Cotton Textiles and the Industrial Revolution

Competing Models and Evidence of Prices and Profits

by

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Conventional dating places the beginning of modern economic growth at the British Industrial Revolution in the last quarter of the eighteenth century. In this view, technological and organisational changes in the cotton industry — the industry that led change during those years —plays the central role in the emergence of the modern economy that was based on mechanized factory production. Certainly, crucial change occurred in the British at roughly the time of the innovations in cotton textiles. Earlier real wages varied inversely with population, after the Industrial Revolution both population and real wages grew at unprecedented rates. Historians, therefore, have studied the new technology and organisation in cotton as a process of "development" that involved qualitative changes not present in simple "growth" within the pre-existing system. In many narratives, new cotton textile technology initiated a "'traverse' [in which] quantitative expansion and structural change were intertwined" (Mokyr, 1976b, p. 372) that drove economic change. Such a perspective owes much to Schumpeter's insights of the central role of entrepreneurship and industrial finance. In this view, discontinuous technological change initiated an Industrial Revolution that involved a protracted diffusion of the improved technology as knowledge spread slowly, constrained by limited enterprise, imperfect diffusion of knowledge and constrained capital mobilization.

Recent research focusing on national income growth questions this view (Crafts, 1985; Harley, 1992; Crafts and Harley, 1992). The spectacular innovations of the late eighteenth century were largely confined to the cotton textile industry and that the industry was too small to have had the aggregate effects implied by usual narratives. To those who proceed from income estimates, the spectacular technological was specific to the cotton industry and diffused rapidly. As conventional general equilibrium economic analysis implies, the new technology drove down the price of cotton textiles, but had little spillover effect. To be sure, the modifications of the

technology diffused to the woollen industries in the early nineteenth century, but here as well the diffusion was rapid and price fell. The effects were industry-specific not economy-wide changes.

This paper examines the cotton textile industry between the 1760s and the early nineteenth century in light of these competing views. The conclusion from the exercise is that the spectacular technological and organisational changes in cotton at the end of the eighteenth and the beginning of the nineteenth century probably have confused us about the beginnings of modern economic growth in Britain. Investigation of the eighteenth century economy reveals both "new" industries and "old" industries that cannot be aggregated into the few sectors needed to make the economy-wide Schumpeterian model a useful guide to understanding change. In Britain, which led in the emergence of modern growth, and probably in other leading economies, the distinction between growth and development seems misleading. British growth between 1750 and 1850 seems to rest not on changing industrial technology and organisation arising from the great cotton spinning inventions but on broader characteristics of the economy that had emerged in the early modern period and effected the economy over a long period.

The paper has been organized around the diffusion of the new technology. Different perceptions regarding three aspects of technological diffusion emerge from the competing views of the Industrial Revolution. First, how great a discontinuity in technology did the famous inventions involve. An extreme version of the Schumpeterian view would characterize the textile (and steam power) innovations of the 1760s as introducing discrete major cost savings over previous practice. An extreme version of a gradualist view sees the cost savings from the initial technological breakthroughs, although considerable, as dwarfed by the savings arising from important technological improvements that were introduced more or less continuously into textile production for a century of so after Arkwright and Crompton's conceptual breakthroughs.

The second contrast involves the nature of technological diffusion. In the first, discontinuous view, the growth of factory production over the succeeding sixty or seventy years was Schumpeterian diffusion. Diffusion took a long time because practitioners within the industry guarded knowledge of the new technology, enterprise was scarce and serious imperfections in the capital market constrained investment in the new firms. Because diffusion was slow, innovators made large profits during the transition. Proponents of the gradualist view see diffusion of technology occurring quite rapidly. At any time, capital and entrepreneurship entered textile production to eliminate excess profits. In this view, the price of industrial products approximated the cost of production and fell as technology improved.

A third contrast in views of technological diffusion involves the "universe" to which the technological change is relevant. Arnold Harberger (1998) recently introduced useful metaphors in his discussion of economic growth in contemporary economies. Should we, he asked, regard an economy undergoing development as analogous to a batter in which technological change acts like yeast and leavens the entire economy? Here the initial innovation may be small but sets off a process that causes the entire economy to expand. Or, alternatively, would we do better to use as a metaphor for imagining technology and economic growth a forest's floor where mushrooms appear in some places without apparently effecting the surrounding terrain? The mushroom image, which Harberger prefers, suggests that innovation occur in well specified production processes and effects certain products and industries without effecting other industries and products. Both views appear in the histography of the Industrial Revolution. The "yeast" view appears most clearly in models built by economists. In particular, Joel Mokyr's "growing up" model (discussed at some length below) and Jeffrey Williamson's (1985) general equilibrium model focus on "batter-like" industrial sectors leavened by the "yeast" of the Industrial

Revolution (also see Landes 1998, pp. 246-53). Historians, particular historians of particular regions or industries, tend toward the "mushroom" view. Sir John Clapham (1926) famously presented this view. More recently, Maxine Berg and Pat Hudson (1992) have stressed diversity among regions and industries in the late eighteenth and early nineteenth century. The specific histories of the cotton industry (Fitton and Wadsworth (1958) Fitton (1989), Chapman (1967), Wadsworth and Mann (1931), Edwards (1967)), implicitly at least, take the "mushroom" view. These narratives stress the particularity of the changes to the cotton industry.

Detailed evidence of the cotton textile industry seems to best fitting a "mushroom" view in which technological change is an ongoing process that diffuses rapidly within the industry. This conclusion arises from considering new data on the movement of the prices of finished and intermediate cotton goods and limited information on capital mobilization and profitability within the framework of competing explicit models of the Industrial Revolution.. Below I present Joel Mokyr's "growing-up" model as representative of the "yeast" school and a simple "mushroom" model based on neo-classical economics to provide an analytic framework. I then present relevant data on prices and profits, most of it extracted from the accounts of three firms which have been preserved in archives in Greater Manchester — two spinners, Samuel Greg and partners, William Grey and partners and one weaving firm, Richard Hornby and partners.

Comparison of Mokyr's model with a neo-classical view suggests two areas that merit investigation: relative price movements and profit history. The history of cotton textiles certainly shows dramatic reduction in the price of cottons rather than Mokyr's picture of an industry growing up and replacing an old sector of the economy with little effect on relative prices. Sustained super-profits to finance investment provide a second important feature of Mokyr's model. Profit history is imprecise, but what information can be drawn from primary sources

suggests that the type of persistent super-profits that drive Mokyr's model did not exist in cotton textiles in Britain after the 1780s.

