanced productivity advance favouring agriculture will have a hard time accounting for the relative demise of agriculture and the relative expansion of industry during the industrialization surge after Waterloo." [1987, p. 274]

Williamson viewed factor markets as segmented during unbalanced growth. A rapidly growing modern sector and a lagging traditional sector, along with psychological and social barriers to mobility, led to considerable higher productivity in the modern sector than in the traditional sector. In this situation, the transfer of factor of production from the traditional to the modern sector would have increased output without increasing factors of production--an increase in total factor productivity. Growth of aggregate output from shifting resources from low productivity traditional to high productivity modern sectors was analyzed by Edward Denison who found that structural shift contributed substantially to fast growth in continental Europe after World War II and in twentieth century American growth. Williamson hypothesized that structural shift twice as important in the British Industrial Revolution as in post war Europe [1985, p. 249]. This assertion denied a central trust of Crafts' results. Deane and Cole's mid-century British accounting showed no important productivity difference between agriculture and industry (output per capita in services was

considerably higher than either). Crafts has recently accepted a role for the Denison intraindustry factor productivity growth effect, but has argued that its impact must have been much closer to its impact in post war Europe [1987, p. 253]. In fact, Crafts' data show a much smaller productivity gap in early nineteenth century Britain than existed in mid twentieth century continental Europe. The speed with which factors left agriculture was a special features of Britain's leadership.

V. Assessment and a Computational Model

Crafts' and Williamson's Views

The data on British growth before 1840 cannot support a definitive description of the Industrial Revolution. Still, Crafts' general view seems superior to Williamson's. Central empirical features of Williamson's view now appear defective. He built his picture of the industrial revolution around divergent movements of the wages of skilled and unskilled labor. Williamson challenged the prevailing view that the distribution of wages did not alter over the industrial revolution, contending that this conclusion had rested on data from too small a part of the labor force. He broadened the data by considering wages in services and found considerable change in the distribution of earnings over the nineteenth century. Skilled wages, particularly in the service sector, increased relative to unskilled wages from the 1820s to the 1860s and then fell. This trend in earnings provided the linchpin around which his explanatory sketch revolved.

Unfortunately, experts have reexamined Williamson's data and raised serious questions about his conclusions [Feinstein, 1988; Jackson, 1987]. Williamson seriously overestimated the growth in inequality in the first half of the nineteenth century. Charles Feinstein concluded that "the general picture is one of broad stability, most notably in the ratio of skilled to unskilled pay and in the overall distribution of earnings" [1988, p. 728]. Williamson's assertion that "[a] working hypothesis is now will established: incomes levelled across the late eighteen century and the French Wars; inequality surged from Waterloo to mid-century; and incomes levelled again during the late nineteenth century" has not survived independent scrutiny.

Revised estimates of industrial output growth by Harley and Crafts, although they differ, seem to command wide acceptance. On the other hand, Crafts' estimate of the growth of agriculture has been widely criticised. Williamson criticised on the basis of his prior belief in the general leadership of the modern sectors and somewhat casual assertions that rapid technological change in agriculture was inconsistent with rapid industrialization [1987, pp. 273-276]. As Craft himself has acknowledged and Mokyr [1987, pp. 305-312] has explored in greater detail, the estimates of agricultural growth are undeniably insecure.

In assessing the agriculture estimates, it is important to remember that our knowledge involves projecting backward from firm knowledge about the end of the period. In the middle of the nineteenth century, British agricultural productivity exceeded that elsewhere in Europe. Agriculture employed only a small proportion of British resources but Britain produced most of her food despite decades of rapid

population growth. Britain's agricultural superiority had increased in the previous two centuries. Aggregate agricultural productivity growth resulted from a myriad of improvements in different agricultural regions that occurred at different times in different place. It is unlikely that precise dating of aggregate productivity advance is possible. Uncertainty seems inevitable, but certain conclusions are inescapable. In particular, estimates of agricultural growth make up an important part of estimates of British aggregate growth prior to the mid nineteenth century. If agricultural growth was slower in the century before 1850 then so too was aggregate growth. Slower aggregate growth implies higher British standards of living in the middle of the eighteenth century and earlier British economic lead. In this case "the conventional dating of the industrial revolution is just plain wrong."

