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Explaining the First Industrial Revolution: Two Views

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Abstract

This review essay looks at the recent books on the British Industrial Revolution by Robert Allen and Joel Mokyr. Both writers seek to explain Britain's primacy. This paper offers a critical but sympathetic account of the main arguments of the two authors considering both the economic logic and the empirical validity of their rival claims. In each case, the ideas are promising but the evidence base seems in need of further support. It may be that eventually these explanations for British economic leadership at the turn of the nineteenth century are recognized as complementary rather than competing.

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Introduction

New books by Robert Allen (2009a) and Joel Mokyr (2009) contain important, but competing, reinterpretations of the British Industrial Revolution. They share common ground in placing the explanation of sustained acceleration in technological progress at the heart of the story. They differ, however, on the reasons for this. Allen stresses that the new technologies were invented in Britain because they were profitable there but not elsewhere while Mokyr sees the Enlightenment as highly significant and underestimated by previous scholars. Each thinks that the other's argument is flawed.

This review essay seeks first to set out the claims of the two authors and to place them in some historiographic context, and then to evaluate them. The tone will, I hope, be one of sympathetic criticism. The task of explaining why the first industrial revolution took place in Britain in the late eighteenth and early nineteenth centuries is far from trivial, indeed, it has been thought of in the past as akin to a search for the Holy Grail. The endeavour undertaken by Allen and Mokyr is most welcome, inter alia, as an antidote to the fashionable approach of Unified Growth Theory (Galor, 2005) which treats the industrial revolution either as essentially a scale effect or as the outcome of some Darwinian selection process. Taking technological change seriously must be the hallmark of an economic historian's perspective on the transition to modern economic growth and these two authors have over some decades been established at the top of the premier league as analysts of the economic history of technology.

Allen's Argument and Mokyr's Objections

Allen's explanation for the time and place of the first industrial revolution can be summarized as follows. He concentrates on examining what stimulated the technological breakthroughs associated with famous inventions which then triggered off sequences of technological progress (p. 135). His conclusion is deceptively simple: "The Industrial Revolution, in short, was invented in Britain in the eighteenth century because it paid to invent it there" (p. 2).

This bottom line is reached in several steps. First, it is stressed that "Britain's unique price and wage structure was the pivot around which the Industrial Revolution turned" (p. 15). In particular, international comparisons show Britain had relatively high wages but cheap capital and very cheap energy. Second, Allen points to the high fixed costs of developing 'macro-inventions' into commercially viable technologies through research and development; he argues that these will only be incurred where the technology is profitable to adopt, a decision which turns on relative factor prices, and where the market is big enough that success in perfecting the technology will deliver enough sales to reward the proprietor (pp. 141-142, 151-154). Third, the profitability of adopting several inventions including the spinning jenny, Arkwright's mill, and coke smelting is examined with the result in each case that adoption is rational at British but not at French prices (ch. 8, 9). Fourth, these technologies are improved markedly through time in a process of micro-invention which is Hicks-neutral rather than labour-saving and eventually means that it is rational for them to diffuse widely across the rest of the world. This 'tipping point' was typically reached some decades later and then British competitive advantage was lost (pp. 154-155). Fifth, it is recognized that a favourable configuration of prices and wages would not be sufficient to deliver the industrial revolution. Allen accepts that "factors touching on the supply of inventors may explain why the Industrial Revolution happened in 1800 rather than 1400" (pp. 268-269); he notes that a cultural revolution had happened in the meantime and that, by the latter date, the British economy had a much greater level of human capital (p. 12).

Although Allen provides much greater detail and conceptual sophistication, in essence, this argument is not new. Earlier vintages tended to talk in terms of the role of 'shortages' in inducing technological progress and to note that Britain differed from its rivals in this regard. For example, Peter Mathias wrote that "It is a commonplace to remark that Britain had been fortunate in her scarcities" (1979, p. 8) while Francois Crouzet (1990) provided a lengthy review of the factor scarcity hypothesis with which he clearly sympathized but for which he could not quite provide a clinching justification. Nevertheless, the construction in the past decade of the extensive datasets that clearly establish Britain as a high-wage economy in the context of Asia-Europe comparisons has thrown new light on these issues and returned them to centre stage, as is underlined by recent research by Stephen Broadberry and Bishnupriya Gupta (2009) on competitive advantage in cotton textiles. Allen himself acknowledges an intellectual debt to H. J. Habakkuk (1962) and sees eighteenth-century Britain as "the prequel to nineteenth-century America" (p. 15). Moreover, as he points out, his approach to micro-inventions is based on the localized-learning formulation of the Habakkuk hypothesis about the role of relative factor prices in promoting labour-saving technological progress in nineteenth-century America developed by Paul David (1975).

While he accepts that the basic assumption that inventive activity was driven by a desire to make money, Mokyr devotes several pages, comprising both theoretical and empirical objections, to a direct rebuttal of Allen's arguments. Mokyr makes three main points. First, in the tradition of W. E. G. Salter's (1960) critique of Sir John Hicks (1932), he notes that, in the search for new techniques, firms will try to save all costs not just those of relatively expensive factors (pp. 268-269). Second, he claims that there is little evidence to support the view that technological progress exhibited a labour-saving bias overall either in terms of its macroeconomic footprint or the evidence from patents compiled by Christine Macleod (1988) which suggest that, even at the end of the eighteenth century, only 21 per cent of inventions could be classified as intended to save labour (p. 269, 271). Third, at most relative factor prices may determine the direction of technological change rather than the intensity of innovative effort which depended on technological capabilities and was constrained by the availability of useful knowledge (p. 270, 272).