I. Mokyr's model of "growing up and the Industrial Revolution"

Currently, Joel Mokyr is the leading proponent of a Schumpeterian model of the Industrial Revolution in which technological diffusion, innovative profits and capital formation play key roles. He presents a particularly clearly articulated model and his exposition of an economy in which a modern industrial sector replaces a traditional manufacturing sector provides a framework for examining this view. Mokyr's model of "Growing-up in the Industrial Revolution" has technological change and investment in "manufacturing" leading to "growing up." The model contains features amenable to empirical testing with detailed information on the cotton industry. Mokyr developed the model a number of years ago in his study of nineteenth century growth in the Low Countries, but the argument forms an important part of his recent summaries of the Industrial Revolution.[1]

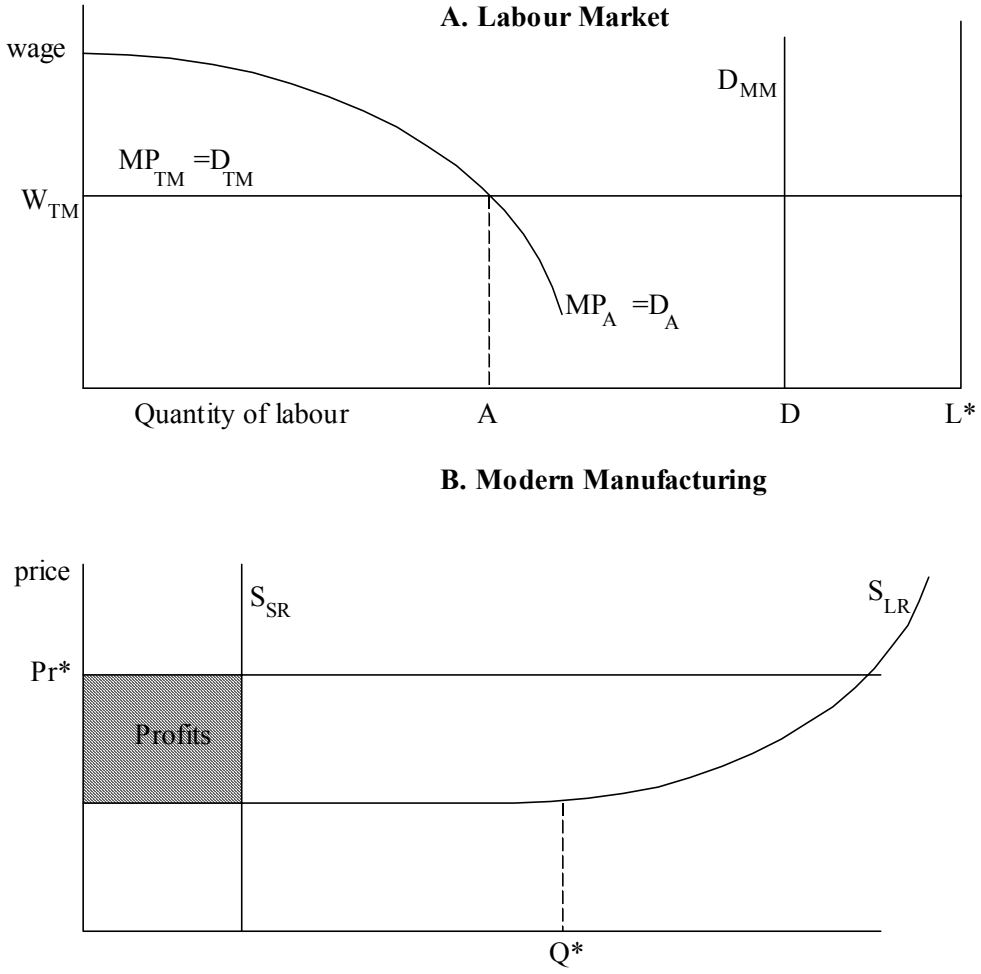
Mokyr's model contains two final goods — agricultural output and manufactured consumer goods — plus a manufactured capital good produced and used in the modern manufacturing sector. The economy is assumed to be small, so prices are exogenously determined and unchanging by industrialisation. In the traditional economy's initial equilibrium, labour productivity in the constant-returns technology of the "traditional" manufactured goods sector, which uses only labour as an input, sets wages. Agriculture, which faces diminishing returns in labour, produces the quantity of output that equates the marginal product of labour to the wage set by the constant labour productivity in manufacturing. The modern sector has a

[1] His view has also been widely influential as McCloskey's (1994, pp. 246-9) overviews demonstrate.

superior technology embodied in the manufactured capital good. With the manufactured good price internationally set and the wage rate set by the traditional sector, production using the new technology earns a large quasi-rent over its replacement cost. Capital markets are unavailable to finance investment in the capital good to eliminate excess profits and the expansion of modern manufacturing is limited to the reinvestment of its profits. In Mokyr's world, the modern sector expands in the face of unchanged wages and output prices, and thus with a constant super profit rate until the labour supply of the traditional manufacturing sector is exhausted. Continued reinvestment of profits then leads to rising wages and eventually eliminating the quasi-rent on capital.

Mokyr's model can be illustrated quite simply with Figure 1. Panel A represents the labour market. The length of the x-axis represents total labour supply. Labour in agriculture is measured from the left. The balance is employed in manufacturing. During the transition or "growing-up" process, the wage rate is determined by the horizontal labour demand curve from the traditional manufacturing sector. Agricultural employment equals the distance OA with the balance of the labour force (AL*) employed in manufacturing. Initially this labour is all in traditional manufacturing but as modern manufacturing accumulates capital it demands labour in proportion to its capital stock (D_{MM}). (For simplicity, Mokyr uses a fixed proportion modern technology in the formal presentation of his model, clearly a downward sloping labour demand curve would make no difference.) During the "growing-up" process the labour force in the modern sector equals ML* which grows as capital accumulates from profits and the balance of the non-agricultural labour force, AM, remains in the traditional sector.

Figure 1
Mokyr's Model



Panel B in the diagram represents the market for modern manufactured goods. The demand curve is horizontal at the exogenously fixed price. The long-run supply curve is horizontal below the world price so long as the wage rate remains at w_{TM}. The wage will remain at this level until employment in the traditional sector is eliminated at Q* by the slow expansion of the modern sector as it accumulates capital through retained profits. During this period of "growing-up" costs will remain below price and profits or "quasi-rents" on capital will remain

high. Once the labour in the traditional manufacturing sector has been absorbed into the modern sector, the wage rate will rise and the supply curve will slope upward. The economy will have "grown-up" when the wage rate has increased enough to bring the minimum average cost of the representative firm in the modern sector up the world price of manufactured goods.[2]

Much of the increased output of the leading industries of the Industrial Revolution was exported. This was particularly true of cotton textiles. Within Mokyr's scheme, exports play a significant role. They underlie the assumption that expansion of the modern sector will not significantly reduce profits by driving down price (1976b. 374. In fact in some of his exposition he assumes that manufactured goods are entirely exported. 1976a, p. 138, 144). During the growing-up traverse any increase in output increases profits in proportion. Therefore the growth of exports, which came to account for over two-thirds of cotton textile output by 1850, was an important part of "growing-up". Increased exports were the result of previously invested profits. Higher exports increased quasi-rents that were invested to generate continued growth.