A Crafts Inspired Computational General Equilibrium Model

One step in testing the adequacy of the competing general views is to construct explicit numerical models, as Williamson has done. Such an exercise with Crafts' general view has several advantages. It highlights the key assumptions of the perception of change, insures consistency and numerically indicates general orders of magnitude. Such a model shows that Williamson was mistaken in his assertions that Crafts' picture is implausible. A very simple computational general equilibrium model with simple production and utility functions that incorporated Crafts' view reproduced the general outline of actual historical changes.

Key features of the model highlight Crafts' differences with Williamson. First, Crafts emphasized growing agricultural productivity. Second, the portion of manufacturing in which technological change occurred very rapidly needs to be distinguished from the rest of manufacturing and services where change was slow. Textiles and iron amounted to only a little over a third of industry even in 1840 after their rapid growth. Third, Crafts saw British terms of trade sharply altered by the growth process. In contrast, Williamson felt it was appropriate to "invoke the 'small country' assumption and allow prices of all tradeables to be determined exogenously...that is that demands for exportables and supplies of importables were both highly price-elastic in nineteenth-century Britain." [1985, p. 110]

The terms of trade must be integral to an assessment of the British industrial revolution. Rapid technological change and British exports both occurred in only a subsector of manufacturing. Bairoch [1982] calculated that more than half the world's "modern" industry in 1840 was located in Britain. In cotton textiles, much the most important of these industries, Britain was the only exporter of any importance. Competing cotton textile mills in the United States and continental Europe depended on tariff protection. Britain's terms of trade deteriorated in the decades following the Napoleonic Wars because cotton textile prices fell. Technology drove economic change and export growth and caused cotton textile prices to fall. A history of the industrial revolution that fails to incorporate the price effects of technological change is a Hamlet without the Dane.

Britain probably also faced an upward sloping supply curve for imports of

foodstuffs and raw materials. Transportation was expensive, so merely being small relative to world output did not insure an elastic supply of bulky imports. Transportation cost constituted a large part of the cost British imports before iron and steam revolutionized transportation during the second half of the nineteenth century. Expansion of grain or timber imports involved tapping more distant supplies and incurring higher transportation costs. By 1850 traditional grain sources in the Baltic became insufficient to supply British needs. Only at higher prices could distant regions in the Black Sea and in American become sources of imports.

A model has been constructed and examined using an available computer program [Rutherford, 1988]. The modelled British economy and the rest of the world both contained four producing sectors: agriculture, 'modern' industry, other industry, and services. Trade occurred in agriculture and 'modern' industry. Each sector produced using capital and labor; agriculture also used land. The production technology was Cobb-Douglas in all sectors except agriculture where a CES function with an elasticity of substitution of 0.5 was employed. Factor markets equated factor prices across sectors. A representative, utility maximizing, consumer in each country owned factors (so the model has no class or distribution features). The utility functions incorporated a Cobb-Douglas subaggregate--manufactured goods--of 'modern' and other industrial goods. The subaggregate, agricultural and service goods entered a CES utility function that had an elasticity of substitution of 0.5. International trade allowed foreigners to purchase British 'modern' industrial goods at British prices but British agricultural imports incurred a transportation cost that increases as imports

increase.

The model used 1841 values of output (see Table 8) as a benchmark from which to estimate the effect of changes in technology and factor supply. A pre-industrial revolution British equilibrium was calculated with a smaller labor force and capital stock. Industrial revolution technological change was Hicks neutral and occurred in British agriculture and 'modern' industry. Pre industrial revolution British agriculture used 1.75 times 1841 resources to produce a given output. British 'modern' manufacturing used 2.8 times the resources. The rest of the world partially shared technological change in modern industry, using 1.5 times the resources around 1760 as around 1840.