Mokyr's Argument and Allen's Objections

Mokyr conceptualizes the Industrial Revolution as "the set of events that placed technology in the position of the main engine of economic change" (p. 5). His aim is to explain this phenomenon. He sums up his thesis as follows: "Britain became the leader of the Industrial Revolution because, more than any other European economy, it was able to take advantage of its endowment of human and physical resources thanks to the great synergy of the

Enlightenment: the combination of the Baconian program in useful knowledge and the recognition that better institutions created better incentives" (p. 122).

Mokyr suggests that what was needed to generate an industrial revolution was the right combination of useful knowledge generated by scientists, engineers and inventors to be exploited by a supply of skilled craftsmen in an institutional environment that produced the correct incentives for entrepreneurs (p. 116). He believes that Britain's advantages must have been on the supply rather than the demand side of the economy since the Netherlands was richer, France was larger, and Spain had more colonies (p. 99). In this regard, the Enlightenment is seen as having two favourable effects in terms of improving both technological capabilities and also institutional quality. The Baconian program comprised research based on experimentation and scientific method, directing the research agenda to focus on solving practical problems, and making the results widely accessible by organization and dissemination of knowledge (p. 40). Mokyr acknowledges that the impact of the Enlightenment on institutions is hard to quantify but argues that the success of its ideology reduced rent-seeking and promoted competitive markets (p. 63). It was manifested in terms of legislation such as the abolition of the Corn Laws but also strengthened informal institutions in the form of social norms that favoured gentlemanly capitalism rather than opportunistic behaviour (ch. 16).

Here too, it is easy to point to precursors in the historiography but, in this case, of the components of the argument rather than the synthesis highlighting the role of ideology that is constructed by Mokyr. The links between scientific thought and the industrial revolution were underlined by T. S. Ashton (1948), extensively documented in A. E. Musson and Eric Robinson (1969) and put into perspective by Mathias (1979) who anticipated Mokyr's emphasis on scientific attitudes rather than scientific knowledge. Recent cliometric work by Joerg Baten and Jan-Luiten van Zanden (2008) has found that the growth of book production had a positive effect on European economic growth in the pre- and early-industrial period. Similarly, the role played by gentlemanly capitalism in reducing transactions costs was promulgated by Peter Cain and Antony Hopkins (1993), while Daniel Bogart and Gary Richardson (2008) have catalogued the role of parliament as a force for institutional adaptability that promoted more efficient markets, and the emphasis on belief systems as a major influence on institutions, especially informal institutions, echoes Douglass North (2005).

Allen devotes chapter 10 of his book to rejecting Mokyr's 'industrial-enlightenment model' of invention using a sample of 79 inventors of whom 10 created macro-inventions that drove the industrial revolution.[1] First, Allen investigates the links of these people with Enlightenment science and finds that these were present for about half but that while this was quite general in the case of steam but it was infrequent for textiles or metals which had much greater economic impact: "using that yardstick, the Industrial Enlightenment did not matter much" (p. 252). Second, Allen considers whether the inventors came from the upper class as

[1] These 10 are Richard Arkwright, Edmund Cartwright, Samuel Crompton, Henry Cort, Abraham Darby, James Hargreaves, Thomas Newcomen, John Smeaton, James Watt and Josiah Wedgwood.

he contends the Enlightenment model predicts. There is some support for this, in particular, merchants, lawyers and capitalists made up 4.6 per cent of the population but 32.8 per cent of the inventors (p. 259); however, at the same time, the fathers of many inventors were artisans. Third, Allen looks at inventors as experimenters; he finds that "Experimentation was ... the common feature that characterized eighteenth-century inventors" (p. 255) but sees this as nothing new and takes any increases in the volume of experimentation to be more a consequence of better education than the Enlightenment per se (pp. 257, 267). Interestingly, Allen says nothing about the impact of the Enlightenment on institutions or economic reform. Presumably, this is because he considers institutional quality to be unimportant as a reason for English primacy in the Industrial Revolution (pp. 5, 15, 125).

Assessment

The Role of Relative Factor Prices

This deserves to be examined in terms both of what modern economic theory has to say and also with regard to the details of the empirical evidence. Taking an approach based on the endogenous-innovation school of new growth economics makes a difference. But while this provides a solid theoretical underpinning for a labour-scarcity hypothesis about the bias and the rate of technological progress it also highlights the need for clarification as to what the key differences were between Britain and other countries. Then, the weight of the evidence put forward by Allen to support his claims can be assessed.

The model set out by Daron Acemoglu (2002) predicts the direction of technical change in a setting where suppliers of different types of new technology respond to market signals. In his model, relative-price and market-size effects both matter; the former creates incentives to develop techniques used in the production of goods that use more expensive factors of production and the latter to invent technologies that have a larger market, i.e., use the more abundant factor. The net effect depends on the elasticity of substitution between factors. The importance of the market size effect can be understood in terms of expected profitability in the context of incurring fixed costs in development of a new technology.[2] Acemoglu (2009) extends this analysis to consider the impact of labour scarcity on the rate, rather than the bias, of technological progress. The key result is that this effect is positive if technological change is strongly labour-saving, i.e., it reduces the marginal product of labour.[3]

Thus, notwithstanding Mokyr's dismissive reaction, Allen's analysis is theoretically defensible and his emphasis on the costs of development of a technology goes with the flow of recent growth economics. In the spirit of Acemoglu's model, the decision to incur the development costs for the technologies that were central to the industrial revolution would be predicted to depend on the number of potential adopters. In turn, this would depend both on

[2] This puts Hicks's (1932) conjecture on a firm foundation. It should also be noted that in this model, in general, technical change is biased towards factors that become relatively more abundant in the sense that, at constant factor proportions, its relative marginal product will be increased.

