# The Industrial Revolution in Miniature:

# The Spinning Jenny in Britain, France, and India

by

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Abstract

This paper uses the adoption and invention of the spinning jenny as a test case to understand why the industrial revolution occurred in Britain in the eighteenth century rather than in France or India. It is shown that wages were much higher relative to capital prices in Britain than in other countries. Calculation of the profitability of adopting the spinning jenny shows that it was profitable in Britain but not in France or in India. Since the jenny was profitable to use only in Britain, it was only in Britain that it was worth incurring the costs necessary to develop it. That is why the jenny was invented in Britain but not elsewhere. Irrespective of the quality of their institutions or the progressiveness of their cultures, neither the French nor the Indians would have found it profitable to mechanize cotton production in the eighteenth century.

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"When we see that Timber is sawd by Wind-mills and Files cut by slight Instruments; and even Silk-stockings woven by an Engine,...we may be tempted to ask, what handy work it is, that Mechanicall contrivances may not enable men to performe by Engines."

–Robert Boyle, 1671, Vol. II, Essay IV, p. 20.

Within a century, Boyle's vision materialized. In the words of Ashton's famous schoolboy: "About 1760 a wave of gadgets swept over England."[1] Some are well known (the spinning jenny, the water frame, the steam engine), and others less so (devices to lay-out and cut the gears of watches, foot powered trip hammers to stamp the heads on nails). Much has been learned about these inventions, but central questions remain: Why did the gadgets sweep over England rather than the Netherlands or France or, for that matter, China or India? And why were these technologies invented in England rather than elsewhere? Why, in other words, was the Industrial Revolution British?

This paper approaches these questions through a case study of the spinning jenny, the machine that kicked off the industrial revolution in cotton. It was invented by James Hargreaves in Lancashire in the mid 1760s, about the same time that Richard Arkwright was inventing his water frame. The spinning jenny, however, was the first to be used on a large scale. It quickly displaced spinning wheels in Britain. France was the other major European cotton producer, but adoption across the Channel was very slow. These industries were small compared to the major Asian producers. In Britain and France, several million pounds of cotton were spun annually in the middle of the eighteenth century.[2] In Bengal, which was major centre of exports to Europe and Africa and, thus, the main competitor of British and French manufacturers, production was about 85 million pounds per year.[3] This was accomplished without any mechanization, and, indeed, explaining "the absence of any technological innovation in the textile industry" is an important problem for Indian historians (Chaudhury 1999, p. 173). In the nineteenth century, British producers out competed all others in the world, and they did it with machines like Crompton's mule that were descendants of Hargreave's jenny. Why did the British start on this propitious line of development, while the French, the Indians and everyone else failed to take the first step?

Explaining the Industrial Revolution is a longstanding question, and many social

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[1]Ashton (1955, p. 42).

[2]According to Crouzet (1985, p. 32), 18 million pounds of raw cotton were imported into Britain in 1786 and 11 million pounds into France. The industries had grown at similar rates previously, so their size was similar earlier. About 3 million pounds per year were imported into Britain in the 1750s (Wadsworth and Mann 1931, p. 521).

[3]Chaudhury (1999, p. 143, 175, 188, 198, 211) indicates that about 60 million rupees of cotton cloth were consumed in Bengal in the middle of the eighteenth century, 10 million rupees were exported by Asian merchants and 6 million by Europeans. European exports in 1750/1-54/5 amounted to 744,652 pieces. The average price of these cloths indicates that they were cheap, not luxurious. Scaling up in proportion to sales (76/6) implies that total production equaled 9,432,259 pieces. A piece was typically 40 x 2.25 covids and a covid was 18 inches, so 212,225,827.5 square yards were produced. Pomeranz's (2000, p. 318) figures indicate that Chinese cloth weighed about 0.4 pounds per square yard, which is plausible. That density implies that production was 85 million pounds per year.

scientists have offered answers.[4] A current favourite is political structure–parliamentary checks on the executive, the security of property rights, the flexibility of the legal system. According to this view, the dramatic changes of the late eighteenth century can be traced back to the Glorious Revolution of 1688 that consolidated parliamentary ascendancy, minimal government, and secure property rights. Supposedly, these legal changes created a favourable climate for investment that made the industrial revolution possible.[5] Another approach is to trace inventiveness back to culture. The oldest variant is Weber's theory that Calvinism made Protestants particularly rational and oriented towards economic achievement. This view lives on in Landes' (1969) thesis that the French were poor entrepreneurs who failed to adopt British technology even though it would have paid and in Clark's (2007) claim that the British worked harder than other people because of genetic selection. Another tack attributes Europe's lead over India (if not Britain's lead over France) to the Scientific Revolution of the seventeenth century, especially as it acted through the Industrial Enlightenment (Mokyr 2002). These hypotheses are being actively investigated, but much remains to be done to establish the importance of political institutions or culture for economic performance.

This paper takes a different approach and argues that we can understand why the great inventions were made in England and adopted there by focussing on their economics. Simply put, I argue that the technologies of the Industrial Revolution were *adopted* in Britain rather than elsewhere because they were profitable in Britain but generated losses elsewhere. This argument also explains Britain's precociousness in invention: The famous inventions of the Industrial Revolution were *invented* in Britain because they generated enough profit to make the cost of developing and perfecting them worthwhile. They were not invented elsewhere because they would not–indeed, were not–used even when they were freely available. Hence, there was no point in inventing them. Or, to put the argument in economic terms: In France and India, the social rate of return to inventing British technology was to too low to justify the necessary R&D.

In this paper, I develop this view by investigating a sequence of problems in the history of the spinning jenny. The first is what did it mean to invent the jenny? We must avoid the appealing–but false–proposition that new technologies with big economic effects must have been the products of big ideas. On the contrary, inventions like the spinning jenny are example's of Edison's dictum that 'invention is 1% inspiration and 99% perspiration.' We can understand why they were made by focussing on the incentives to do the hard work of development rather than concentrating on the sources of inspiration. Second, how did the inventions affect the input requirements of production? If they were neutral technical changes, they would have created the same proportional cost decline whatever the factor price configuration, and so the incentives to adopt them would have been the same in England, France, and India. I argue instead that techniques like the spinning jenny were biased and increased capital requirements while reducing labour requirements. This meant that the incentive to adopt the new techniques was greatest where wages were highest relative

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[4]Hartwell (1967) and Mokyr (1999) provide surveys. Crafts (1977) has suggested that Britain's lead was fortuitous.

[5]North and Weingast (1989), De Long and Schleifer (1993), LaPorta, Lopez-de-Silanes, Schleifer, Vishny (1998), and Acemoglu, Johnson, and Robinson (2005). For critiques see Clark (1996, 2007), Epstein (2000), and Quinn (2001).

to capital costs. Third, England stood apart from the rest of the world in having high relative wages. That is why British technology was adopted initially in Britain and not elsewhere. Fourth, since invention was basically research and development, it generated expenses. Modern problems of venture capital and benefit recovery emerged. It was only in Britain, which was the only place where the new technologies generated profits, that it was worth while to incur the R&D expenses needed to invent them. That is why the Industrial Revolution was British.

