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Working Paper Series

Working Paper No. 2013-015

England's Eighteenth Century Demand for High-Quality Workmanship: Evidence from Apprenticeship, 1710-1770

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September, 2013

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England's eighteenth century demand for *high-quality workmanship*: Evidence from apprenticeship, 1710-1770[1]

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The notion that technological changes and investment in human capital are positively correlated has been empirically validated in the modern context, mainly, in the case of computer-based technologies. Such a correlation has not been demonstrated in the case of the Industrial Revolution. In his seminal book, *The Enlightened Economy*, Joel Mokyr argued that *"in Britain the high quality of workmanship available to support innovation, local and imported, helped create the Industrial Revolution"*[2]. By these, Mokyr refers to *"the top 3-5 percent of the labor force in terms of skills: engineers, mechanics, millwrights, chemists, clock- and instrument makers, skilled carpenters and metal workers, wheelwrights, and similar workmen"*.[3] This article provides empirical evidence from a variety of sources supporting Mokyr's claim. It uses wages books from textile mills, labor contracts from Bolton and Watt's engine shop, advertisements in newspapers, as well as the stamp tax registers on apprenticeship contracts, and shows that indeed, the innovations and technological changes that were taking place in eighteenth century England increased the demand for these high quality mechanical workmen and that their numbers were rising throughout the period as a result.[4] It also shows that the most relevant occupation within this group was the

[1] I gratefully acknowledge the financial support from the Israel Science Foundation (Grant No. 1097/11).

[2] Mokyr, The Enlightened Economy: An Economic History of Britain, 1700-1850 2009

[3] Meisenzahl and Mokyr 2012, p. 447

[4] The evidence from the stamp tax registers in this paper is based on the analysis in Feldman and Van der Beek 2013.

wright, a workmen who *"Erects and installs, in place of use, machinery and other mechanical equipment"*.[5]

These findings are therefore also consistent with the assumption made in many models of economic growth, of a positive relationship between technological change and human capital. It supports the view that acceleration in technological progress increases the demand for skilled workers (i.e. skilled-biased technical change), which in turn, increase the rate of technological change. This hypothesis could thus far not be empirically tested in the context of the eighteenth century industrial revolution in England, due to the scarce and scattered evidence from this period. This paper uses different primary sources to identify the first part of this hypothesis, the response of the labor markets to the technological changes in eighteenth century England. Mainly, it uses, for the first time an exceptional and comprehensive set of evidence that allows a serious examination of questions relating to developments and changes in the composition of skilled labor in England during the first phases of its Industrial Revolution. It uses stamp tax records of the duty that was raised on apprenticeship contracts all over England in 1710, covering the period 1710-1770. The advantage of this dataset is not only that it is very large (a sample of 50,200 entries) and systematic, but also that it provides direct annual information on skill formation, both in terms of quantities and prices. Data on individual apprentices and masters include the occupation and location of the master, as well as the payment he received from the apprentice's parents. I use this information to examine the response of the human capital markets in eighteenth century England to the technological changes by looking at changes in the composition of occupations that apprentices chose throughout the century. I find that technological changes did have an effect on the skill formation and composition, with a growing number of children being apprenticed to 'high-quality workmen'.

The demand for 'high-quality workmen' – different sources

Technological changes and the adoption of machinery in cotton mills obviously had an important effect on the demand for skilled mechanical workers. Their skills were required in order to maintain and fix the machinery in the newly created cotton mills,

[5] Van Leeuwen, Maas and Miles 2002

as described by S. D. Chapman (1972): *"The mill owners' problem can only be understood by examining the recruitment of skilled workers (machine builders, millwrights and mule spinners) separately from that of the unskilled machine minders who formed the majority of labour force in Arkwright-type mills. The fundamental difficulty in obtaining skilled men was simply the consequence of the rapid growth of the cotton industry, which made artisans with relevant skills very much at a premium. Local newspaper advertisements, memoirs, private correspondence and high wage rates all bear testimony to the acute shortage of craftsmen whose skills could be applied to textile machine building or to the installation of water wheels and transmission systems."*[6] The wages books of some of the earliest mechanized cotton mills, support Chapman's observations, including Strutt, Need and Arkwright at Cromford, Derbyshire, (erected 1771), Strutt's later mill in Belper, Derbyshire, (1778) and Greg's Quarry Bank Mill in Styal, Cheshire (1784).[7] These wages books, which list their employees by the different rooms in which they worked, contain a remarkable number of workmen enlisted as a separate category. For example, in Greg's Quarry Bank Mill wages book craftsmen such as clock makers, smiths, joiners and turners are listed in December 12, 1789, under the category *Sundrys*, which consists of about 14% of the 230 employees (see FigureA1).