[3] Technology is strongly labour saving if in the production function $Y = f(L, Z, \theta)$, where θ is a vector of technologies where an increase in any component raises output, there are decreasing differences in θ and L. This might be where machines replace tasks previously undertaken by labour as in Joseph Zeira (1998).

whether it was profitable for firms to adopt the technology, given factor prices, and also on how many firms were in the market, as Allen points out (pp. 152-3). Either relative factor prices or market size might undermine the viability of developing the technology and it would be nice to distinguish clearly between the two. Let us review Allen's evidence with this in mind.

Allen considers the profitability of adopting the spinning jenny in detail (pp. 185, 194-195, 213-215). He compares savings in wages with the cost of the jenny and finds that the rate of return around 1780 was 38 per cent in England, compared with a required rate of return assumed to be 15 per cent, but only 2.5 per cent in France and minus 5.2 per cent in India. England's advantage over France accrues both from higher wages and cheaper jennies in the former. Allen's calculations are reported in Table 1 together with some further permutations.

Several interesting points emerge from Table 1. First, at the English price, the jenny would be profitable at French wages. It is incorrect to say that low wages were the reason the French did not use the jenny. Indeed, at the French jenny price, adoption would not have been profitable at English wages. Second, it looks very profitable to invent and adopt the jenny in America.[4] So, perhaps it is really the small size of the market there that is the obstacle, as Allen seems to suggest (p. 41), or perhaps human capital is inadequate (p. 212).[5] Third, in England, the jenny would have been profitable at wages of 3.75d (60 per cent of the figure used by Allen). Based on Allen's wage and prices dataset, this implies that it had been profitable since 1650, over a century before Hargreaves's invention. Fourth, it should also be noted that the rate of return is quite sensitive to the utilization assumptions.[6] If it is assumed that the jenny would be in use for half the day on 300 days of the year rather than 40 per cent of the day on 250 days, as assumed by Allen, then $\Delta L = 100$ and the rate of return in France becomes 18 per cent while it would have been profitable with English wages at 2.51d (40 per cent of Allen's wage rate).

Overall, Allen's headline story that the combination of high wages and cheap coal was the key to inventing the industrial revolution seems a bit too bold. Market size may well matter and coal does not come into it in the important case of the breakthroughs in cotton-textile technology; devoting some effort to quantifying market size would be valuable. The delay in inventing the jenny, although it appears that it would have been profitable long before the 1760s, and the questionable robustness of the rate-of-return calculations add to the sense that the argument is oversold. More work on similar calculations for the other inventions would strengthen Allen's claims.

Macro- and Micro-Inventions

[4] This also seems to be true of the Arkwright mill. Using a procedure analogous to that used by Allen (2009, pp. 215-216) based on American wages divided by American jenny costs relative to English wages divided by English jenny costs (= 1.049), I calculate that the potential rate of return on the Arkwright mill in Philadelphia was 32.5 per cent.

[5] Allen makes a similar point about the invention of the steam engine; in comparing England and Belgium, he appeals to the small size of the Belgian coal industry rather than relative factor prices as Belgium's key disadvantage.

[6] I am grateful to John Lyons for making the point to me that Allen's utilization rates appear very low.

Both Allen and Mokyr use the terminology of 'macro-inventions' and 'micro-inventions' and this distinction is not only valuable in thinking about technological change in the industrial Revolution but it also has implications in terms of the evidence for their rival interpretations. To avoid serious confusion, however, it is important to recognize that they use different definitions of these terms.

The Enlightened Economy continues in the tradition of Mokyr (1990) where macro-inventions are radical new ideas without clear precedent that emerge more or less ab nihilo with potentially dramatic effects. The industrial revolution was notable for a cluster of such inventions. Micro-inventions represent the development stage which turns the original invention into a viable business proposition (Mokyr, 2002, p. 48, 105) and the continuous flow of incremental improvements that made the new techniques work better (Mokyr, 2009, p. 81). In other words, micro-inventions are a combination of research and development and learning by doing/using. Mokyr sees macro-inventions as only weakly, if at all, related to economic forces but the process of micro-invention is responsive to economic incentives (1990, p. 295). Micro-inventions are far more frequent and account for the lion's share of productivity gains (Mokyr, 1990, p. 13).

Allen also sees macro-inventions as important breakthroughs that give rise to long trajectories of advance but, for him, a key characteristic is that they radically changed factor proportions, and in the case of the industrial revolution were labour-saving (p. 136). To perfect a macro-invention to the point where it is commercially viable requires a great deal of perspiration (and expense) and this explains why macro-invention is biased and sensitive to relative factor prices (p. 141). Micro-invention is the process of localized learning after the technology has been introduced and this is neutral rather than prone to a factor-saving bias. Allen thinks in terms of a diagram introduced by David (1975) and reproduced here as Figure 1. The process of macro-invention makes point C possible, which will only appeal to the country with the P_1 relative factor prices, but then learning generates movement down the α ray.

If we think of sequence which comprises three phases which are 1) idea → 2) R & D including substantial development expenditure → 3) incremental improvement, then Allen considers 1) and 2) as 'macro-invention' and 3) as 'micro-invention' whereas for Mokyr 1) is 'macro-invention' while 2) and 3) are both aspects of 'micro-invention'. The different treatment of Development explains why for Allen macro but not micro invention is sensitive to price signals but for Mokyr the opposite is the case. Adopting a common convention on terminology could eliminate this apparent discrepancy and allow the two approaches to be combined. Then the big difference between the two authors would concern their hypotheses about the major influences on the successful development of new technology (phase 2).[7]

If micro-invention is central to technological advance especially with regard to realizing its productivity potential, then, if the Industrial Enlightenment hypothesis is to carry weight, it must explain why it entails a substantial impact on micro-invention. Indeed, this is central to Mokyr's argument. He maintains that micro-invention required a great deal of pragmatic and

[7] Their hypotheses are not mutually exclusive and the real argument may be about their relative importance.

informal knowledge and a systematic method of experimentation (2002, p. 48), that at the heart of the process were anonymous craftsmen who investigated what worked and what did not work (2009, p. 44), and that a major contribution came from reduced access costs to useful knowledge. The human capital of the workforce then gave Britain a comparative advantage in micro-invention (2009, p.113).