## How the spinning jenny was invented

To understand what was involved in inventing the jenny, first consider the spinning wheel, which it replaced. The spinning wheel consisted of a vertical wheel, a spindle that was parallel to the axle of the wheel, and a string that acted as a belt so the turning wheel rotated the spindle. Sometimes a treadle was used to turn the wheel; otherwise, the spinner did it with her right hand. In either case, the spindle spun as the wheel turned, and the inertia of the wheel stabilized the speed.

Before the cotton was spun it was cleaned and then carded to produce a loose strand called a roving. The spinster faced the spinning wheel, so the spindle was in front of her and the wheel was to its right. One end of the roving was attached to the spindle, and she held the rest of it in her left hand. The two fundamental operations in spinning were drawing and twisting. First, she drew her left hand away from the spindle. This lengthened the roving and made it thinner. Second, she moved her left hand to the left and beyond the end of the spindle. As the spindle turned, the cotton slipped off its end once every revolution and was twisted. This made the yarn strong. When it was twisted enough, the spinster moved her left hand back between her body and the spindle, at which point, the yarn was wound onto the spindle. This sequence was repeated until the entire roving was drawn, twisted, and wound.

Some inventions required strokes of genius, flashes of insight, or newly discovered scientific knowledge. The spinning jenny was not one of them. Many people had thought of devising an engine to spin fibre. Indeed, Kerridge (1985, p. 269) claims to have discovered examples of spinning machines in use in Norwich early in the eighteenth century. None, however, was widely used before Hargreaves' invention in 1764. The story, which is perhaps apocryphal, is that he was inspired by seeing how a spinning wheel, which had toppled over on its side, continued to rotate and spin automatically. Previously, Hargreaves had tried to operate several wheels simultaneously by holding all of the threads from each in his left hand, but that proved impossible with horizontal spindles. When the wheel was on its side, its spindle was vertical, however, and that made it feasible to draw and twist on many spindles. Vertical spindles became a fundamental feature of the jenny.

The spinning jenny had a row of spindles on one side and, on the other side, a parallel row of pins. The rovings were wound on these pins, and each roving extended across the jenny to the opposite spindle. The spindles were spun by belts from a single wheel. Between the spindles and the pins was a sliding bar with clamps that could grasp the rovings and draw them out. Twist was then imparted by turning the spindles, and finally, the yarn was wound onto the spindles as the sliding bar was pushed towards them. At the same time, the sliding bar pulled out more roving, and the sequence was repeated.

The spinning jenny was not rocket science: the apparatus clearly mimicked the actions of a spinster and wheel but on an expanded scale. It may have required more sweat and less thought than Edison imagined. The trick was clearly to get it all to work. The dimensions had to be worked out and the linkages and the sequences perfected. An important feature was the deflection wire that ensured the yarn was wound evenly on the spindle rather than bunching at one end. Invention in the eighteenth century should not be thought of as an exercise of genius. Instead, Research & Development is the appropriate gloss.

Indeed, it took Hargreaves several years to perfect the jenny, which may account for Arkwright's saying that it was invented in 1767. At first, Hargreaves was supplied with accommodation in Ramsclough, a remote village in Lancashire, and support by Robert Peel, who was acting as his 'venture capitalist.' Peel sired a line of Sir Robert Peels including the prime minster, but Hargreave's backer had no title and was not a cultivated man of the Enlightenment; rather, he was a small scale farmer and putting out merchant known as 'Parsley' Peel after the sketch of a parsley sprig he used as a trade-mark. When word got out that Hargreaves had made a spinning machine, neighbours broke into his house and destroyed the jenny and much of his furniture. In 1768 Hargreaves moved to Brookside where Peel paid for manufacturing premises. They were attacked by a mob and jennies were again destroyed. Hargreaves then moved to Nottingham where he first worked with a man named Shipley and then erected a mill with Thomas James, a joiner, who became his new financier. Hargreaves patented the jenny, but, when he tried to enforce his rights in 1770, was advised by his attorney that he would not succeed in court since he had earlier sold jennies in Lancashire (Aspin and Chapman 1964, pp. 13-24, Baines 1835, p. 158).

Improvements in the jenny were rapid in the 1770s. The wheel was changed from a horizontal to a vertical orientation, and the treadle that turned it was replaced by a simpler hand operated device. A roller was introduced that allowed the number of spindles to be increased to as many as the operator could turn. The first jennies had 12 spindles, but quickly 24 spindles became a standard design. The earliest picture of a jenny is of a 24 spindle model introduced into the United States in 1775 (Aspin and Chapman 1964, plate facing p. 45). These jennies were used in people's houses. By 1780 a 120 spindle jenny was built, although 80 spindles became a standard. These jennies were located in workshops. This mode of production was cheaper than small jennies in cottages, and large workshop jennies had displaced smaller cottage jennies by 1790 (Aspin and Chapman 1964, p. 48-52). These improvements in the jenny were accomplished without patenting and were effected by collective invention (Allen 1983).

What is striking about the history of the jenny is how ordinary everything was. Despite its revolutionary effects, the jenny was a simple machine that did little more than run a lot of spindles off a single spinning wheel. It was hardly a conceptual breakthrough. And James Hargreaves, the inventor, was a very ordinary man. He was born in 1721 in a poor and semi-moorland district of Lancashire where the cotton trade was the main source of employment. He was illiterate and supported himself as a hand-loom weaver for most of his life. The jenny was not his first invention: He was responsible for several simple machines to increase the productivity of labour in carding. One was described thus:

> A plain surface of wood was standing upright and was covered with wire cards which received the cotton, and the hand card which was applied to comb...was moved up and down against the cotton by means of a treddle on the floor...A wood board acting as a spring was affixed to the ceiling, being tied to the card in hand. (As quoted by Aspin and Chapman 1964, p. 11).

Many machines of this sort were being invented in England at this time.

Mokyr (2002) sees the Industrial Revolution as the consequence of the Industrial Enlightenment. This movement involved the collection and dissemination of descriptions of technical processes through publications like the Encylopédie. It also involved professional meetings and informal discussions involving leading manufacturers and scientists in provincial associations, universities, and the Royal Society. Mokyr believes this vanguard of industrial progress was limited to a few thousand people. They were mainly from the upper classes.