The rising need for machine maintenance, however, was not the only reason for the increasing demand for skilled mechanical workers. Eighteenth century technological changes had another critical effect on economic development besides its effect on textile manufacturing. According to Musson and Robinson (1960), focusing on the sources of engineering: *"The tremendous growth of the Lancashire cotton industry, from about 1770 onwards, based on the mechanical inventions of Hargreaves, Arkwright, Crompton, and Cartwright, powered by water wheels and steam engines, gave rise to an equally rapid development of mechanical engineering. Lancashire soon came to manufacture not only cotton, but also cotton machinery, steam engines, boilers, machine tools, and, later on, railway locomotives, iron bridges, gasworks plant, and a vast range of other engineering product."*[8] The rise in machine

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[6] Chapman 1972, p. 54.

[7] Manchester Central Library, C5/1/15/1, March 1790.

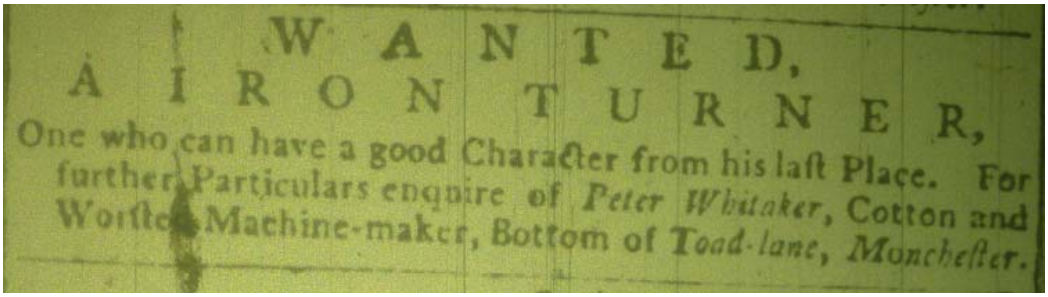
[8] Musson and Robinson 1960, pp. 209-210.

manufacturing required skilled mechanical labor as well and it therefore contributed to the increased demand for these workmen who were already required in the cotton mills. Musson and Robinson present a large number of eighteenth century contemporary job advertisements (1770-1800) from the *Manchester Mercury*, illustrating this phenomenon and allowing the identification of the type of occupations that were in demand in the growing machinery sector. For example, according to the advertisements that are presented in Figure1 Mr. Stopford from Manchester, who describes himself as "inventor of the spinning machine", was looking for "three or four journeymen carpenters" for his workshop in 1785. In 1789, Peter Whitaker from Manchester, a "cotton and worsted machine-maker" was looking to employ an iron turner, and more of this type of advertisements can easily be found in the newspaper.[9]

Figure 1: Examples for Job advertisements from the *Manchester Mercury*


WANTED IMMEDIATELY,
Three or Four Journeymen Carpenters,
Who may meet with Conſtant Employ, and good Wages, by applying to Mr. *Stopford*, Inventor of the Spinning Machine, *Church-ſtreet, Manchester.*

March 10, 1785


WANTED,
AN IRON TURNER,
One who can have a good Character from his laſt Place. For further Particulars enquire of *Peter Whitaker*, Cotton and Worſted Machine-maker, Bottom of *Toad-lane, Manchester.*

February 10, 1789

As for engine production, only a few men were employed in this industry in the 1770s and therefore the data used in this paper does not capture its demand. Nevertheless, the following evidence suggests that the engine industry required the same type of skills as machinery, with a bias towards smiths, filers and founders. At Boulton and

[9] Manchester Central Library Microfilm - MFMM1- :N.

Watt's Soho Manufactory for example, the workforce gradually grew as the workshops expanded and the engine business increased, and the construction of Soho Foundry from 1795 marked a major increase in the workforce.[10] An examination of the Foundry's Articles of Agreement (1796 to 1800) demonstrates the skills that were in demand in this industry towards the end of the century.[11] The majority of the men employed were metal workers of some description – smiths, forgers, founders, filers, turners and fitters. Carpenters, bricklayers, furnace men and laborers were also employed. In addition to the workforce at Soho, Boulton and Watt also employed travelling field engineers or "engine erectors" to attend the customer's premises, erect the engine, and if necessary train someone to work the engine. In the first few years of the business, they tended to hire local engineers on an ad hoc basis, but by the late 1790s the firm had a network of erectors based not just at Soho but also in Cornwall, London, Manchester and Newcastle upon Tyne. The following correspondence between Boulton and Watt, and Peter Ewart, an engine erector in Manchester, illustrates again the trouble of finding and employing skilled mechanical workers in Lancashire by the end of the century. Ewart reported that it was almost impossible to get good millwrights, turners, and filers and that *"the very few general good filers and turners that are here, are all engaged for a term of years in the different Cotton Mills… there is not a hand that is good for anything can be had here for less than 17 or 18 Shill. pr. week."*[12]

The demand for 'high-quality workmen' – the Stamp tax registers

The main source that is used in this study is the payment register of the Board of Stamps. Until 1710, there was no centralized record of apprentices, the main formal systems for acquiring skills in eighteenth century England.