The model was very simple and the parameterization crude so results are simply indications of possibilities. Nonetheless the calculated pre-industrial revolution equilibrium (summarized in Table 8) supports Crafts' general view. Crafts' estimates of relative sectoral technological change emerge as consistent with industrialization, contrary to Williamson's assertion. Industrialization results from the export success of 'modern' industry and diminishing returns in agriculture in face of growing population and income.

Calculations with the model can help to separate various effects. Agricultural technological change alone from '1760' equilibrium, would have resulted in Britain becoming, as Williamson surmised, a substantial exporter of agricultural goods. A similar tentative calculation for 1841 population and capital resources but with 1760 agricultural technology suggests that British with a stagnant agricultural sector would

have produced only half its actual 1841 agricultural output. 'Other' industries would have absorbed resources and been more that twice their actual 1841 size.[15] Calculated per capita utility without agricultural technological change (but with extreme factor mobility) fell by 13 percent, slightly exceeding the utility fall for a move from the 1841 benchmark to the '1760' equilibrium. The positive effect of more abundant land in 1760 slightly exceeded the effect of poorer industrial technology. Just eliminating industrial productivity gain with 1841 factor supplies and agricultural productivity lowered utility about 8 percent.

VI. Conclusion

Williamson's projection of the experience of the contemporary third world, early twentieth century Japan and nineteenth century United States onto the British industrial revolution appears to be an anachronism. The United States industrialized as an expanding continental economy and the others were late followers. The initial growing modern economy probably followed a different path than more backward economies. Recent work on continental European industrialization suggests slow acceleration rather than the sudden emergence of a leading sector pulling the economy into modern growth.[16] Even in the European context, Britain was a leader and appears to have followed a different path.[17]

Britain's path to mid nineteenth century predominance had two important characteristics. First, British agriculture--probably because of a greater separation of

ownership, entrepreneurship and labor--developed and adopted productivity enhancing changes on an unusually large scale. As part of the same process, agriculture released factors of production to other activities, not completely without friction but extremely rapidly by international standards. Second, a few key innovations occurred in British industry after the middle of the eighteenth century that provided technological leadership in textiles and iron production. This particularly industrial revolution probably contributed less than agricultural change to Britain's emergence into modern growth. The technological breakthrough in industry occurred in Britain in part because of the dynamic character of the economy but Britain probably also benefitted from a lucky draw in the random process of invention [Crafts, 1977]. The industrial inventions provided Britain with a comparative advantage in cotton textiles and later in iron. British firms came to dominate international trade in those commodities.

Comparative advantage in textiles and iron, coupled with rapid movement of resources from agriculture, led to the rapid industrialization and urbanization. Since industrial productivity was only modestly above agricultural productivity, industrialization and urbanization, per se, resulted in little increase in aggregate output and real wages. The competitive structure of British industry conferred the benefits of technological change in the new export industries on foreigners. The British gained little from their position as workshop of the world.

Notes

1. Most importantly, of course, is Wrigley and Schofield, 1981.

2. Deane and Cole undertook the early work. See [1962, Ch. 6].

3. For a compendium, see Hartwell, 1971.

4. Between 1770 and 1841 the price of cotton goods fell dramatically. Cottons in 1841 were only a third as expensive relative to other manufactured goods as they had been in 1770 and only half as expensive as in 1815. Aggregation using 1770 prices (a Laspeyres index) will value the large 1841 cotton textile sector more than will aggregation using 1841 prices (a Paasche index) and lead to an estimate of more rapid growth. This discrepancy is unfortunate but unavoidable--"the index number problem." Some compromise between initial and terminal weights has intuitive appeal and can be supported by an appeal to formal theory of consumption. This leads to indices such as Fisher's Ideal index and the Divisia index (presented below). Nonetheless an inherent problem exists because we are attempting to aggregate when strict conditions allowing aggregation are absence.