Hargreaves does not fit this model. He was not from a high social class, nor did he ever hobnob with the great and the good. One exception does not, of course, invalidate the Industrial Enlightenment model, but it does raise the question of its generality. Hargreaves' experience is much more consistent with the democratic view of invention propounded by Khan (2005, pp. 106-127) and Khan and Sokoloff (2006) for the United States. They believed that inventors were drawn from across the social spectrum with many coming from humble backgrounds. While England certainly had the upper class inventors described by Mokyr, Hargreaves's life raises the question of whether England did not also have a broad swath of inventors from humble backgrounds who were doing things like fitting treddles to boards hung from springy sticks on the ceiling. Was this how England developed so many labouring savings techniques in the eighteenth century? Henson's (1831) History of the Framework-Knitters describes many people like that inventing improvements to the knitting frame. Only with detailed studies of more industries will we reach a definitive assessment, but Hargreaves' life is a cautionary tale.

## English technology increased the capital-labour ratio

Since the spinning jenny was initially bought by country women for home use, there is a tendency to regard it as not being a capital intensive production method. Aspin and Chapman (1964, p. 46), for instance, contrast 'the comparatively inexpensive jenny' to the mule, which was ' a costly machine.' "Because it was driven by hand and because it was easier to make or far cheaper to buy than either the mule or the waterframe, the jenny was chosen by many men who set up in business with limited capital." While it is true that buying a jenny was cheaper than building an Arkwright-style factory, nonetheless, the jenny had a big impact on input requirements in cotton spinning. Spinning wheels were far cheaper than jennies. Muldrew (2007, p. 8), for instance, reports that in probate inventories he has examined "it is rare to find wheels valued at more than a shilling and some were worth considerably less." In contrast, the spinning jenny with 24 spindles cost about 70 shillings. Since the wheel and the jenny were each operated by one woman, Hargreave's invention raised the capital-labour ratio seventy-fold.[6] That was, indeed, a biased technical change.

## Factor prices in Europe and India

With so much capital tied up in the jenny, its impact on spinning costs depended on the prices of capital and labour. These were very different in England, France, and India. England stands out as the country with expansive labour and cheap capital, and that explains why English producers took up the jenny so enthusiastically. We have the fullest price

[6]The probate inventories predate the spinning jenny, but changes in the price level between the two data sources were not great enough to change the tenor of the conclusion.

information for England and France, so I begin with them.

Wages in France were lower than wages in England in several senses. The first is comparison at the exchange rate. According to Arthur Young (1950, p. 311), for instance, a French spinner earned about 9 sous per day in the late 1780s, while an English spinner could earn 6-1/4 d. or 12-1/2 sous. The low wage earned by workers in France was not matched by low consumer goods prices, so a second sense in which French labour was cheap was that its purchasing power was lower. Young (1950, pp. 314-15) made the point by comparing wage rates to the prices of bread and meat in the two countries. He found that rural workers in France were "76 per cent less at their ease; worse fed, worse clothed and worse supported, than the same classes in England." This point holds more generally when more wages are considered and consumer price indices are defined over a wider spectrum of goods (Allen 2001).

However, for the question at hand, the pertinent sense in which wages were higher in England than elsewhere is the wage rate relative to the price of capital. Here the price of capital is the user cost of capital (r), that is the purchase price of capital goods ($P_K$) multiplied by the interest rate ( i) plus the depreciation rate (d): $r = P_K (i+d)$. Long run interest rates were used to measure i (Homer 1977, pp. 117, 126, 157, Epstein 2000, pp. 20-3), and d was taken to be 5%. The price of new capital goods ($P_K$) was represented by a geometric average of the prices of labour[7] and building materials. This corresponds to the production of capital goods with a Cobb-Douglas technology with materials and labour receiving equal shares. The price of building materials, in turn, was measured as a simple arithmetic average of the prices of iron, bricks, and soft-wood[8]. Figure 1 presents the history of this ratio in England and France from 1550 to 1828. In this graph, England in 1600 is set equal to one, and values for England and France are calculated relative to that.

Figure 1 makes several important points. First, at the end of the middle ages, there was little difference between England and France in the wage relative to the price of capital. Second, after 1600 the series diverged. The wage gradually fell in France relative to the cost of capital, while it rose in England. Third, by the eighteenth century, the wage relative to the cost of capital was as much as two and a half times higher (1.9/.8) in England than in France. With such a large difference, many projects to mechanize production that were profitable in England proved unprofitable in France.

The data respecting wages and prices in India are much less complete than those for Europe. Wages in Bengal and other parts of India were lower than in England at the exchange rate. When the prices of consumer goods are taken into account, Indian wages were too low to purchase the standard of living enjoyed by English workers (Allen 2007a, Broadberry and Gupta 2006). We do not presently have prices of capital goods that would let us to compare India and Europe across the early modern period. The earliest comparison that

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[7]The wage rate in these calculations is that of building labourers in southern England and in Strasbourg as described in Allen (2001).

[8]For England, the price of iron is from Rogers (1866-1892, IV, pp. 404-7, V, pp. 501-4), Aström (1982, pp. 130-1), Hyde (1977, p. 44), and Gayer, Rostow, Schwartz (1953, statistical supplement, pp. 615-6). Bricks are from Beveridge (1939, pp. 671-80), extrapolated earlier with Rogers (1866-1892, IV, pp. 468-72) and later with Beveridge (1939, pp. 298). Wood is from Rogers (1866-1892, IV, pp. 382-7, V, 398-405, and Beveridge 1939, p. 124.) For France, the prices are from Hanauer (1878, Vol. II, pp. 394-401, 437, 584).

can be made for India is for Pune in southwestern India in 1819 (Divekar 1989). This comparison is represented by a single point in Figure 1. In 1819, the wage in India was even lower relative to the price of capital than it was in France for the seventeenth and eighteenth centuries. This means that the incentive to mechanize production in India was even weaker than on the European continent.

## Why the English adopted the spinning jenny and the French and Indians did not

The jenny was taken up very rapidly in England. Aspin and Chapman (1964) reported the use of jennies in many towns across northwestern England in the 1770s and 1780s. A historian in Manchester in 1783 recounted how the first 12 spindle jennies were 'thought a great affair'. The spread of jennies, especially large ones in workshops, was punctuated by riots and arson as spinners protested against their use. By 1788, reportedly 20,070 jennies were spinning cotton in Britain (Aspin and Chapman 1964, p. 48-9).

The situation was very different in India and in France. There is no record that the jenny was ever considered in India. Ignorance may have been one reason, but there are grounds for believing that the cause was more fundamental. China provides a point of contact: A hemp spinning machine was invented there in the thirteenth century, but it was never generally adopted and fell out of use. Does this show a cultural or institutional failure or were there rational economic reasons for continuing with hand processes? I shall argue that it would not have paid to use jennies in eighteenth century India even if they had been known. This assessment, if true, is not a definitive solution to the 'Needham Problem'–far more would have to be considered–but it supports the view that Asia's not developing machine technology was a rational response to the economic environment and not a 'failure'.

The French case is better documented than the Indian, for jennies were a live option south of the Channel. In the event, only about 900 jennies were used in France in 1790, and they were confined almost exclusively to state-aided factories (Wadsworth and Mann 1931, p. 504). The jenny was not adopted by cottage producers in the way it had been in Britain.