Several points arise from this with regard to attempts to test Mokyr's hypothesis. First, Allen's focus on the origins and contacts of the macro-inventors is at best a partial test or, at worst, misplaced and the very anonymity of micro-invention makes quantitative investigation of the craftsmen's role impossible. Second, if artisanal micro-invention is important, the connections of this with the Enlightenment remain somewhat elusive and, at best, indirect, as Mokyr admits (2009, pp. 57-61). Third, the notion of lower access costs to knowledge as a stimulus to micro-invention during the industrial revolution is attractive but again remains to be quantified and may be the result of the spread of tacit knowledge through the factory system or urbanization rather than the availability of technical manuals or the activities of scientific societies.

The notion of micro-invention embodied in Figure 1 has implications for the identification of labour-saving bias in technological progress. If there is movement towards the origin down the α ray, then the cumulative effect of these locally-neutral improvements is to impart a labour-saving bias to the shape of the isoquant. (Indeed, this is exactly what David had in mind (1975, p. 59) when he devised this set-up as a solution to the problems posed by the Habakkuk debate). However, in this case, there is no reason to expect that the associated patent citations will on average exhibit claims of labour saving. Indeed, following Moses Abramovitz and David (2001), the place to look for evidence would be in the macroeconomic footprint of technological change on relative factor shares as capital-to-labour ratios change.

Here, pace Mokyr, there is some evidence in support of Allen's view that technological change in the industrial revolution was labour saving. Allen (2009b) offers a calibrated model of the British economy based on a translog production function that approximately replicates the stagnation of real wages and the rise in the share of profits in national income at this time together with faster growth of the capital stock than the labour force. The calibration assumes that technical change is entirely labour augmenting and has an elasticity of substitution between capital and labour of 0.2. This is similar to the view of technological change in nineteenth-century America offered by Abramovitz and David (2001).[8]

Was micro-invention really neutral? David (1975) asserted that localized learning would have this characteristic and had technical reasons for wanting this to be the case but offered little evidence to support his claim. Allen's discussion of several cases offers at best mixed support. While coke-smelting seems to fit the assumption (p. 217), micro-invention in cotton textiles was relentlessly labour-saving (p. 184, 209) while in steam engines it actually

[8] An implication is that estimates of TFP growth devised from imposition of standard Cobb-Douglas assumptions are biased downwards. However, using the formula in Dani Rodrik (1997) indicates that the bias is small; 0.04 and 0.17 percentage points per year in 1760-1801 and 1801-31, respectively. These numbers reflect the slow increase in the capital to labour ratio.

entailed a reversal of the original bias and became energy-saving (p. 177). When micro-invention is interpreted a la Mokyr, then bias might be predicted if, for example, trying to find point C is interpreted as factor substitution with the process of trying to convert ideas into commercial propositions is guided by price signals (cf. David, 1975, p. 35).

If micro-invention is interpreted as a flow of incremental improvements, then it remains to be established how far the resulting labour productivity growth was the result of passive learning rather than investments in intangible capital or changes in physical or human capital to labour ratios. Generally speaking, the literature on learning by doing has tended over time to think that omitted-variables bias has inflated estimates of productivity growth from case studies of learning-by-doing. This appears to be true in the famous cases both of Liberty ships (Thompson, 2001) and the Lowell textile mills (Bessen, 2003; Lazonick and Brush, 1985) although in neither case has this bias been fully purged. The bottom line seems to be that we need to know considerably more about micro-invention and, especially, learning in order to evaluate the competing claims of Allen and Mokyr.

Ideology, Institutional Change and Economic Reform

Mokyr stresses that the ideology of the Enlightenment had a dual impact on the First Industrial Revolution both because it was conducive to the production of more useful knowledge while at the same time reducing access costs and also through its effects in improving incentive structures through promoting better economic policy and institutions. This argument fits perfectly with endogenous growth theory in the tradition of Philippe Aghion and Peter Howitt (1992). Once again, the issues that arise are not so much with the logic of the argument but its empirical validity.

In terms of Figure 2, the Enlightenment would raise λ, the innovation-friendliness of the economy, thus shifting the Schumpeter relationship upwards and increasing the amount of technological progress expected for any level of the capital to effective labour ratio. The favourable impact on λ came both through lower costs of innovating and also from better payoffs from innovating as the process of creative destruction was facilitated and rent-seeking opportunities were greatly reduced. Mokyr sees the breakthrough of the British Industrial Revolution in terms of a transition to *sustained* technological advance and thus the real contribution of the higher λ thanks to the Enlightenment was to underpin productivity growth through micro-invention (pp. 487-488).

Mokyr's argument is much more subtle than earlier discussions of institutional change in the context of the industrial revolution. For example, in emphasizing the effectiveness of the parliamentary system as an agent of reforms that make markets work better he is more convincing on how the Glorious Revolution mattered than North and Barry Weingast (1989), in downplaying the role of the 'deeply-flawed' patent system (p. 410) relative to other aspects of institutional quality he rightly dismisses the claims of North and Robert Thomas (1973), and in focusing on the incentives for micro-invention he need not be perturbed by the rejection of the institutional-improvement hypothesis by Greg Clark (2007) on the grounds that many famous inventors made no money.

Mokyr can certainly point to evidence of improvements in institutions and reductions in rent-seeking from the mid-eighteenth to the mid-nineteenth centuries. Bogart and Richardson (2008) noted the number of parliamentary acts that reorganized property rights numbered about 25 per year in the 1720s compared with 175 per year in the 1820s. Forrest Capie (2004) calculated an increase in the coefficient of contract-intensive money (defined as non-currency money divided by total money supply), a proxy for the enforceability and security of property rights, from 0.26 in 1790 to 0.76 in 1870. William Rubinstein's research on probates (1992) showed that fortunes based on exploiting rent-seeking opportunities provided by the state were still very prominent in 1809-1839 but not thereafter.