Laspeyres and Paasche index numbers are usually calculated by constructing a weighted average of the quantity indices of the components of the aggregate. The appropriate weights consist of the shares of each component in the value of total output in the base period. If initial shares are employed the index is Laspeyres; if terminal shares, Paasche. Fisher Ideal index is the geometric mean of the correspond-

ing Laspeyres and Paasche indices. The Divisia index differs in its construction. For very small changes, an aggregate's rate of growth equals the weighted sum of the growth rates of its components, with each component's growth weighted by its share in the aggregate. The relationship does not hold exactly for large changes, of the sort we are considering, unless the shares of each item in the aggregate, at current price, do not change over time. During the industrial revolution, the shares of various industries in the total value of manufacturing output changed significantly. An approximation when weights change calculates the growth rate of the aggregate as the weighted sum of the growth rates of the components, using the geometric mean of the initial and terminal shares as weights.

5. As they acknowledged, these data were suspect before 1840, since the census did not contain reliable occupational information before 1840 and the income tax was repealed at the end of the Napoleonic War.

6. Even this contribution is overstated since adjustment is needed to properly assess the impact of exports by the new industries. This issue is discussed below.

7. A useful critique of the aggregate indices and a consideration of other issues involved in appropriately studying late eighteenth and early nineteenth century industrialization have recently been presented in Hoppit, 1990.

8. Since agricultural output growth was a part of to total output growth, the rate of agricultural and total growth had to be calculated simultaneously.

9. Crafts has never attempted to redo McCloskey's table, perhaps as a wise desire to avoid spurious precision. The results are sufficiently interesting to make it a worthwhile exercise but the imprecision of the results must be kept in mind.

10. See the sources McCloskey cites [1981, p. 124]. Alternative price estimates are discussed in Harley, 1982, pp. 271 and 286-91.

11. Bairoch, 1982, estimates that Britain contained more than half of modern industry in 1840; Britain took 55% of the worlds raw cotton output and accounted for substantially more of value of output because of the higher average count of yarn spun in Britain [Ellison p. 100, p. 146].

12. This hypothesis and the origins of the class relationship in British agriculture have been explored at some length by Robert Brenner. See Aston and Philpin, 1985.

13. The primary reference is to McCloskey's table discussed above and the modified calculations in Table 6 cast doubt on this assertion.

14. These are predictions of the effects of accumulation and unequal technological change in simple models of international trade for small economies where international terms of trade are uninfluenced by domestic developments.

15. This calculated structural change almost certainly assumes too much factor mobility.

16. See Cameron, Komlos, Good, Tilly, O'Brien and Keddar [1978].

17. See, for example, O'Brien and Keddar, 1978, and Gerschenkron, 1956.

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Table 1

Indices of Output, Various Industries
(1841 = 100)

Industry	1770	1815
Cotton	0.8	19
Wool	46	65
Linen	47	75
Silk	28	40
Clothing	20	43
Leather	41	61
Metal	7	29
Food and Drink	47	69
Paper and Printing	17	47
Mining	15	46
Building	16	42
Other	15-50	40-60

Source: Harley, 1982, p. 273.

Table 2

Industrial Structure, 1841, 1815 and 1770

Industry	1841	1815	1770
Textiles			
Cotton	.10	.08	.01
Wool	.08	.11	.15
Linen	.04	.06	.08
Silk	.03	.02	.04
Clothing	.13	.12	.11
Leather	.11	.14	.19
Metal	.11	.08	.05
Food and Drink	.04	.06	.08
Paper and Printing	.02	.02	.01
Mining	.08	.08	.05
Building	.18	.15	.12
Other	.09	.09	.12

Source: Harley, 1882, p. 269.

Table 3

Indices of Aggregate Industrial Production, 1700-1840

	Harley	Crafts	Hoffmann	Deane & Cole
1700		11	8	9
1730			10	10
1760		16	12	14
1770	22	19	14	13
1780		22	16	15
1790			23	18
1801		35	32	23
1811			40	24
1815	45			
1821			51	57
1831		85	72	85
1841	100	100	100	100

Source: Harley, 1982, p. 276, calculated from mean of Divisia range; Crafts, 1985, p. 26 calculated using series with weights based on geometric average of adjacent years (Divisia); Hoffmann, 1955, Appendix; Deane and Cole, 1962, calculated from data pp. 78, 106.