The French aversion to jennies was not due to lack of knowledge; indeed, the French government actively promoted them. John Holker was the key figure. He was an English Catholic who took part in the Jacobite rebellion. He was imprisoned and escaped in 1745 when he fled to France. In 1750 he was a cotton manufacturer in Rouen and in 1754 he was appointed to the Colbertist post of Inspector General of Foreign Manufactures. In this postion, he sought to modernize French industry by enticing English entrepreneurs to France. Holker was well informed about developments in the English cotton industry and in 1771 sent his son to Lancashire to obtain a jenny which was set up in Normandy and copied. Efforts were taken to popularize the machine, but it was never adopted by domestic producers. (Wadsworth and Mann 1931, p. 195-99, 503-4)

Why were the French unenthusiastic about the jenny? Is this an example of Weber's dismissal of Catholicism, or Landes' critique of French entrepreneurs, or Clark's distaste for foreign genes? These answers assume that the profitability of adopting a jenny in France was just as high as it was in England, but we must doubt that in view of the bias of the technical change and the difference in factor prices. To pin the matter down, I analyse the rate of return to buying a spinning jenny when it was used in a domestic situation. Technology has a path-dependent character, which means that each technique in the sequence is explained by reference to its immediate predecessor. To explain the chain, one must explain the first step, and that was the decision to buy–or not to buy–a small domestic jenny. The decision makers were domestic producers. They contracted with weavers or cotton merchants to spin cotton that was provided. In both England and France (and, indeed, in India), the domestic producers were paid by the hank (a length of 840 yards) or the pound that they spun (Wadsworth and Mann 1931, p. 173, 177, Bhalla, p. 614), and they bought jennies to increase their production and thus their earnings. The question is whether it was equally profitable for French and English spinners to do this.

The spinning jenny increased labour productivity, so it can be analysed as a way to increase output or to cut costs. The second perspective is adopted here. The question is whether the purchase of a jenny lowered labour costs enough to justify its purchase. The rate of return is found by solving the equation:

$$J = \sum (w\Delta L-m)/(1+r)^t \text{ where the summation is over } t = 1,2,...n \qquad (1)$$

Here J is the purchase price of a jenny, w is the daily wage of a spinner, ΔL is the number of days of labour saved per year, m is the additional maintenance costs associated with the jenny, t is time, n is the length of life of the jenny in years, and r is the internal rate of return, which is the variable to be computed. The savings in labour per year is computed as:

$$\Delta L = YD(1-1/P) \qquad (2)$$

where Y is the number of days the jenny was used in a year, D is the 'part-time fraction' (the proportion of a full day that the jenny was actually worked), and P is output per hour worked with the jenny relative to the spinning wheel. Y and D enter the equation since the women who bought jennies were usually only part time spinners. If a spinster worked 250 days per year but only for half a day each day, then YD=125 full time equivalent days of work that are paid at the rate of w. Now if the jenny allowed the spinster to produce twice as much per hour as she could with a wheel, then P=2, and 50% of the labour is saved, i.e. .5 = (1-1/2).

The difficulty in applying equations 1 and 2 is determining the values of the various parameters. There is much uncertainty here. We can glean information about many of these parameters from eighteenth century English sources, which contrast the experience of jenny and wheel operators and discuss the conditions of their life and work. These sources do not contain everything we need, however. Some parameters are taken from discussions in India in the 1950s and 1960s. During the second Five Year Plan (1951-56), the Ambar Charkha was promoted as an alternative to the traditional wheel (the Charkha) that was used by many Indian women who spun part-time in their homes. The Ambar Charkha was a hand-operated spinning machine that was analogous to the spinning jenny in many respects. The Ambar Charkha had four spindles (less than the spinning jenny) but included carding apparatus. The ratio of the purchase price of an Ambar Charkha to a traditional wheel was of the same order of magnitude as the corresponding ratio for a spinning jenny. The circumstances of domestic producers in twentieth century India through light on the situation two centuries earlier.

<u>The purchase price of a jenny (J)</u>–What we would like is the price of a jenny for cottage use (i.e. 24 spindles). The only prices I have found are for larger workshop jennies of 60 - 80 spindles. In the late 1780s, these cost 140 shillings in England and 280 livre tournois in France (Chapman and Butt 1988, p. 107, Chassagne 1991, p. 191). 24 spindle jennies cost less but probably not in proportion to the number of spindles, so I price them at half the

workshop values–70 shillings and 140 livres tournois.

The wage rate of a spinner (w)–Arthur Young (1950, p. 311) reports that in the late 1780s spinners in England earned 6-1/4 d. per day, while their counterparts in France earned 9 sou. These were earnings of full time workers spinning wool. Earlier data indicate that daily earnings were similar whatever the fibre spun. The English earnings were depressed–indeed, it was the distress of the trade that prompted Young to collect wage data–perhaps from the beginnings of mechanization in wool spinning or the displacement of cotton spinners into wool. In the recent past, earnings had been 8 - 10 d. for a 10-12 hour day (Pinchbeck 1930, pp. 138-53). I set the English spinner's wage at 6-1/4 d. per day and the French wage at 9 sou. Raising the English wage to 9 d. per day would raise the profitability of the spinning jenny to even higher levels.

The life of a jenny (n)–This was short due to the high rate of technical change, and because jennies wore out. Since workshop jennies were driving the domestic producers out of business by the mid 1780s, a 24 spindle jenny purchased for home use in 1775, say, would have been obsolete ten years later. A ten year life span is also supported by the speed with which such machinery wears out. The Ambar Charkha jennies used in India in the 1950s, for instance, were assumed in the planning literature of have a life of ten years (Sen 1968, p. 107), and these machines were used about as intensively as domestic jennies. In the calculations I set n equal to 10 years in view of these considerations.

Maintenance costs (m)–Machinery has to be repaired and maintained. We have no information about these costs for domestic producers in the 1770s. The Ambar Charkha is our best counterpart to the jenny. In the 1950s, annual maintenance costs (exclusive of depreciation) equalled 10% of the purchase price of the machine (Sen 1968, p. 108). I apply the same percentage to spinning jennies.

The number of days per year the jenny was operated (Y)–I use 250, which was what I have elsewhere assumed to have been full time work for labourers (Allen 2001). There was no work on Sundays or religious holidays or on unofficial holidays like 'Saint Monday'.[9] Also, spinning was done in rural villages, and spinsters could earned more from harvest work and gleaning than from spinning, further reducing the time their jennies were used (Pinchbeck 1930, pp. 53-7). This was also true of rural India in the twentieth century. The first calculations of the profitability of the Ambar Charkha assumed that it would be operated 300 days per year, but in reality 200 days was more realistic due to 'the seasonal operation of the charkhas during the slack season of agricultural activity" (Bhalla 1964, p. 613).