Mokyr's application of his model to the British Industrial Revolution, particularly his discussion of real wage trends, indicates that he sees the "growing-up phase" lasting until about 1850 (Mokyr 1991, p. 190; Mokyr 1993, p. 92). It is useful, therefore, to consider the implications of the model for prices, profits and the role of exports in the cotton textile industry — clearly the leading modern manufacturing industry. The model is driven by a persistent surplus — super-profits — in the modern sector that arises because technological change has increased labour productivity but wages and product prices remain unchanged. In Mokyr's

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[2] As Mokyr points out this model follows the well-known Arthur Lewis (1954) model of development with unlimited supplies of labour, with the important exception that wages to the modern sector are kept constant by the assumptions of fixed product prices and constant returns technology in traditional manufacturing

model, increasing wages eventually eliminate super-profits. It is important to realize however that the surplus persists because manufactured goods prices are not driven down by the expansion of the modern sector as well as by the failure of wages to increase. The underlying cause of the persistence of profits is the continued presence of the old manufacturing sector and the smallness of the modern sector in world product markets. In general the argument rests on a view that the expansion of a small modern sector in a small open economy will not change the price of manufactured goods (expressed in terms of an agricultural good numeraire)[3]. In fact, of course, there were many goods and their relative prices could change. It seems appropriate, therefore, when examining the usefulness of the model to look at the relationship between the price of cotton textiles, other manufactured goods and the wage rate.

Large quasi-rents to capital continuing over many years are a distinguishing feature of "growing-up." As Mokyr notes (1993, p. 86) "this rent ... provides the fuel for further growth of the modern sector" and (1976a, p. 147) "The sustained growth is self-propelled by the reinvestment of profits, the "engine of growth".... It is important to realise that profits are the pivotal dynamic element in the present model." The elimination of super-normal profits marks the end of the growing-up period. As Mokyr recognises, if capital could flow unimpeded to the modern sector the transition would be very short. He rejects this possibility because evidence suggests most investment in firms using the new technology of the Industrial Revolution was

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[3] Mokyr points out in his discussion (1976b, p. 382) that the model does not strictly require that the terms of trade between agriculture and manufactured goods be unchanging. In the model, whose labour productivity using traditional techniques to produce a single manufactured good determines the wage rate. Thus a fall in the price of the manufactured good as modern output increased would result in a proportional decline in wages and in the cost of capital goods. The profit rate and the rate of accumulation would not be effected.

internally financed[4] and because the Industrial Revolution was spread out over two or more generations. The growing-up view implicitly regards a single discontinuous technological advance in the third quarter of the seventeenth century as the driving force for change for fifty years or more. Mokyr implicitly rejects a continuing process of technological advance generating a moving equilibrium despite his discussion of such a case (1976a, pp. 153-155).

II. A Simple Neo-classical alternative

A simple alternative, neo-classical view contrasts with Mokyr's model. In this view, first, the cotton textile industry is not constrained by capital shortage. Second, the modern industry produces goods that are close substitutes for only a small part of the traditional sector (that is to say aggregation of various industries into "manufacturing" is not warranted). Third, the British cotton industry, although quite small relative to the British economy, is large relative to world demand for cotton goods. As a result, the industry can expand only with a decline in the price of its product relative to other goods. In this view, the labour market is similar to that in Mokyr's model. Because the industry is small relative to the overall labour market in the economy, it can hire labour for expansion at a constant wage. In contrast to Mokyr's model, super-profits quickly attract capital that expands output. Increased output quickly drives down the price of the goods to the cost of production with the improved technology eliminating quasi-rents from innovation. Cotton goods prices continue to fall over a long period in the late eighteenth and early nineteenth centuries because innovation continued to lower costs of production that stimulated competitive expansion of output that could only be sold at lower prices.

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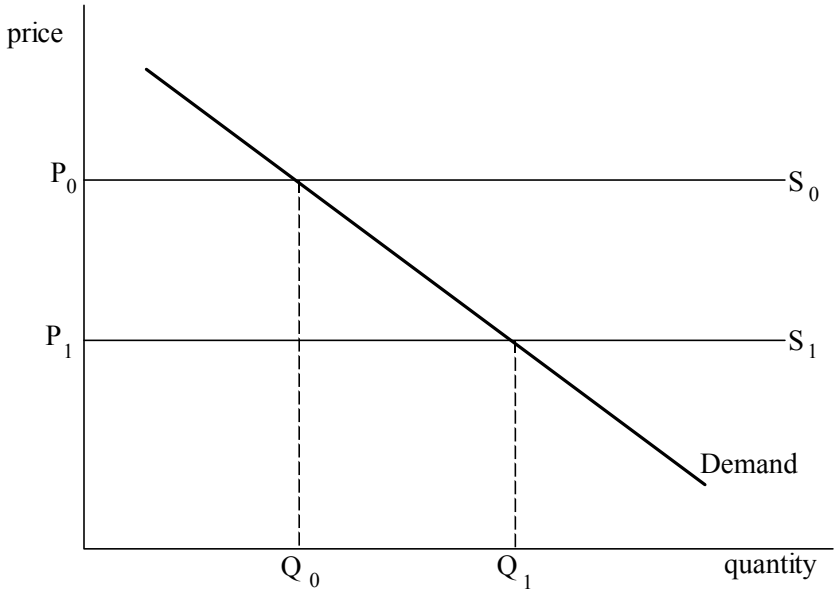
[4] He justifies this characterization primarily by reference to Crouzet (1962, 1972).

Figure 2
Simple Neoclassical Model of the Cotton Textile Market



This view is very simply illustrated in the cotton textile market in Figure 2. Originally, price is P_0, corresponding to the constant cost of production with per-modern technology that generates the supply curve S_0. Technological change lowers costs and the supply curve falls to S_1. At the old output, the new technology generates profits equal to $(P_0-P_1) * Q_0$. The profits attract capital that hires labour. Output expands and drives price down along the demand curve. The new equilibrium occurs when price has fallen to P_1, which is equal to the new cost of production, eliminating the excess profits that attract capital. In this view, output expands, price falls and profits equal the economy-wide opportunity cost of capital.

III. Implications of the competing views

The two views of the Industrial Revolution predict differences in the economic history of the late eighteenth and early nineteenth centuries following the famous cotton innovations of the

1760s and 1770s. Prices movements are the most easily observable implication. Mokyr's model depends on a delay in the fall of the price of manufactured goods after the technological breakthrough (or if they fall, a proportionate decline in wages). The neo-classical view emphasizes the diversity of manufactured products and the product specific nature of technological change. In this view the expectation is that the prices of cotton textiles, the specific goods in which technological breakthroughs occurred, fall relative to the prices of other goods, both manufactured and agricultural, as cotton output expands.

The relationship between the expanding industries and the capital market provide another contrast implication of the views. In Mokyr's model, capital market failure occurs. Consequently, profits do not attract outside capital. This leads to a long period of super-profits. The neo-classical view does not expect prolonged capital market failure. Profit opportunities are rapidly exploited, attracting capital from elsewhere in the economy if necessary. Product prices fall and eliminate super-profits. The different views of capital markets invite investigation of the availability of capital for expansion of the new industries. The closely related implications for profit rates also provide an avenue for discriminating between the views.