Table 4

National Income, 1700-1870
Crafts and Deane and Cole
(US 1970 $ after Crafts)

	Crafts		Deane and Cole	
	Total (Mn.)	Per capita	Total (Mn.)	Per capita
1700	1.98	333	1.27	191
1760	2.99	399	1.88	250
1780	3.44	400	2.14	248
1800	4.48	427	3.23	308
1830	8.10	499	8.10	499
1870	23.59	904	23.59	904

Sources: Crafts, 1985, pp. 45 and 62. Deane and Cole, pp. 78 and 106.

Table 5

Sources of Growth, 1700-1860
Crafts' Estimates
(% per year)

	Growth Rate:				Contribution to Growth:			
	Income	K	L	T	K	L	T	"Residual"
1700-60	0.69	0.7	0.3	0.05	0.24	0.15	0.01	0.3
1760-1800	1.01	1.0	0.8	0.2	0.35	0.40	0.03	0.2
1801-31	1.97	1.5	1.4	0.4	0.52	0.70	0.06	0.7
1831-60	2.50	2.0	1.4	0.6	0.70	0.70	0.09	1.0

Notes: K = capital; L = labor; T = land. Factor shares for the calculation are: capital, 0.35; labor, 0.5; land, 0.15.

Source: Crafts, 1985, Table 4.2, p. 81.

Table 6

Sectoral Contributions to Productivity
Annual percentage growth, 1780 -1860

	Share	Product-ivity	Contrib-ution	McCloskey's Estimate: Product-ivity	Contrib-ution
Cotton	0.070	1.9	0.13	2.6	0.18
Worsteds	0.035	1.3	0.05	1.8	0.06
Woolens	0.035	0.6	0.02	0.9	0.03
Iron	0.020	0.9	0.02	0.9	0.02
Canals and railways	0.070	1.3	0.09	1.3	0.09
Shipping	0.060	0.5	0.03	2.3	0.14
Sum of modernized	0.290	1.2	0.34	1.8	0.52
Agriculture	0.270	0.7	0.19	0.4	0.12
All others	0.850	0.02	0.02	0.6	0.55
Total	1.410		0.55		1.19

Source: McCloskey, 1981, p. 114 with corrections discussed in text.

Table 7

Cotton Textile Production and Consumption,
Effects of Terms of Trade

	Quantities		Prices	
	1815	1841	1815	1841
Output	100	520	1.0	0.5
Raw cotton	25	236.5		
Consumption:				
Cotton	40	208	1.0	0.5
Imports	35	75.5	1.0	1.0
Aggregate Consumption:			Index, 1815 = 100	
1815 prices	75	283.5	378	
1841 prices	55	179.5	326	

Source: see text.

Table 8

A Computational General Equilibrium Model

	1841 Benchmark	Calculated '1770'
Quantities:		
British output:		
Modern industry	12.4	1.8
Other industry	22.0	9.9
Agriculture	22.1	8.2
Services	43.5	17.6
British factor supplies:		
labor	53.1	22.8
capital	38.1	16.4
land	8.8	8.8
Rest of World output:		
Modern industry	11.2	11.2
Other industry	126.4	128.3
Agriculture	297.0	293.7
Services	219.2	216.8
Rest of World factor supplies:		
labor	332	332
capital	205	205
land	120	120
British Trade:		
Exports, modern	6.8	0.9
Imports, agriculture	6.8	2.0
Prices:		
Modern industry	1.00	2.11
Other industry	1.00	0.76
Agriculture	1.00	1.00
Services	1.00	0.76
British labor	1.00	0.76
British capital	1.00	0.75
British land	1.00	0.37
British utility per capita:	100	88