The proportion of a day that was worked (D)–Domestic spinners were often part-time workers. This is reflected in the broad range of daily earnings reported by contemporaries–from two to five shillings per week by Young (1770, III, p. 248), for instance. If five shillings per week represented full time work, then two shillings indicates production at 40% of the maximum. Sir Frederick Eden (1797, p. 796) observed "that a woman, in a good state of health, and not incumbered with a family, can [do] one pound of spinning-work the day, and [that] is the utmost that can be done: but if she has a family, she

[9]Pollard (1965, pp. 189-244) discusses these issues from the employers point of view.

cannot...spin more than 2 pounds and a half in a week," which is again about 40% of full time output. The same factors were in play in twentieth century India where rural women spun for only 4-6 hours per day (Bhalla 1964, p. 613). I report the results of profitability calculations assuming women spun 30%, 40%, and 50% of full time, but 40% looks closest to being a typical value.

Another consideration supports low values for D. Domestic spinners were paid by the hank rather than by the day. Many spinners were old or infirm, and their productivity was low (notice Eden's stipulation of good health). They may have worked many hours to spin only a few hanks and earn only a meagre income. Their inefficiency is captured by D.

<u>The proportional increase in productivity due to the jenny (P)</u>–A woman operating a 24 spindle jenny did not spin twenty-four times as much per day as a woman operating a hand wheel. The gain was much less. Since spinners were paid by the hank, the impact of the jenny on labour productivity can be inferred from the increase in spinners' earnings. Various comparisons were made in the late eighteenth century, but many of them were polemical, either supporting or opposing machine spinning (Pinchbeck 1930, p. 150-1, Wadsworth and Mann 1931, p 403). Among the more sober assessments was a petition of women in 1780 that they had been earning 8 -10 s per week on 24 spindle jennies (a rate under threat from larger jennies in workshops). This range is itself in the middle of the range of 7s 6d to 12 s. cited by Bentley (1780, p. 31). Other figures quoted by Pinchbeck and Wadsworth and Mann were scattered around these. In contrast, as noted, a women spinning full time on a wheel could make 8 -10 d per day (4 -5 shillings per week) in the 1770s and early 1780s. If we accept 10 s per week as full time earnings on a 24 spindle jenny and 5 shillings on the spinning wheel, then labour productivity was doubled by the jenny. Larger increases are certainly defensible. Reducing full time earnings on the spinning wheel to 6d per day (3 s. per week) pushes the labour productivity advantage of the jenny to just above three. Definitiveness is impossible, so I report rates of return assuming that the jenny raised output per worker by a factor of two to four. Three looks like a typical increase.

Table 1 reports rates of return calculated under various assumptions. For the central and most likely case (a tripling of labour productivity and a work day equal to 40% of full time), the rate of return to buying a jenny was 38% in England and 2.5% in France. On the figures, it is no wonder that the jenny was enthusiastically taken up by women in England but not in France! To see how sensitive the conclusion is to the assumptions, the Table reports a series of alternatives with productivity increasing by a factor of 2, 3, or 4, and spinsters working 30%, 40%, or 50% of a full day.

The rates of return must be compared to returns in other activities to decide whether the jenny was worthwhile. Other investments yielded 15% or more. In his <u>General View of the Agriculture of Bedfordshire</u>, Batchelor (1808, p.153) remarked "the capital employed in many trades and professions is said to produce fifteen per cent." Industrial investment yielded about 15% when profits are imputed to fixed capital (Allen 2007b, Harley 2006). Spinsters probably expected at least as much. The purchase of a jenny absorbed half a year's earnings in Britain and a year and a half's earnings in France. Purchasing a jenny represented such a large commitment that modest people may have expected an exceptional return.

Several features of Table 1 are striking. First, the rate of return to buying a jenny was always much higher in England than in France. This is true under any set of assumptions and is a consequence of the difference between the countries in the ratio of the price of a jenny to the cost of a day of a spinner's labour. Second, the rates of return in England were very high. The lowest was 12%. This is the only case when the jenny was unprofitable in England–and not by much. Otherwise profitability ranged between 24% and 59%. Third, the rates of return in France were low. In only one case did the rate of return reached the opportunity cost of capital (15.3%). In four cases, the rate of return was negative and in four more it was too low to warrant adoption.

We cannot be certain which set of assumptions corresponds to the historical situation. Indeed, differences in family circumstances probably meant that a range of assumptions applied in all countries. However, the meagre data available to us can be reasonably interpreted to mean that buying a jenny for home use was usually profitable in England but not in France. The different adoption rates of the jenny are understandable in view of the differences we have computed in the rate of return to the investment.

What about India? Broadberry and Gupta (2007) have recently emphasized the wage difference between Britain and India, and the commercial opportunity open to British manufacturers if they could mechanize production and cut their costs. My analysis complements theirs by showing the importance of relative factor prices in explaining why the British found it profitable to use the jenny. The low wage in India meant that manufacturers there had no incentive to do the same. This claim is supported by the rates of return to buying a jenny in India, as shown in Table 1. It must be emphasized that these must be treated very cautiously since they are conjectured from differences in prices rather than from direct measurement. In the absence of prices paid for jennies, the cost of a jenny in India has been estimated by applying an index of relative capital prices to the price of a jenny in England. The available Indian wage data pertain to men. I have taken the daily earnings of women spinning full time in India to have been half of the male labourers' wage since that was approximately the proportion in England and France. While these figures might be revised, they do highlight the unprofitability of using jennies in India. For the most likely case of a tripling of labour productivity and a woman working 40% of full time, the rate of return to the jenny was -5.2%. Under the most favourable circumstance, the rate of return to buying a jenny was only 7.3%. In most scenarios, there were losses. With prospective rates of return like this, it is no wonder there was no interest in mechanizing production in India–or, indeed, in Asia generally where prices and wages were similar.

## Why the spinning jenny was invented in England rather than in France or India

Explaining why the famous inventions of the eighteenth century were made in England rather than elsewhere is one of the great challenges in explaining the industrial revolution. Inventions have two aspects: a novel idea and the solution of the technical problems that stand in the way of its commercial application. When the novel ideas are considered to the be crux of the problem, the historian analyses the development of science or the sources of creativity in order to explain them. The ideas embodied in the spinning jenny, however, were so mundane that its invention cannot be understood in these terms.

Instead, we must focus on the R&D aspect of invention. The question is why anyone would have gone to the expense and trouble of figuring out how to power many spindles with the same wheel and how to manipulate the threads with sliding bars and clamps that imitated the nimble fingers of the spinster. Hargreaves seems to have spent three years perfecting the jenny during which time he was supported by Robert Peel. Since Hargreaves was a hand loom weaver, his income could not be rated at more than £50 per year. There were certainly other expenses involved in buying materials for experimental machines. Perhaps sometimes, Hargreaves had assistance. By any reckoning, it is hard to see how the spinning jenny cost more than £500 to develop. This was a significant sum, but it was less than many other textile inventions. Wyatt and Paul were said to have spent £50,000 - £60,000 in their unsuccessful attempt to develop roller spinning in the 1740s, and Jedediah Strutt, who was one of Arkwright's venture capitalists, claimed in 1774 that £13,000 had been spent on the project (Hills 1970, pp. 52, 71). Nonetheless, why spend £500 on the spinning jenny? In particular, is there any reason why someone would do that in England but not in France or India?