Published histories of the cotton industry contain surprisingly limited information on the industry's prices and profits during the early Industrial Revolution. More has been discovered about sources of capital, but the results remain somewhat inconclusive. I have recently worked with company records that survive in archive in Greater Manchester (Harley, 1998). The evidence they contain shows that Mokyr's model fits the history of the Lancashire cotton textile industry during the Industrial Revolution poorly. The industry's price and profit history more closely resemble a neo-classical process.

Arkwright's water-frame, patented in 1769, and a few years later, Crampon's mule were major technological breakthroughs in spinning technology. Arkwright and his partners, as initial innovators in the new technology reaped large profits under patent protection. Competitors challenged the patent monopoly and imitation began to erode cotton prices and profits even before the ending of the patent in the early 1780s. With the end of patent protection, competition quickly lowered yarn prices. In 1788, the expansion of English production and the end of a period of restricted supply from India seems to have marked the end of the era of super-profits. The improved technology no longer created a surplus that accrued as profits to firms in the industry, but rather provided consumers with textiles at lower prices. Thereafter the industry grew as a result of continued technological progress and demand expansion. The evidence available on profits shows that they fluctuated sharply but do not seem to have exceed a competitive rate of return commensurate with the risks involved. In the competitive environment that had emerged by the last decade of the eighteenth century, the expansion of exports appears not to have been a source of continuing profit accumulation and a major source of reinvestment funds but a response to the lower prices of textiles that allowed British firms to capture foreign markets. The competition that resulted in lowered cloth prices and growing exports brought the benefits of the technological advance to foreigners but made little contribution to British welfare.

IV. Prices

The general downward movement of the prices of cotton goods caused by new technology, first in spinning and then from the second quarter of the nineteenth century in power weaving, is well known. Detailed research into archival sources has recently traced the price movements with greater precision (Harley, 1998). Initially innovation was confined to spinning and had much greater impact on fine yarns and warps than on coarse wefts. Nonetheless all yarn

prices declined dramatically from the at least the mid 1780s (See Table 1 and Figure 3). Certainly, yarn prices did not remain constant as the new spinning technology spread as Mokyr's model supposes. Nor did the falling price of yarn drive wages down in proportion. Wage data are still somewhat uncertain. Few scholars contend that real wages advanced significantly during the Napoleonic Wars. But real wages certainly declined by no more than ten percent. In contrast, the real price of even the coarsest weft yarns fell to only a third their early 1780s level by 1815 and prices of other yarns fell by much more.

Table 1

Yarn Prices, Nominal and Deflated, 1769 - 1827

(pence per lb.)

	Current Prices			Deflated Prices		
	18 weft	40 warp	100 twist	18 weft	40 warp	100 twist
1769	33					
1778	34					
1780/4	33	122		47	168	
1785/9	33	99	532	47	142	761
1790/4	27	74	240	36	97	318
1795/9	33	71	104	36	77	112
1800/4	31	62	92	27	55	80
1805/9	22	46	78	19	39	66
1810/4	21	42	69	15	30	50
1815/9	18	35	72	15	30	62
1820/4	11	22	51	11	22	51
1825/7	10	21	53	10	20	52

Source: Harley, 1998. Deflation uses Feinstein (1985) cost of living index.