That said, it has to be noted that Mokyr offers no quantification either of institutional quality or its impact on technological progress and, indeed, this may not be possible, especially if informal institutions are held to be the key; λ is unobservable. Moreover, while Mokyr can point to better economic policy in terms, for example, of the abolition of the Statute of Artificers, the Bubble Act and the Usury Laws, the reform of the patent system, and the Repeal of the Corn Laws, many of these were long-delayed. And it is easy to point to major failures of government policy which might well disappoint those imbued with Enlightenment views, for example, the refusal to promote state-financed primary education despite the high social (and fiscal) rate of return it could have delivered (Lindert, 2009), the incompetent regulation of the railway system that involved the construction of a seriously sub-optimal network at high cost (Casson, 2009; Foreman-Peck, 1987), and the obvious shortcomings of company law even in the second half of the nineteenth century (Cottrell, 1980). These really seem to be the outcome of interest-group politics not evidence-based policy design.

So did Enlightenment ideology matter as much as Mokyr claims? The most serious and quantitative debate on the role of ideology in policy reform has related to the repeal of the Corn Laws in 1846. Using various econometric methodologies, results have differed but it would fair to conclude that it is possible to detect roles for ideology, party affiliation and economic interests in the crucial vote (McKeown, 1989; McLean and Bustani, 1999). However, the ideology which is held to matter is not that of the Enlightenment. The most sophisticated interpretation by Cheryl Schonhardt-Bailey (2003) actually concludes that the success of repeal in 1846 was based on a *weakening* of the role of ideology relative to constituency economic interest within the split Tory party and the ideology in question relates to defending traditional British institutions.

Of course, Mokyr repeatedly acknowledges qualifications to his hypothesis along similar lines to the above and accepts that the evidence for his claims will not strike everyone as compelling while at the same time definitely thinking that 'the glass is half-full'. To be convinced that the Enlightenment had the two-fold favourable impact on λ that Mokyr claims, requires not only that institutions and/or policy improved but also that this was driven by ideology. In particular, this entails dropping the traditional belief that economic interests were much more important than ideas in shaping economic reform and being able to show that there were significant positive impacts of reforms on innovative effort. Before this interpretation gains general acceptance, especially among those of a cliometric disposition, more quantitative evidence will be required.

Concluding Comments

These books are really valuable additions to the historiography of the Industrial Revolution. Not surprisingly, they do not solve the problem of explaining why the ideas for the famous inventions came along where and when they did; that would be to ask too much. But they do make progress in offering plausible ideas as to why these ideas fell on fertile ground and they do offer important insights into what we need to know to understand how and why a sustained and significant acceleration of technological progress took place in Britain from the late eighteenth century onwards. Unlike Unified Growth Theory they seek to understand this phenomenon rather than, in effect, to explain it away.

In the best argumentative traditions of the new economic history, Allen and Mokyr see their accounts as competing. In essence, however, they are not mutually exclusive and perhaps eventually will more appropriately be seen as complementary. It is widely accepted by economic historians that the explanation for a sustained acceleration of productivity growth must come from understanding the development and subsequent incremental improvement of new technologies. Thus, a combination of Allen and Mokyr's claims might produce the hypothesis that this resulted from the responsiveness of agents, which was augmented by the Enlightenment, to the wage and price configuration that underpinned the profitability of innovative effort in the eighteenth century.

References

Abramovitz, M. and David, P. (2001), "Two Centuries of American Macroeconomic Growth: from Exploitation of Resource Abundance to Knowledge-Driven Development", Stanford Institute for Economic Policy Research Discussion Paper No. 01-05.

Acemoglu, D. (2002), "Directed Technical Change", *Review of Economic Studies*, 69, 781-809.

Acemoglu, D. (2009), "When Does Labor Scarcity Encourage Innovation?", NBER Working Paper No. 14809.

Adams, D. R. (1970), "Some Evidence on English and American Wage Rates, 1790-1830", *Journal of Economic History*, 30, 499-520.

Aghion, P. And Howitt, P. (1992), *Endogenous Growth Theory*. Cambridge, Mass.: MIT Press.

Allen, R. C. (2009a), *The British Industrial Revolution in Global Perspective*. Cambridge: Cambridge University Press.

Allen, R. C. (2009b), "Engels' Pause: Technical Change, Capital Accumulation, and Inequality in the British Industrial Revolution", *Explorations in Economic History*, 46, 418-435.

Ashton, T. S. (1948), *The Industrial Revolution, 1760-1830*. London: Oxford University Press.

Baten, J. and van Zanden, J-L. (2008), "Book Production and the Onset of Modern Economic Growth", *Journal of Economic Growth*, 13, 217-235.

Bessen, J. (2003), "Technology and Learning by Factory Workers: the Stretch-Out at Lowell, 1842", *Journal of Economic History*, 63, 33-64.

Bogart, D. and Richardson, G. (2008), "Institutional Adaptability and Economic Development: the Property Rights Revolution in Britain, 1700-1830", NBER Working Paper No. 13757.

Broadberry, S. and Gupta, B. (2009), "Lancashire, India, and Shifting Competitive Advantage in Cotton Textiles, 1700-1850: the Neglected Role of Factor Prices", *Economic History Review*, 62, 279-305.

Cain. P. J. and Hopkins, A. G. (1993), *British Imperialism: Innovation and Expansion 1688-1914*. London: Longman.