Figure 1
Population and Real Wage
England and Wales, 1250 - 1980

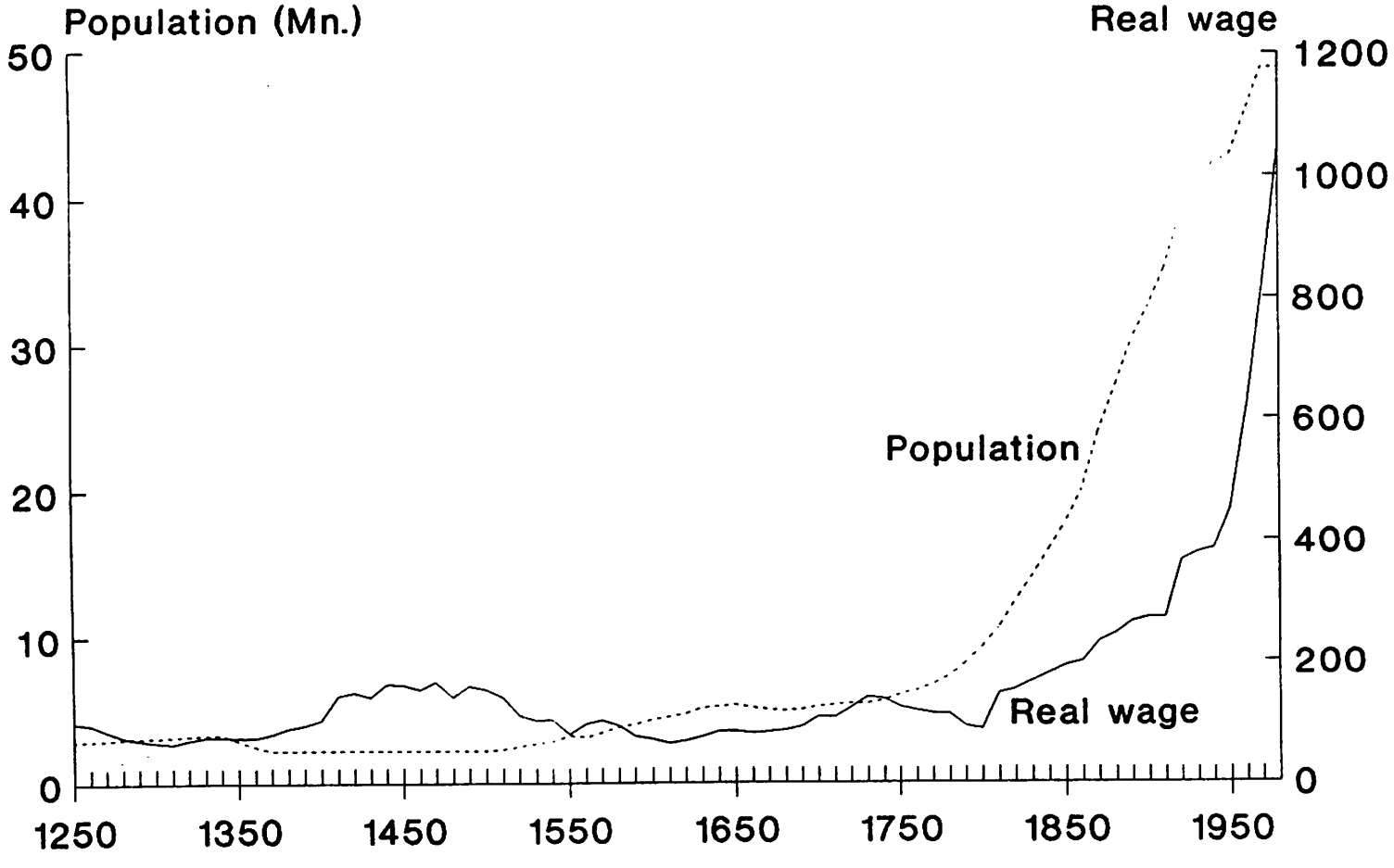

Figure 2