Figure 3
Yarn Prices, 1760s – 1825

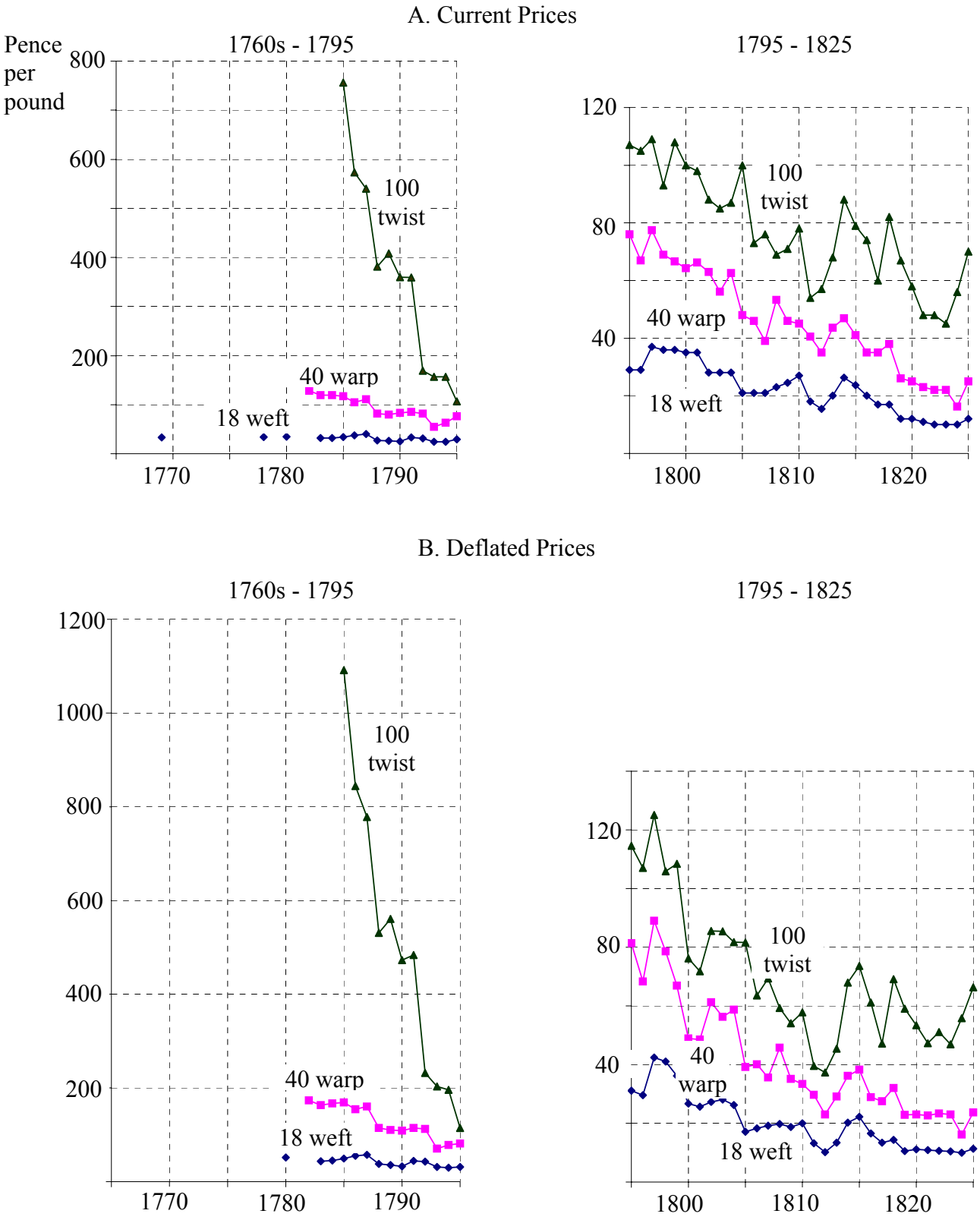


Figure 4
Cloth Prices, 1760s –1830s

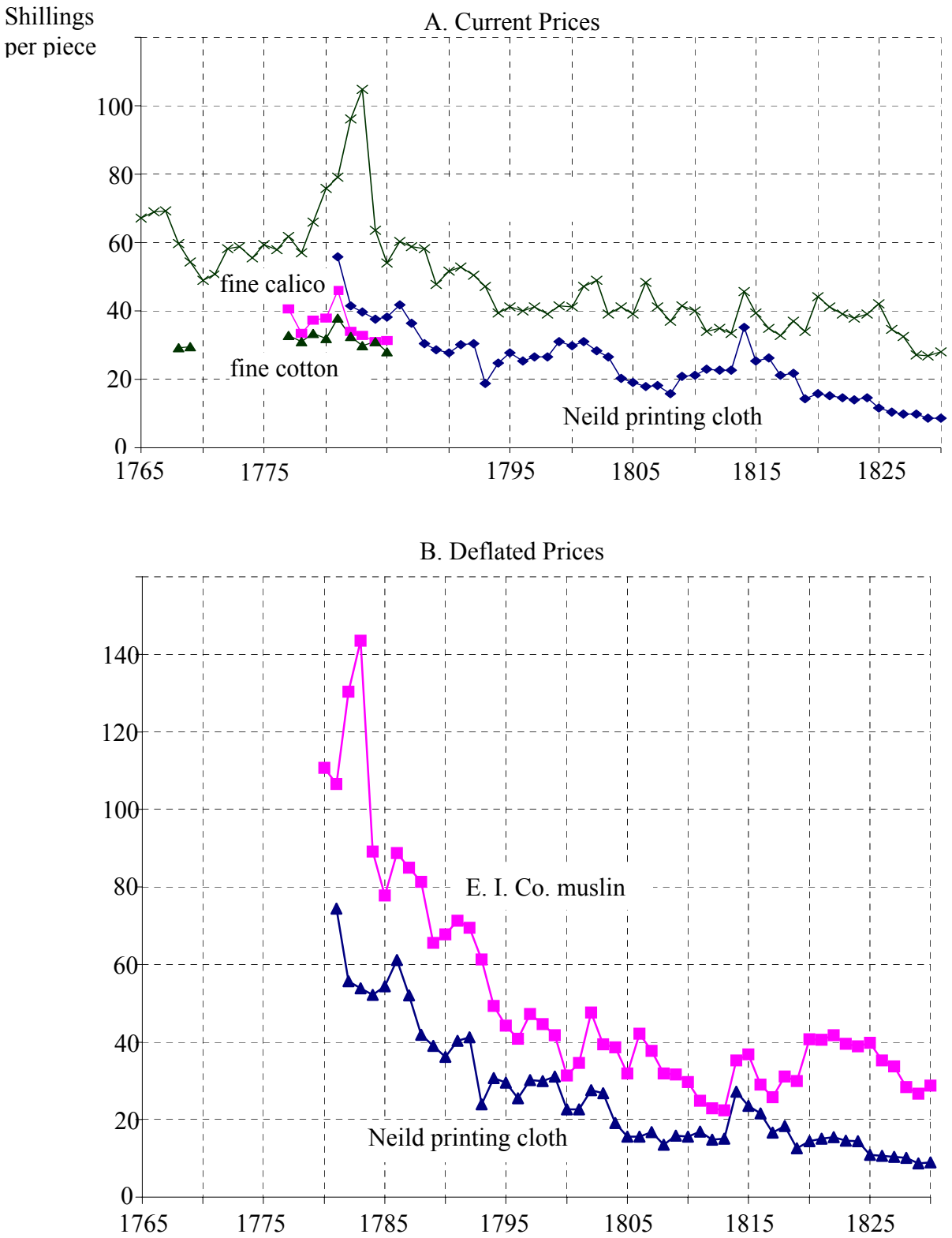
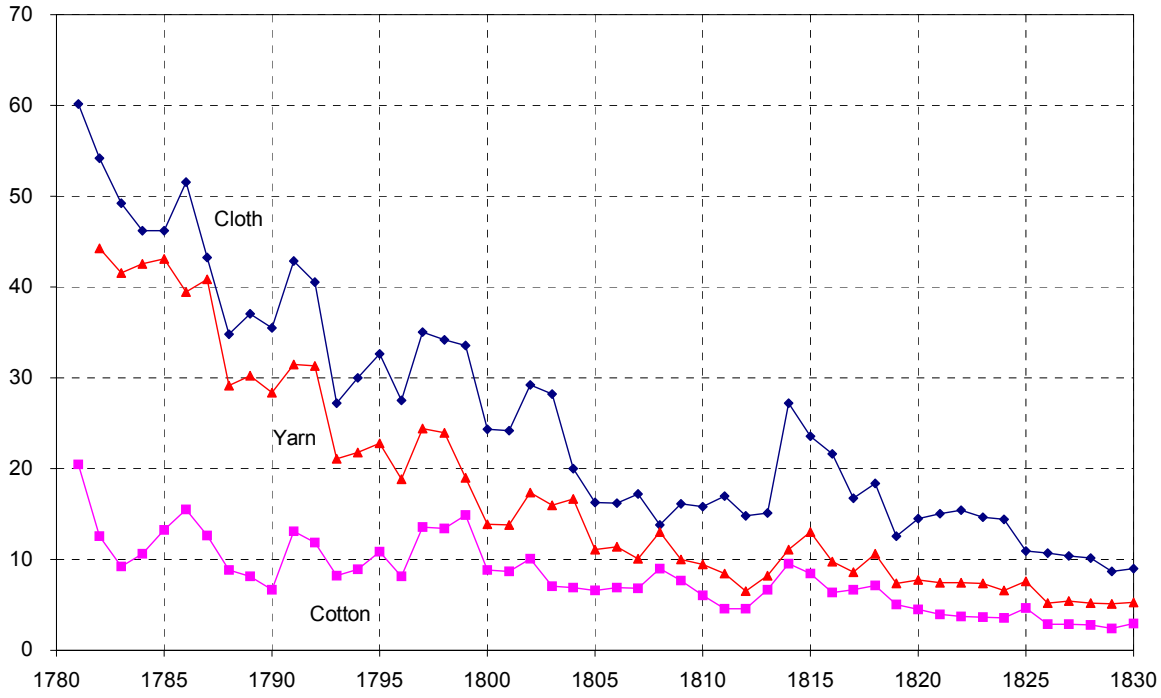


Figure 5

Deflated Cloth Prices and Componants



Cotton cloth prices fell much more slowly than yarn prices in the first generation of the Industrial Revolution. The slower price decline occurred, however, not as a result of insufficient competition restricted by capital availability but because technological advance had not occurred in weaving. Even so, as Figure 4 shows, cloth prices fell quite impressively in real terms before the end of the Napoleonic Wars because the price of yarn had fallen so far. Cloth prices continued to fall thereafter as technology improved in weaving and finishing. Among the various cotton textiles, the particular nature of technological advance changed relative prices. The varied effects of innovations even within spinning have already been noted (see Figure 3). Figure 5 shows the movement of prices of various components of a standard printing calico between the

early 1780s and the 1830s.[5] From the 1780s to the end of the century, yarn prices fell, but the value added in weaving yarn into grey cloth did not. Weaving wages even rose in the 1780s as the quantity of cloth demanded increased as a result of the fall of yarn prices. Weavers' real wages, however, returned to pre-war levels by the 1820s as an abundant pool of labour within traditional sectors of the economy moved into weaving in response to temporarily higher wages. But, consumers rather than capitalists benefited because the return of wages to long-run equilibrium caused a fall in cloth prices rather than an increase in profits. Only after the 1820s did mechanization of weaving have an important effect.