The obvious answer is that the spinning jenny was used in England but not in the other cotton producing countries. It was used because it was profitable, and that profit is a measure of its social utility. We cannot compute the social rate of return to Hargreave's R&D project without more information about the rate of adoption of the jenny, but it cost so little that it must have been socially profitable. The social utility (total profit) is the product of the number of pounds spun and the profit per pound, so total profit depended on the size of the market as well as the reduction in unit costs. From the middle of the eighteenth century, consumption of cotton was increasing in England and that may have spurred invention by increasing the prospective overall return. By the same token, invention was much more likely to take place in England rather than the Dutch Republic, which was the other high wage economy in Europe, since there was no cotton industry in the Netherlands. Acemoglu (2002) has argued that the increase in the availability of an input like raw cotton will lead inventors to augment its value since the market for their inventions will be larger. The timing and location of the invention of the spinning jenny illustrates this theory.

The profit generated by the jenny is also a measure of the income that Hargreaves could hope to realize by patenting it. Hargreaves did get a patent, but he was not able to defend his rights. Were he successful, he would certainly have made a lot of money.

Even if high income was not a motive for an inventor, the usefulness of the invention was still a motivating factor. This was true of Samuel Crompton, for instance, who invented the mule by adding rollers to the jenny. Crompton did not patent the mule since he invented it for the use of the trade. Without use, however, invention was pointless even if private profit was not the objective.

By this reasoning, there was no point in inventing the jenny in either France or India. It was not used in those countries even when it was available, so the social rate of return to inventing it would have been negative. The French government financed some 'high tech' projects with this characteristic like Vaucanson's numerically controlled loom and Cugnot's steam tractor. While technically precocious, these inventions were never applied commercially because they were not cost effective at French factor prices. Had the jenny been invented in France as a state industrial initiative, it would have suffered the same fate. Private investors saw no point in pursuing it. But the economic conditions were very different in England, which is why it was invented there.

## Conclusion

Many explanations have been offered for Britain's leading role in technological innovation in the eighteenth century. The invention of the spinning jenny is a good test of their importance. Hargreaves did not benefit from a state that protected his property rights: His jennies were destroyed by mobs on several occasions, and the patent law was sufficiently convoluted that he failed to meet its requirements and never did secure his intellectual property rights. Nor did the seventeenth century Scientific Revolution nor the Industrial Enlightenment, at least as it was manifest among the English upper classes, play a role in the invention of the spinning jenny. It owed nothing to science, it was invented by an illiterate artisan, and its development was financed by investors from the same social stratum and cultural background. Focusing on the artisans is more promising than focusing on the upper classes in understanding England's ascendancy since many of the inventions of the industrial revolution originated from below. Jacob (1988, 1997) has emphasized the role of artisan culture in Britain, and Raychaudhuri (1982 p. 297), has noted its absence in India: "there was a remarkable lack of preoccupation with things mechanical." The question is whether England's distinctiveness should be attributed to a unique trajectory of cultural development uninfluenced by economic incentives or whether it should be seen as an endogenous response to the opportunities presented by the economy.

This paper has emphasized the importance of endogenous response. The English economy in the eighteenth century was almost unique in the world by virtue of the high level of its wages with respect to capital goods prices. This price structure created unique incentives to develop machines that substituted capital for labour. They were profitable to use in Britain–and unprofitable elsewhere. As a result, they were used in Britain and 'economic benefits' (high incomes) were created that balanced the costs of their invention. The contrast with France and India is striking, for the machines that paid in England were not profitable to use there–so they were not used. As a result there was no incentive to invent them in France or India. The 'preoccupation with things mechanical,' whose absence Raychaudhuri lamented in India and whose presence in England was noted by Jacob, was a cultural manifestation of the profitability of substituting capital for labour, of which the jenny was a particular example.

In talking about economic development, it is easy to use the metaphor of the path: 'Eighteenth century England set out on the path to modern industry, while France and India did not.' There is considerable truth in this metaphor since the development of technology is a path dependent process in which most inventions can only be understood by reference to the technology that preceded them and which they replaced (David 1975). The cotton industry in the nineteenth century is a case in point. In the nineteenth century, the world's cotton industry relied on mule spinning. Crompton invented the mule by adding Arkwright's rollers to Hargreaves' jenny, so there would have been no mule in 1850 had the jenny not been invented eighty years earlier. That first step on the path could only have occurred in England because that was the only place where the jenny was profitable to use and to invent. While the mule was profitable to install in many places in 1850, the path of development that led to the mule would never have occurred had there not been a country with the economic conditions of eighteenth century Britain. This was true no matter how progressive were the cultures, nor how supportive of capitalism were the political systems, of other countries in the world.

The story of the jenny illustrates another feature of technology and economic development. In the modern world, much technology is developed in rich countries and proves highly profitable there. This technology is much less profitable in poor countries and is consequently much less used. The reason is straightforward. Technology developed in rich countries reflects their factor prices–their high wages in particular–and embodies that influence in a high capital-labour ratio. This factor proportion makes their use uneconomic in low wage economies (Acemoglu 2002). The spinning jenny is an example of the same phenomenon. In the eighteenth century, England was the high wage economy and consequently technologies with high-capital labour ratios were developed there. These technologies were inappropriate for low wage economies like France and India, and so they were not used, and the countries fell further and further behind technologically. What is surprising is that this situation was not a consequence of the Industrial Revolution but obtained at its inception. The unexpected conclusion is that the Industrial Revolution was the consequence of the high wage economy–not its cause.