Capie, F. (2004), "Money and Economic Development in Eighteenth-Century England", in L. Prados de la Escosura (ed.), *Exceptionalism and Industrialisation: Britain and Its European Rivals, 1688-1815*. Cambridge: Cambridge University Press.

Carlin, W. and Soskice, D. (2006), *Macroeconomics: Imperfections, Institutions and Policies*. Oxford: Oxford University Press.

Casson, M. (2009), *The World's First Railway System: Enterprise, Competition, and Regulation on the Railway Network in Victorian Britain*. Oxford: Oxford University Press.

Clark, G. (2007), *A Farewell to Alms*. Princeton: Princeton University Press.

Cottrell, P. L. (1980), *Industrial Finance, 1830-1914*. London: Methuen.

Crouzet, F. (1990), *Britain Ascendant: Comparative Studies in Franco-British Economic History*. Cambridge: Cambridge University Press.

David, P. A. (1975), *Technical Choice, Innovation and Economic Growth*. Cambridge: Cambridge University Press.

Foreman-Peck, J. S. (1987), "Natural Monopoly and Railway Policy in the Nineteenth Century", *Oxford Economic Papers*, 39, 699-718.

Galor, O. (2005), "From Stagnation to Growth: Unified Growth Theory" in P. Aghion and S. Durlauf (eds.), *Handbook of Economic Growth*. Amsterdam: North-Holland.

Habakkuk, H. J. (1962), *American and British Technology in the Nineteenth Century*. Cambridge: Cambridge University Press.

Hicks, J. R. (1932), *The Theory of Wages*. London: Macmillan.

Jeremy, D. J. (1973), "British Textile Technology Transmission to the United States: the Philadelphia Region Experience, 1770-1820", *Business History Review*, 47, 24-52.

Lazonick, W. and Brush, T, (1985), "The 'Horndal Effect' in Early U.S. Manufacturing", *Explorations in Economic History*, 22, 53-96.

Lindert, P. H. (2009), "Revealing Failures in the History of School Finance", NBER Working Paper No. 15491.

Macleod, C. (1988), *Inventing the Industrial Revolution*. Cambridge: Cambridge University Press.

Mathias, P. (1979), *The Transformation of England*. London: Methuen.

McKeown, T. J. (1989), "The Politics of Corn Law Repeal and Theories of Commercial Policy", *British Journal of Political Science*, 19, 353-380.

McLean, I. And Bustani, C. (1999), "Irish Potatoes and British Politics: Interests, Ideology, Heresthetic and the Repeal of the Corn Laws", *Political Studies*, 47, 817-836.

Mokyr, J. (1990), *The Lever of Riches*. Oxford: Oxford University Press.

Mokyr, J. (2002), *The Gifts of Athena*. Princeton: Princeton University Press.

Mokyr, J. (2009), *The Enlightened Economy: an Economic History of Britain 1700-1850*. New Haven: Yale University Press.

Musson, A. E. and Robinson, E. (1969), *Science and Technology in the Industrial Revolution*. Manchester: Manchester University Press.

North, D. C. (2005), *Understanding the Process of Economic Change*. Princeton: Princeton University Press.

North, D.C. and Thomas, R. P. (1973), *The Rise of the Western World: a New Economic History*. Cambridge: Cambridge University Press.

North, D. C. and Weingast, B. (1989), "Constitutions and Commitment: Evolution of Institutions Governing Public Choice in Seventeenth-Century England", *Journal of Economic History*, 49, 803-832.

Rodrik, D. (1997), "TFPG Controversies, Institutions and Economic Performance in East Asia", CEPR Discussion Paper No. 1587.

Rubinstein, W. D. (1992), "The Structure of Wealth-Holding in Britain, 1809-1839: a Preliminary Anatomy", *Historical Research*, 65, 74-89.

Salter, W. E. G. (1960), *Productivity and Technical Change*. Cambridge: Cambridge University Press.

Schonhardt-Bailey, C. (2003), "Ideology, Party and Interests in the British Parliament of 1841-47", *British Journal of Political Science*, 33, 581-605.

Thompson, P. (2001), "How Much Did the Liberty Shipbuilders Learn? New Evidence for an Old Case Study", *Journal of Political Economy*, 109, 103-137.

Zeira, J. (1998), "Workers, Machines and Economic Growth", *Quarterly Journal of Economics*, 113, 1091-1113.

Table 1. Internal Rate of Return on Purchase of Spinning Jenny, c. 1780 (%)

Cost of Jenny	***840d***	***1450d***	***1500d***
Wages			
9.375d	64.0	31.0	29.5
6.25d	38.0	13.5	12.0
4.66d	24.0	2.5	1.5
3.75d	15.0	-5.0	-6.5

Notes:

England: price of jenny = 840d, wage = 6.25d (Allen, 2009, p.214)
France: price of jenny = 1450d, wage = 4.66d (Allen, 2009, p.214)
United States (Philadelphia): price of jenny = 1500d (Jeremy, 1973, p. 30), wage = 9.375d based on 50 per cent differential with England (Adams, 1970).

Rate of return is derived from the expression

$J = \Sigma(w\Delta L - m)/(1 + r)^t$

where J is the price of the jenny, w is the daily wage of a spinner, m is the additional maintenance cost of the jenny assumed to be 10% of the purchase price each year and the lifetime of the machine is 10 years.