V. Investment and the Capital Market

Mokyr's model depends crucially on severe limitations on capital mobilization. The delayed traverse to a modern economy depends on limitations to investment in modern machinery. Despite modern capital earning super-profits, outside capital does not enter to expand the output of the modern industry. The failure of the formal capital market to developed finance for industrial entrepreneurs caused the profits and delayed expansion. Furthermore technological knowledge is guarded by innovators and not allowed to diffuse outside the industry. Growth of the modern sector in the model, therefore, depends on the profit rate of innovating firms and entrepreneurial willingness to reinvest profits.

Mokyr motivated his view by reference to the widespread observation that reinvested profits financed most of the expansion of firms during the Industrial Revolution. Certainly reinvested profits were a major source of investment funds, but this remains true for firms today. By itself it is poor evidence of capital market failure.

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[5] The vertical disintegration of the industry provided market prices of various stages of production. Weaving firms

The characterisation of firms isolation from the capital market conflicts with most detailed studies of the late eighteenth century textile industry (including Crouzet (1972), Mokyr's principal authority). The histories of the industry suggest several reasons for doubting the existence of a serious capital constraint. Fixed capital played a relatively modest role in the costs of new firms. The new technology attracted capital from pre-existing putting out and mercantile sources. New firms using the new technology were able to fit into the sophisticated "web of credit" that existed in Britain by the late eighteenth century (Crouzet, 1972; Heaton, 1935; Pollard, 1964; Chapman, 1967; Cotterell, 1980; Hudson, 1986). The credit system involved book credit among customers, bills of exchange and the emerging country banking system. Crouzet (1972, p. 45 citing Pollard (1964)) concludes "that 'this web of credit should be placed near the centre of the exposition of the accumulation of capital.' Merchant firms, which supplied industry with a large part of the circulating capital, thus played a dominant and decisive part in the industrial revolution, and the financing of stocks by mercantile capital was much more important than industry's self-finance, at least up to 1815." Crouzet ends his discussion of the financing of firms (p. 53) concluding that "the emphasis which recent writing has placed upon trade credit, a closer relationship between banks and industry, and the early capital market, has tended to show that in eighteenth century and early nineteenth century Britain, with its sophisticated and innovating financial system, capital supply was not a serious problem."

Certainly eighteenth century businesses drew heavily on internal funds and any external funds came from individuals with personal or business contacts with the firm's owners. This, however, should not be a source of surprise. Investment always involves the surrender of

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bought yarn and sold grey cloth.

command over current resources for expectations of future return. Future returns depend in large measure on the ability, diligence and honesty of those running the firm that is using the investment. When outsiders lend they must be compensated for the risks they bear in depending on the performance of others in managing the firm. This risk of uncertain agent behaviour does not arise when partners in the firm invest their own funds. Consequently internally generated funds are cheapest to the firm and will be used in preference to other funds if they are available. The next cheapest funds come from those who are able independently to judge the character of the firm's partners. Only when the economies of scale in the technology are so great as to necessitate very large firms for efficient production does it become appropriate to invest in managerial and accounting techniques that can provide investors, who do not personally know the managers of the firm, the reassurance they need to be willing to part with their funds.[6]

The predominance of internally generated funds in the expansion of firms during the Industrial Revolution cannot, by itself, tell us whether the capital market operated efficiently or not. Perhaps firms needed no additional funds to exploit the opportunities the technology presented. The rate of return that capital earned in the industry relative to its earnings in other uses with comparable risk provides a much better test of the availability of capital. There was a meaningful capital shortage in the new industry only if, as Mokyr maintains, the rate of return on investment in the industry was abnormally high. Unfortunately, of course, we do not have comprehensive data on the return to capital in cotton textiles or in the economy generally. Nonetheless, rates of return that can be calculated from the accounts of cotton firms provide useful clues.

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[6] See Neal (1994, pp. 151-7) for a discussion of this issue.

VI. Profits Rates

Profit data are much more difficult to obtain than price data since private partnerships generally have no interest in publicizing profits. Furthermore, while a competitive market will generally equalise product prices among firms (with due allowance for quality differences), profit levels will vary with management ability and luck. The general histories of the cotton industry offer conflicting evidence. Certainly Arkwright became very rich off his invention. Jedediah Strutt, one of his initial partners, although already rich, benefited greatly from his early involvement in the new spinning technology (Fitton and Wadsworth, 1958). We also know, however, that Samuel Oldknow who invested in spinning in the 1780s in close connection with the Arkwrights was kept afloat in his lifetime only by the help of the younger Richard Arkwright who assumed his assets on his death (Fitton, 1989). It is also well known that Samuel Crompton never reaped financial fortune from the mule that he invented. In the cotton finishing business, the Peels became very rich (in part form early connection with Arkwright) but their late eighteenth century rivals, Hargreaves and Liversey, succumbed to spectacular bankruptcy in 1788.

The qualitative evidence suggests that there was a broad range of profit experience but provides no precise indication of its average size. Unfortunately, it also suggests that a small sample of carefully examined firm level profit data may fail to reveal the average industry trend. Nonetheless, it is useful to examine the profit performance from the surviving company records. In particular, I have carefully examined the books of three companies, Samuel Greg and his partners; William Grey and his partners; and Richard Hornby and his partners, whose records survive for years around the turn of the century. Greg was a water-frame spinner and Grey, a mule-spinner while Hornby's was a cloth-weaving firm. All firms were notably successful. Greg

and Hornby and their descendants were major figures in the industry of the first half of the nineteenth century. Grey's firm continued to prosper until at least the 1850s. Since we know many firms failed the data from these probably exaggerate the overall industry profit rate, but on this we have no direct evidence.

Calculating profit rates from surviving business accounts of the late eighteenth century and early nineteenth century requires care. The major accounting device was the balance sheet struck at regular intervals (annually, semi-annually, or quarterly). Profits were calculated as the change in the net worth of the firm. Examination of partners' accounts in Private Ledgers makes it clear, however, that normally the partners credited themselves with a 5 percent annual rate of return on their initial capital and on their accumulated retained earnings before striking the balance. In calculating the profit rates reported below I have added these "interest" payments to partners to the accounting profit. The rate of profit is this gross return divided by the sum of the partners' initial capital plus their retained earnings in the firm.