Figure 1

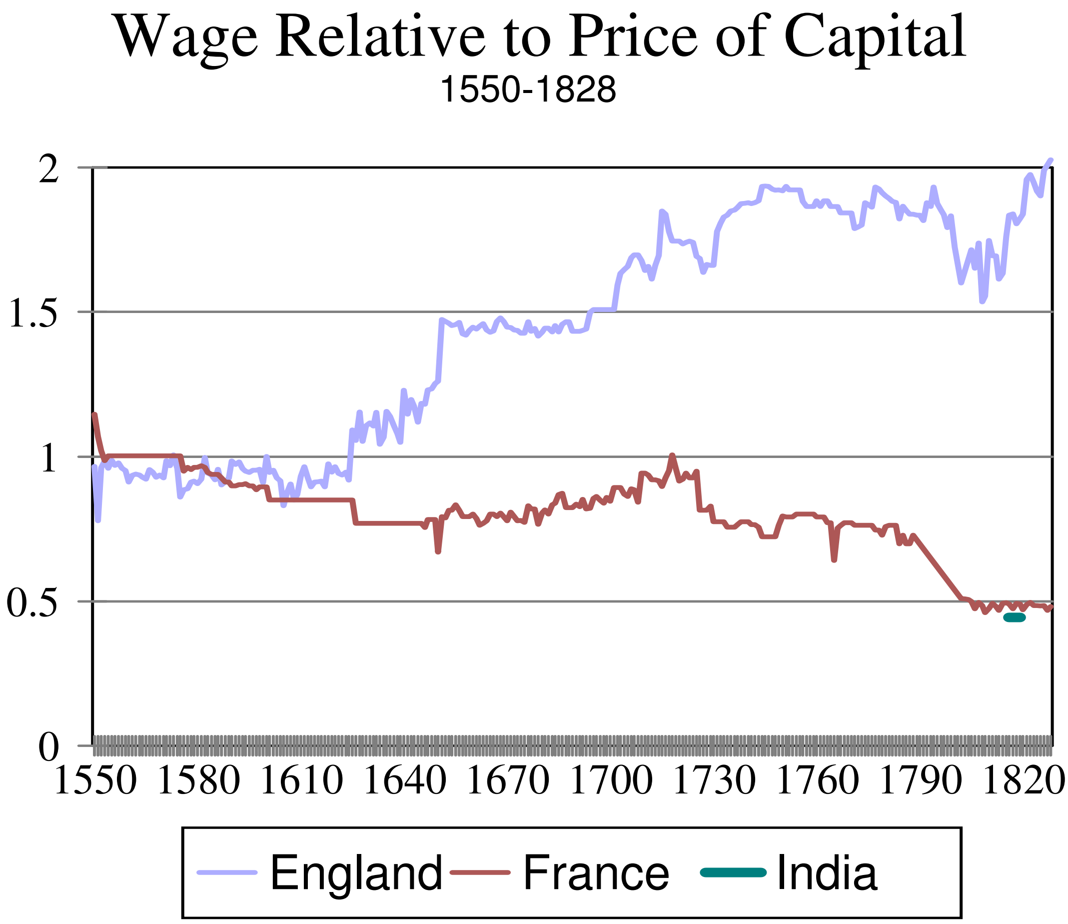
Wage Relative to Price of Capital
1550-1828
2
1.5
1
0.5
0
1550
1580
1610
1640
1670
1700
1730
1760
1790
1820
England
France
India

Table 1

Rates of Return to buying a Spinning Jenny in Britain and France

| relative product'ty | %fulltime | Britain | France | India |
|---|---|---|---|---|
| 2 | 0.5 | 34.6% | 0.2% | -7.7% |
| 2 | 0.4 | 24.0% | -8.2% | -17.4% |
| 2 | 0.3 | 12.3% | -21.7% | -100.0% |
| 3 | 0.5 | 51.2% | 10.7% | 3.0% |
| 3 | 0.4 | 38.0% | 2.5% | -5.2% |
| 3 | 0.3 | 24.0% | -8.2% | -17.3% |
| 4 | 0.5 | 59.2% | 15.3% | 7.3% |
| 4 | 0.4 | 44.7% | 6.8% | -0.1% |
| 4 | 0.3 | 29.4% | -3.7% | -12.0% |

References

Acemoglu, Daron (2002). "Directed Technical Change," Review of Economic Studies, Vol. 69, pp. 781-809.

Acemoglu, Daren, Johnson, Simon, and Robinson, James (2005). 'The Rise of Europe: Atlantic Trade, Institutional Change and Economic Growth,' American Economic Review, Vol. 95, pp. 546-79.

Allen, Robert C. (1983). "Collective Invention," Journal of Economic Behavior and Organization, Vol. 4, No. 1, pp. 1-24.

Allen, Robert C. (2001). "The Great Divergence in European Wages and Prices from the Middle Ages to the First World War," Explorations in Economic History, Vol. 38, pp. 411-447.

Allen, Robert C. (2007a). "India in the Great Divergence," in Timothy J. Hatton, Kevin H. O'Rourke, and Alan M. Taylor, eds., The New Comparative Economic History: Essays in Honor of Jeffery G. Williamson, Cambridge, MA, MIT Press, 2007, pp. 9-32.

Allen, Robert C. (2007b). "Engel's Pause: A Pessimist's Guide to the British Industrial Revolution," Oxford University, Department of Economics, Working Paper 315.

Ashton, T.S. (1955). An Economic History of England: The 18th Century, London, Methuen.

Aström, Sven-Erik (1982). "Swedish Iron and the English Iron Industry about 1700: Some Neglected Aspects," Scandinavian Economic History Review, Vol. 30, pp. 129-41.

Baines, Edward (1835). History of the Cotton Manufacture in Great Britain, London, H. Fisher, R. Fisher, and P. Jackson.

Batchelor, T. (1808). General View of the Agriculture of the County of Bedford, R. Phillips.

Beveridge, Lord (1939). Prices and Wages in England from the Twelfth to the Nineteenth Century, London, Frank Cass & Co., Ltd., 1965.

Broadberry, Stephen, and Gupta, Bishnupriya (2006). "The Early Modern Great Divergence: Wages, Prices and Economic Development in Europe and Asia, 1500-1800," Economic History Review, Vol. 59, pp. 2-31.

Broadberry, Stephen, and Gupta, Bishnupriya (2007). "Lancashire, India and Shifting Competitive Advantage in Cotton Textiles, 1700-1850: The Neglected Role of Factor Prices."

Boyle, Robert (1671). Some Considerations Touching the Usefulnesse of Experimental

Naturall Philosophy, Oxford, Hendry Hall, printer to the University.

Chapman, S.D., and Butt, John (1988). “The Cotton Industry, 1775-1856,” in Charles H. Feinstein, and Sidney Pollard, eds., Studies in Capital Formation in the United Kingdom, 1750-1920, Oxford, Clarendon Press, pp. 105-125.

Chassagne, Serge (1991). Le coton et ses patrons: France, 1780-1840, Paris, Édition de d’École des hautes études en sciences sociales.

Chaudhury, Sushil (1999). From Prosperity to Decline: Eighteenth Century Bengal, New Delhi, Manohar Publishers & Distributors.

Clark, Greg (1996). “The Political Foundations of Modern Economic Growth: England, 1540-1800,” Journal of Interdisciplinary History, Vol. 26, pp. 563-87.

Clark, Greg (2007). A Farewell to Alms: A Brief Economic History of the World, Princeton, Princeton University Press.

Crafts, N.F.R. (1977). “Industrial Revolution in England and France: Some Thoughts on the Question: ‘Why was England First?’” Economic History Review, Vol. 30, pp. 429-41.

Crafts, N.F.R. and Harley, C.K. (2000). ‘Simulating the Two Views of the Industrial Revolution,’ Journal of Economic History, Vol. 60, pp. 819-841.