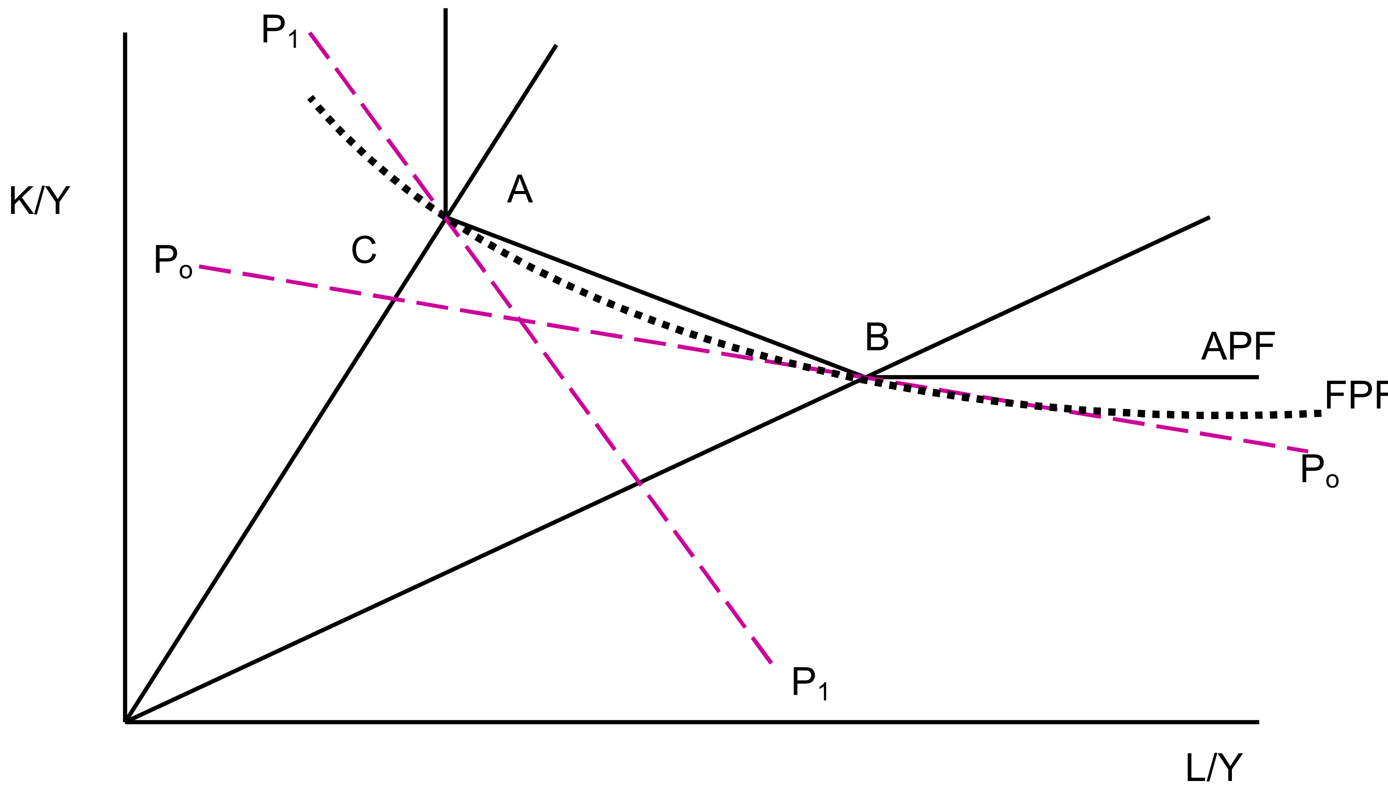
ΔL is the saving of labour based on the formula

$\Delta L = YD(1 - 1/P)$

Where Y is the number of days the jenny is used each year, D is the proportion of a full day that it was used for, and P is the relative labour productivity of a spinner with the jenny compared with the spinning wheel. Allen's base-case assumptions are that Y = 250, D = 0.4 and P =3 so $\Delta L = 67$.

Source: own calculations based on these assumptions

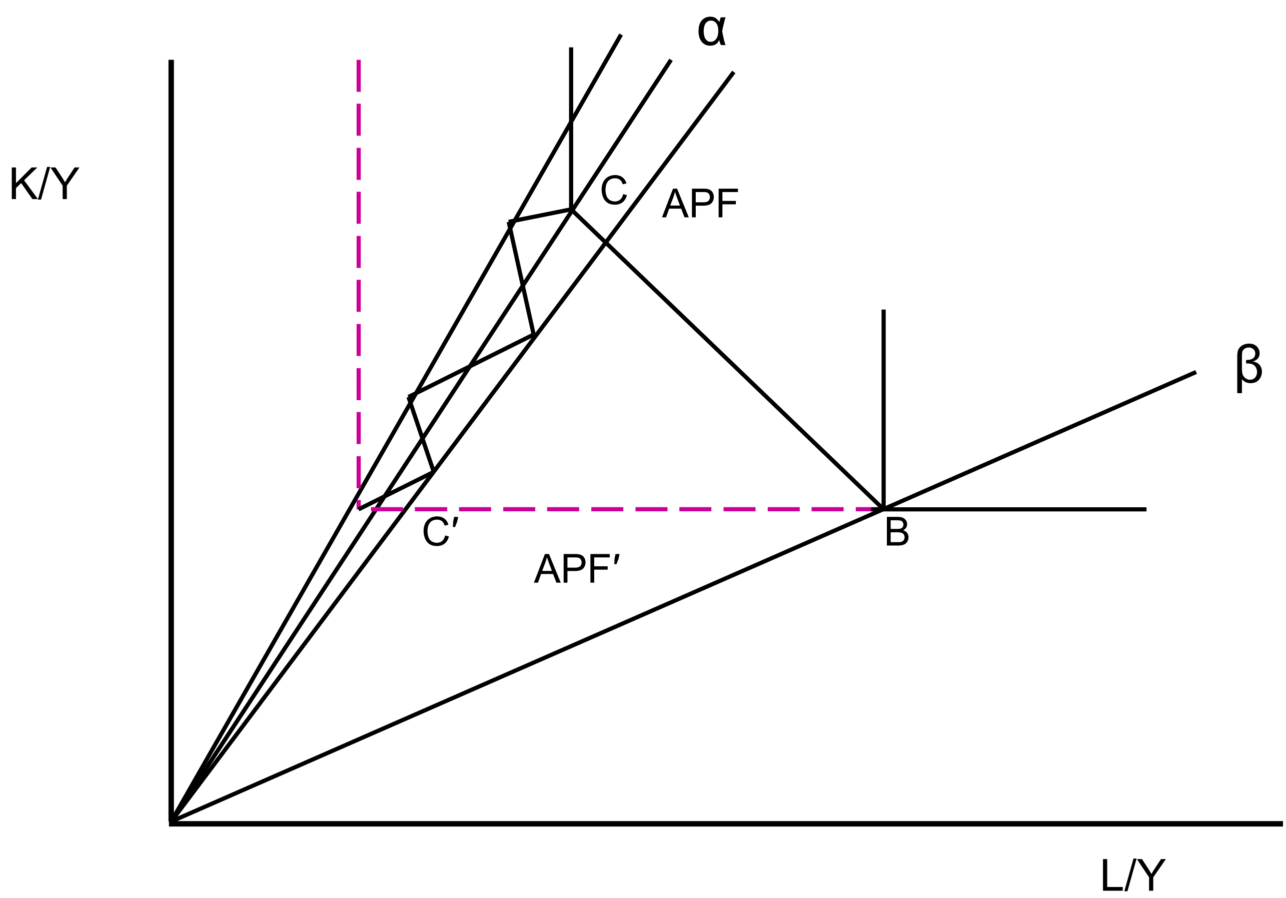
1a-Choice of Technology: The role of factor prices