In the case of Samuel Greg, I have made another adjustment. The balance sheets for the first decade of the nineteenth century show very large bank balances. In September 1805, for example, the bankers' balance was £42,761 while the fixed capital of the firm was valued at £15,728, inventory at £7,662 and accounts receivable at £14,911. Certainly this was not a firm of the sort Mokyr envisages where expansion was constrained by lack of financing. To arrive at a reasonable estimate of the rate of return on Greg's capital in cotton spinning, I felt it was appropriate to adjust for this cash holding and its counterpart as retained earnings on the debit side of the accounts. Unfortunately, I have not found any indication of the interest received on the bankers' balance but I do know Greg was credited with 5 percent on his account by the firm. I have decided to subtract the bankers' balance from both sides of the account prior to

calculating profit rate and to exclude its 5 percent interest from profits. In effect, I am assuming the bank balance paid the same 5 percent interest that was credited to the partners' accounts and have netted it from the spinning profit calculation.[7]

Depreciation of fixed capital also presents a problem in assessing the profits of the spinning firms. Greg and Grey handled depreciation differently. Grey revalued machinery regularly although depreciation was not taken by any simple formula. Grey's profit rates calculated from their balance sheets should be regarded as net of depreciation. Greg's firm, i.e. the partnership, did not own its fixed capital; rather Samuel Greg as an individual owned the mill and its machinery. The partnership rented the fixed capital at an annual rent of 10 per cent of its value as carried on the firm's books. The cost of additions to capital was charged to Samuel Greg and added to the base on which 10 per cent was paid. In the calculations I present below, I have assumed the half of the rent was depreciation and the other half the 5 percent opportunity cost the firm paid on partners' capital and retained earnings. The "depreciation" has been deducted to arrive at the net profit rate that is reported.

The profits calculated in this way exceed the pure return to partnership capital since they include any implicit payment to partners for managerial services. I have attempted to make allowance for this in the Greg and Hornby accounts. In Greg's case his partner, Peter Earle, brought no capital into the firms but had mechanical expertise. Earle received one quarter of the profits after 5 percent had been paid to capital. This averaged about £800 pounds annually. In the net estimate of Greg's profits, I have deducted a similar amount for Samuel Greg's managerial

[7] Notice that if I had not made this adjustment, the calculated rate of profit would have been considerably lower – a weighted average of the 5 percent assumed on the bank balances and the nearly 12 percent I calculate below on the spinning business.

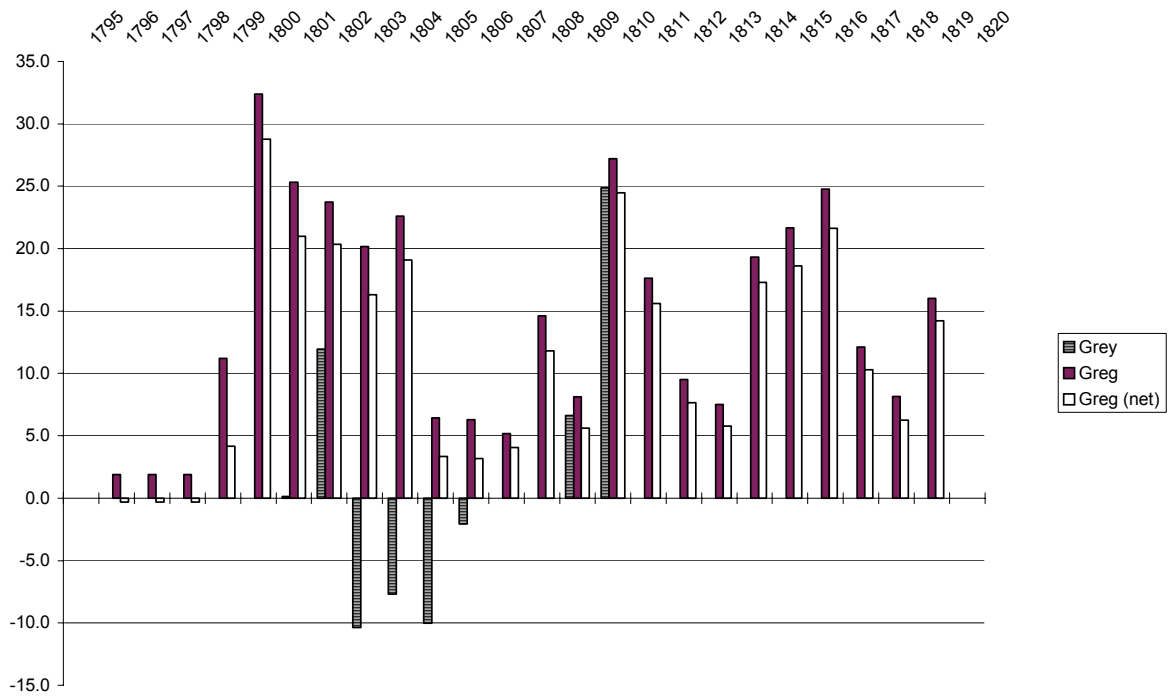
income. The result is the lower profit rate in Figure 6. I have made a similar, although smaller, adjustment to the Hornby accounts. During the last years of the accounts, the firm paid H.H. Hornby, a son of the senior partner who became a partner himself in 1804, £200 per year for managing the firm's Manchester business. I have deducted a similar £200 payment for each partner before calculating the lower net profit rate in Figure 8.

Finally some attention should be drawn to the problem of calculating meaningful profits during an inflationary era. In the accounting practices used, a rising price level will lead to a higher valuation of the circulating capital and accounts receivable that constituted the bulk of the firms assets than would have been the case if prices had remained stable. Consider a firm that ended the year with exactly the same assets, in terms of physical inventory and accounts receivable relative to sales, it started the year with. In real terms, its assets had not increased in value but the balance sheet would reveal an increase. This increase would be reported as profits, thus exaggerating the rate of return of capital. This problem is particularly important in the early years of the war when prices rose rapidly. Of course, a similar but exactly opposite distortion occurred during the post-war deflation.