Crouzet, François (1985). De la superiorité de l’Angleterre sur la France, Paris, Librairie Académique Perrin.

David, Paul (1975). Technical Choice, Innovation, and Economic Growth: Essay on American and British Experience in the Nineteenth Century, Cambridge, Cambridge University Press.

De Long, J. Bradford and Schleifer, Andrei (1993). ‘Princes and Merchants: European City Growth before the Industrial Revolution,’ Journal of Law and Economics, Vol. 36, pp. 671-702.

Divekar, V.D. (1989). Prices and Wages in Pune Region, 1805-1830, Pune.

Eden, Sir Frederick Morton (1797). The State of the Poor, London, J. Davis.

Epstein, S.R. (2000). Freedom and Growth: The rise of states and Markets in Europe, 1300-1750, London, Routledge.

Fremdling, Rainer (2000). “Transfer Patterns of British Technology to the Continent: The Case of the Iron Industry,” European Review of Economic History, Vol. 4, pp. 195-222.

Fremdling, Rainer (2004). “Continental Responses to British Innovations in the Iron Industry during the Eighteenth and Early Nineteenth Centuries,” in Leandro Prados de la

Escosura, ed., Exceptionalism and Industrialisation: Britain and Its European Rivals, 1688-1815, Cambridge, Cambridge University Press, pp. 145-69.

Gayer, A.D., Rostow, W.W., and Schwartz, A.J. (1953). The Growth and Fluctuation of the British Economy, 1790-1850, Oxford, Clarendon Press.

Hanauer, A. (1878). Etudes économiques sur l'Alsace, ancienne et moderne, Strasbourg Hagemann, Librairie.

Harley, C. Knick (2006). "Cotton Textiles and the Industrial Revolution: Competing Models and Evidence of Prices and Profits."

Hartwell, R.M. (1967). The Causes of the Industrial Revolution, London, Methuen & Co.

Henson, Gravenor (1831). The Civil, Political, and Mechanical History of the Framework-Knitters in Europe and America, ed. by Stanley D. Chapman, Newton Abbot, David & Charles Reprints, 1970.

Hills, Richard L. (1989). Power from Steam: A History of the Stationary Steam Engine, Cambridge, Cambridge University Press.

Hoffman, Philip T. and Norberg, Kathryn (1994). Fiscal Crises, Liberty, and Representative Government, 1450-1789, Stanford, Stanford University Press.

Hoffman, Philip T., Postel-Vinay, Gilles, and Rosenthal, Jean-Laurent (2000). Priceless Markets: The Political Economy of Credit in Paris, 1660-1870, Chicago, University of Chicago Press.

Homer, Sidney (1977). A History of Interest Rates, New Brunswick, NJ, Rutgers University Press, second edition.

Hoppit, Julian (1996). "Patterns of Parliamentary Legislation, 1660-1800," The History Journal, Vol. 39, pp. 109-31.

Hoppit, J., Innes, J., Styles, J. (1994). "Towards a History of Parliamentary Legislation, 1660-1800," Parliamentary History, Vol. XX.

Innes, Joanne (1992). "Politics, Property, and the Middle Class," Parliamentary History, Vol. XI.

Innes, Joanne (1998). "The Local Acts of a National Parliament: Parliament's Role in Sanctioning Local Action in Eighteenth-Century Britain" in D. Dean and C. Jones eds., Parliament and Locality, Edinburgh, pp. 23-47.

Jacob, Margaret C. (1988). The Cultural Meaning of the Scientific Revolution, Philadelphia, Temple University Press.

Jacob, Margaret C. (1997). Scientific Culture and the Making of the Industrial West, New York, Oxford University Press.

Kerridge, Eric (1985). Textile Manufactures in Early Modern England, Manchester, Manchester University Press.

Khan, Zorina (2005). The Democratization of Invention: Patents, and Copyrights in American Economic Development: 1790-1920, Cambridge, Cambridge University press.

Khan, Zorina, and Sokoloff, Ken (2006). "Of Patents and Prizes: Great Inventors and the Evolution of Useful Knowledge in Britain and America, 1750-1930," presented to American Economic Association.

Landes, David S. (1969). The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present, Cambridge, Cambridge University Press.

LaPorta, R., Lopez-de-Silanes, F., Schleifer, A., Vishny, R.W. (1998). "Law and Finance," Journal of Political Economy, Vol. 106, pp. 1113-1155.

Mathias, P. and O'Brien, P.K. (1976). 'Taxation in England and France, 1715-1810,' Journal of European Economic History, Vol. 5, pp. 601-50.

Mathias, P. And O'Brien, P.K. (1978). 'The Incidence of Taxes and the Burden of Proof' Journal of European Economic History, Vol. 7, pp. 211-13.

Mokyr, Joel (1999). "Editor's Introduction: The New Economic History and the Industrial Revolution," in Joel Mokyr, ed., The British Industrial Revolution: An Economic Perspective, Bouler, Westview Press.

Mokyr, Joel (2002). The Gifts of Athena: Historical Origins of the Knowledge Economy, Princeton, Princeton University Press.

Muldrew, Craig (2007). "The 'Ancient Distaff and Whirling Spindle:' Measuring the Contribution of Spinning to Household Earnings and the National Economy in England, 1550-1770," paper presented to Economic History Society Conference, Exeter.

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

Pinchbeck, Ivy (1930). Women Workers and the Industrial Revolution, 1750-1850, London, George Routledge & Sons, Ltd.

Pomeranz, K. (2000) *The Great Divergence: China, Europe, and the Making of the Modern World*. Princeton: Princeton University Press.

Quinn, Stephen (2001). "The Glorious Revolution's Effect on English Private Finance: A Microhistory, 1680-1705," JEH Vol. 61, pp. 593-615.

Raychaudhuri, Rapan (1982). "Mughal India," in The Cambridge Economic History of India, Vol. I: c. 1200-c. 1750, ed. By Tapan Raychaudhuri and Irfan Habib, Cambridge, Cambridge University Press, pp. 261-307.

Rogers, J.E.T. (1866-1892). A History of Agriculture and Prices in England, Oxford, Clarendon Press, 7 volumes.

Rosenthal, J.-L. (1990). The Development of Irrigation in Provence,' Journal of Economic History, pp. 615-38.

Temin, Peter (1997). "Two Views of the British Industrial Revolution," Journal of Economic History, Vol. 57, pp. 63-82.

Temin, Peter (2000). "A Response to Harley and Crafts," Journal of Economic History, Vol. 60, pp. 842-6.

Wadsworth, Alfred P. and Mann, Julia de Lacy (1931). The Cotton Trade and Industrial Lancashire, 1600-1780, Manchester, Manchester University Press.

Young, Arthur (1770). A Six Month's Tour Through the North of England, London, W. Strahan.

Young, Arthur (1950). Travels in France during the Years 1787, 1788 & 1789, ed. by Constantia Maxwell, Cambridge, Cambridge University Press.