Source: David, 1975

Note: K is capital, L is labour and APF is the available production techniques frontier. The dotted lines P_0P_0 and P_1P_1 are isocost lines at different relative factor prices. At P_1 (P_0) relative factor prices, point A (B) on the Available Process Frontier will be chosen. Compared with these original points, C is on a lower (higher) isocost line at P_1 (P_0) relative factor prices.

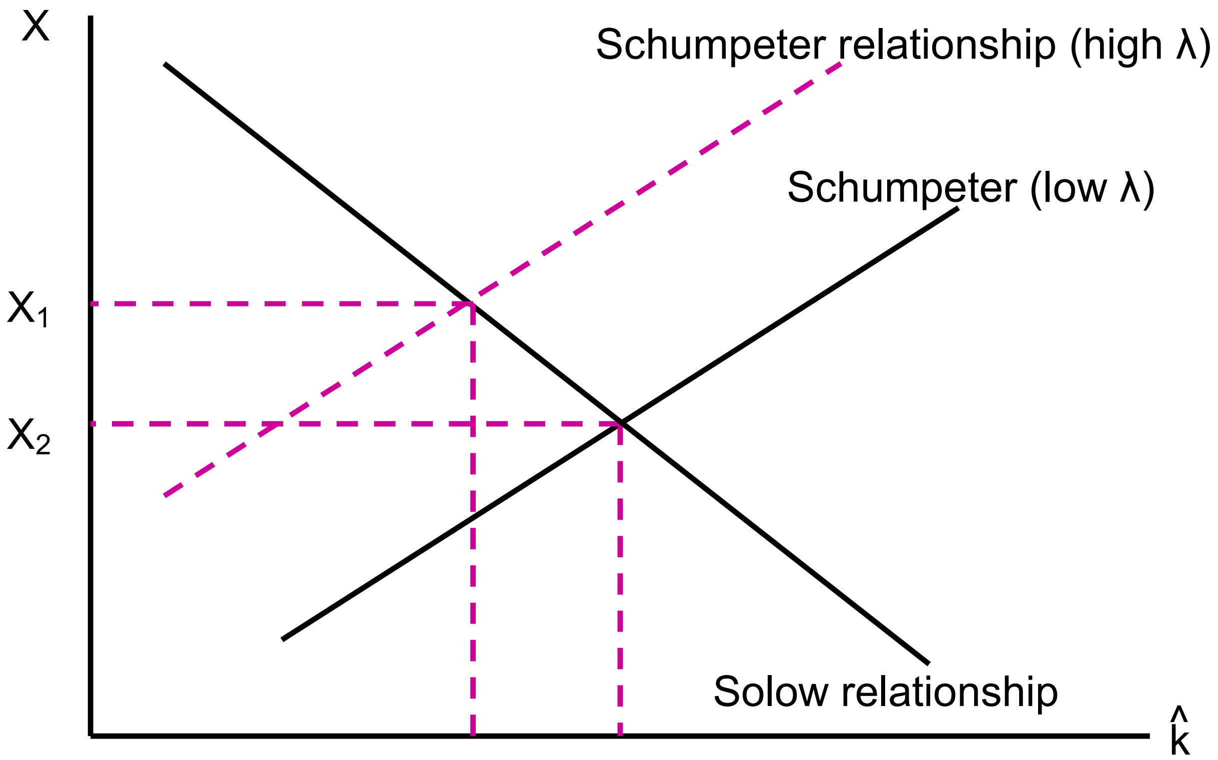
1b-Technical progress: Localised change



Source: David, 1975

Note: from point C neutral localized learning proceeds down the α ray towards the origin. Eventually, this technology will be preferred at both sets of relative factor prices if there is no progress down the β ray. Following David (1975), Broadberry and Gupta (2009) suggest that progress down the α ray will be much faster than down the β ray.

Figure 2: Endogenous Growth



Source: based on Carlin and Soskice (2006)

Note: the rate of technological change is on the vertical axis and the capital to effective labour ratio on the horizontal axis. The Solow relationship captures the steady-state relationship between capital intensity and the rate of technological change for a given savings ratio. The Schumpeter relationship captures the standard assumption of endogenous-innovation growth models. Higher λ represents an economic environment that is more conducive to innovation, for example, because institutions are better, R & D is more productive because of a better science base, etc..