Calculations of profits show great variation, but the average levels do not seem to indicate that the firms were earning significant quasi-rents. On average over the long run from 1796 to 1819, Samuel Greg earned an average annual rate of profit (net of 5 percent depreciation and estimated managerial payment) of 11.7 percent. Probably an acceptable rate of return but surely not much of a super-premium over the safe rate of 5 percent considering the fluctuations of earnings and the risks of bankruptcy he accepted. The Bolton fine-spinning firm of William Grey and partners did not do nearly so well in the years between 1801 and 1810 when we can trace their fortunes. In the difficult years after the resumption of war with France they saw the

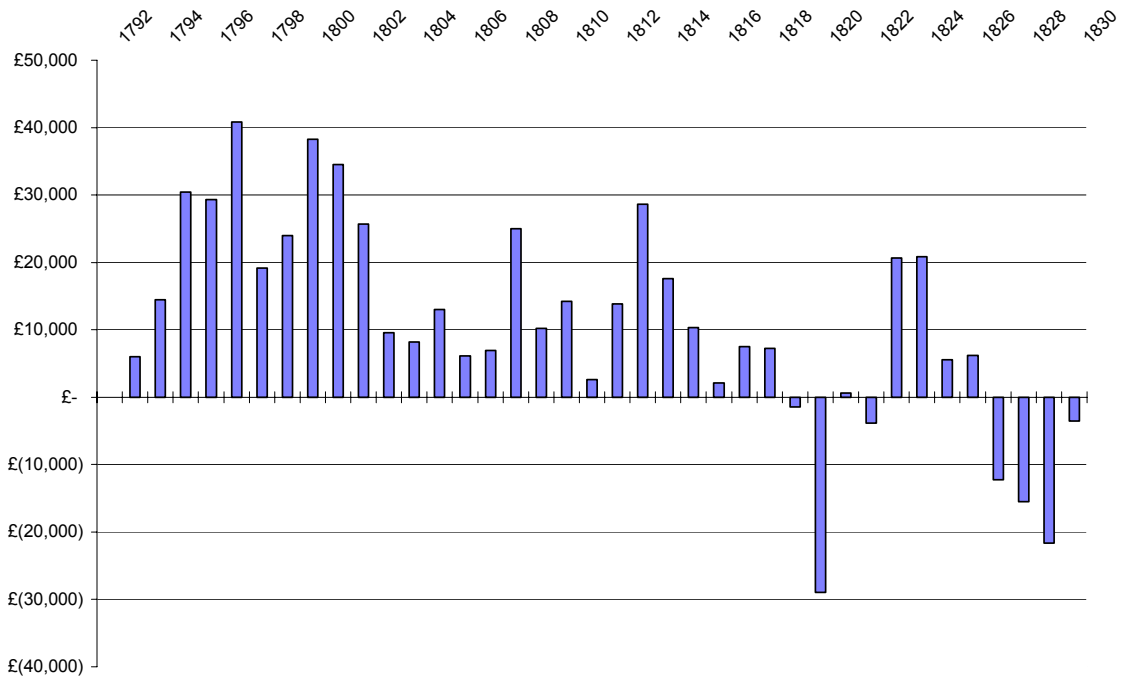
value of their net worth in the firm disappear and were only kept in business by capital infusion from their father. Over the decade their average return appears to have been under 2 percent annually, even without any allowance for managerial income.

Figure 6: Spinners' Profits



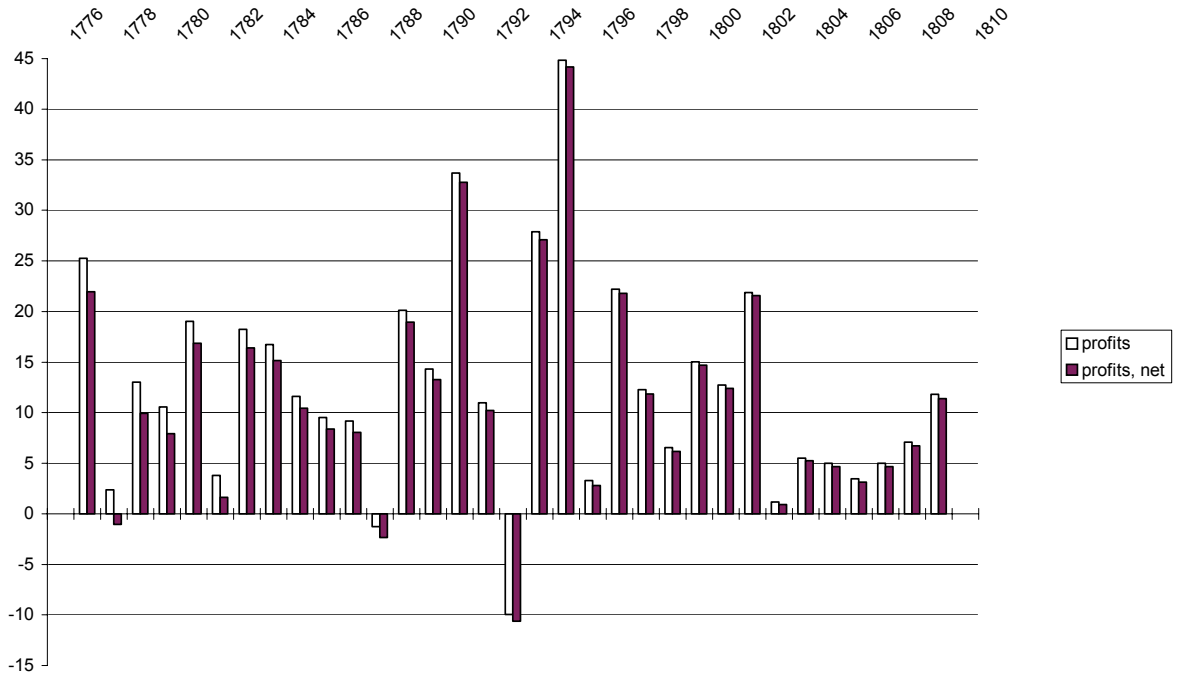
Spinners, at the forefront of the technological change of the late nineteen-century, do not seem to have been earning excess profits by 1800 or so. This impression is reinforced by Richard Arkwright Jr.'s profits that are summarised in Figure 7 (Fitton, 1989, pp. 225-8). These are annual profits in money terms and, unfortunately, I do not know how were calculated or the capital base to which they relate. Nonetheless they confirm both that profits fluctuated and their declining trend.

Figure 7: Arkwright's Profits



Richard Hornby and his partners were cloth manufacturers who employed weavers on a putting-out basis. Their business was not effected by new technology until well into the nineteenth century except, of course, that they were able to purchase yarn, their primary input, at increasing lower prices. Nor did they employ any substantial fixed capital embodying new technology. Figure 8 shows the course of their profits between 1777 and 1809. Its average level was 11.4 percent nearly exactly the same as that earned by Samuel Greg in spinning over a different but overlapping period.

Figure 8: Hornby Profits



Conclusions

Examination of details of cotton textile prices and the profits earned by a small sample of firms in the early years of the Industrial Revolution indicates that technological change that lowered costs of production quickly attracted capital. Output expanded and prices fell. Limited data on profits are far from conclusive, but they indicate that sufficient capital was attracted to the industry to expand output and drive profits down to something that resembles the equilibrium of the economists' model of a perfectly competitive market. The data examined here do not support the contention that the process originated by improved cotton technology is usefully analysed by a special model that emphasizes, as Mokyr's model of "growing up," the difficulty that outsiders had in gaining knowledge of the technology and the imperfections in the capital market. It suggests, instead, that an approach that focuses on the distinctions among industries

and recognized the limitations of the impact of technological change in a single industry probably have more to offer in understanding the beginnings of modern economic growth in Britain. This in turn suggests that although the history of the cotton textile industry deserves the attention it receives, it is far from providing the key to understanding of the modern growth process.

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