Estimates of Industrial Production

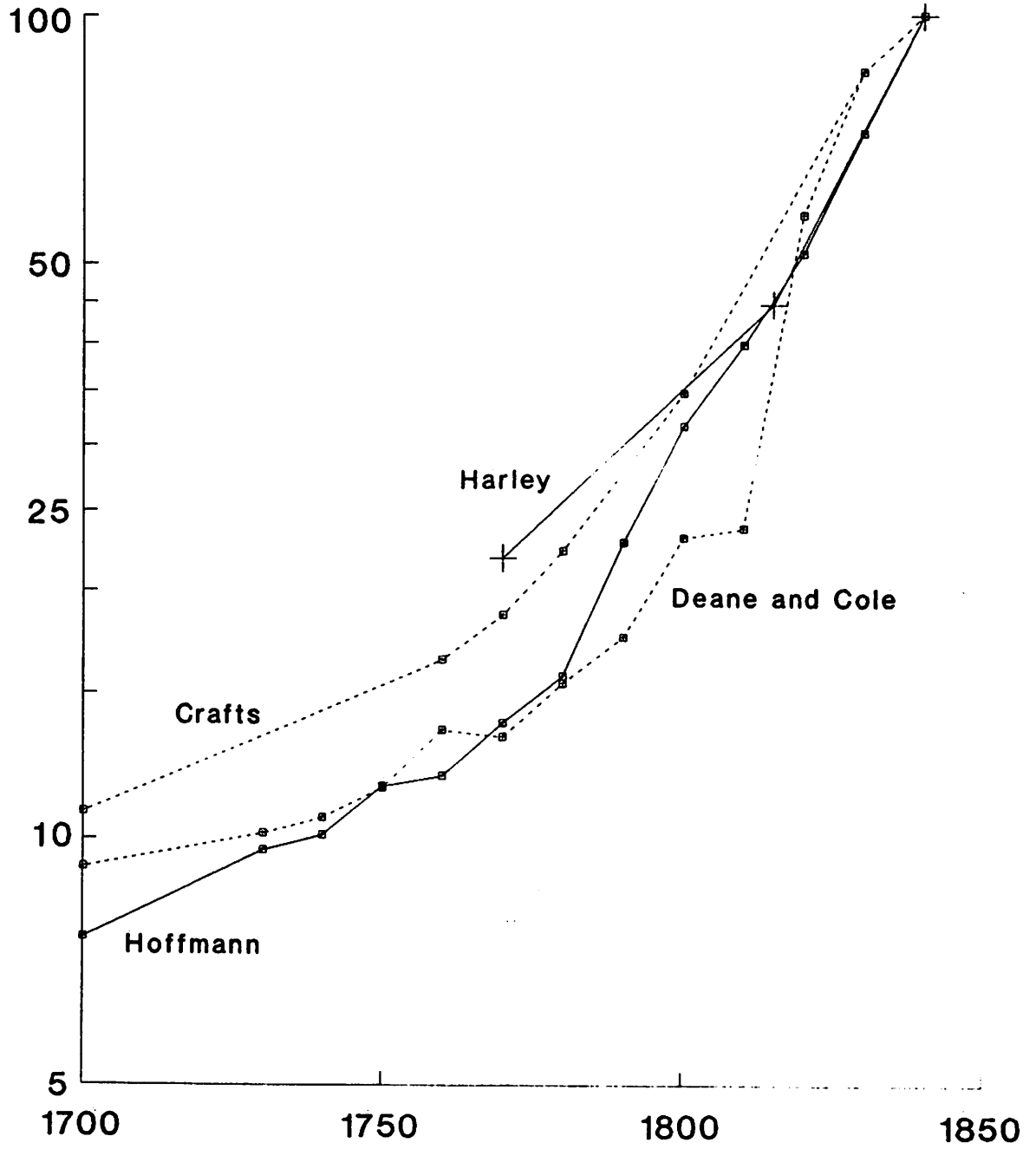

Figure 3
British National Income, 1700 - 1870