As children grew up and reached their early and mid-teens, many left their homes for schools, apprenticeships, domestic and agricultural service. The formal structure of early modern apprenticeship can be traced back to the middle ages in the practices of

[10] Boulton and Watt's partnership was formed in 1775 to exploit Watt's patent and had a monopoly on steam engine construction.

[11] The agreements are conserved in The Birmingham City Archives, under the Reference Code: GB 143 BCA MS3147/8.

[12] Musson and Robinson 1960, p. 220.

guilds and cities. It was applied nationwide in 1563 in the *Statute of Artificers* until its repeal in 1814. While some details were negotiable, the core of English apprenticeship contracts was fixed by law. Unlike pauper apprenticeship, classic apprenticeship, involved a written contract (*indenture*), bounding master and apprentice for a pre-specified period, usually of seven years, during which the master undertook to teach the apprentice and introduce him to the *modus operandi* of his trade, as well as provide him with board and lodging and safeguard his moral welfare.[13] The apprentice, on his side, took an oath 'duly and truly to serve' and a *premium*, or cash payment was commonly paid to the master. Children were usually 14 when indentured, however, this age varied with the specific requirements.[14] For example, in trades requiring physical strength (e.g. tanner, baker, butcher, bricklayer, blacksmith) or greater maturity (e.g. milliners, mantua-makers or hairdressers), older boys, aged 15 or 16, were more useful. Occupations that indentured substantial numbers of children younger than 14, such as nailing and other small-metal trades, framework knitting, ribbon weaving, and shoemaking, were mostly low skilled and labor intensive.[15] Interestingly, it seems that many apprentices did not complete their terms of indenture and late arrival and early departure from the master's household were widespread. According to Wallis (2008), neither master nor apprentice risked significant loss from such early termination due to the value of apprentices' unskilled labor in the first years of their term, and that the patterns of presence and absence reflect the external opportunities available to apprentices.

In 1710 a stamp duty payment on private indentures of apprenticeship was raised and the records of the duty paid were kept by the Inland Revenue.[16] The tax was at the rate

[13] Pauper apprenticeship involved children who could not be cared for by their own family because they had no parents, or came from a poor family. These children were a problem to the poor law administrators, as they frequently lacked any means of support, and were too young to earn their own living. The Poor Law Act of 1597 gave Overseers of the Poor and Churchwardens the power to set these children to work, and so a large number of pauper children were put out as apprentices by parish officers.

[14] According to Wallis, Webb and Minns, (2009), leaving home and entering service: the age of apprenticeship in early modern London apprentices in London were bound around the age of 16 in the sixteenth century and this age declined throughout the eighteenth century, reaching 15.5 by 1810.

[15] Lane 1996, pp. 12-13. For the specific requirements of the different trades see also Humphries, Childhood and Child Labour in the British Industrial Revolution 2011, and Justman and van der Beek 2013.

[16] The manuscripts are conserved at the National Archives, Kew, under Series IR 1.

of 6d in the pound (2.5%) on agreements of £50 or less, plus one shilling (5%) for every pound above that sum. In modern terms, if we take an average tuition of 20 pounds and the 1750 labor value of a pound in 2010, which is about $2700, this represents a tax payment of about $1350. The payment of the tax was entered on the reverse of the indenture, which was void without this payment. It is important to note, however, that masters did not have to pay stamp duty on the indentures of pauper apprentices, taken on at the common or public charity. It was also ruled that the Statute of Apprentices did not apply to *modern* trades, which did not exist when the law was passed in the sixteenth century. This element does not bias my results in any significant manner since the sums that were raised by the overseers of the poor were just high enough to attract masters to take children, so that paupers were not preferred to other children in any way.[17] Secondly, paupers were sent in large numbers to housewifery, husbandry and large-scale industry, which are low skilled occupations.[18]

Besides the masters that did not have to pay stamp duty, using information from tax record also raises the issue of tax evasion, which may be problematic, mainly if it varies over time and across occupations. It would, however, be reasonable to assume that, if at all, evasion would bias our results on the prosperous occupations (mainly in services and sales), where status and large amounts were involved, rather than on the manufacturing occupations, which comprise more than 70% of the observations and for which tuitions were relatively low (£10-20). As I show however, this is not the case and the same results are obtained when the analysis is conducted separately, on all the occupations and on the manufacturing occupations alone.

The stamp tax registers are originally organized in 72 volumes, which are available on a microfilm format at the National Archives, Kew, in London. The volumes consist of: City or Town registers, October 1711 to January 1811, with daily entries of the indentures upon which duty was paid in London; Country registers, May 1710 to September 1808 with entries, made in London, of the indentures upon which duty had been paid to district collectors and which were then sent in condensed batches to be stamped. An index of these records was compiled by the Society of Genealogists in

[17] Lane (1996).

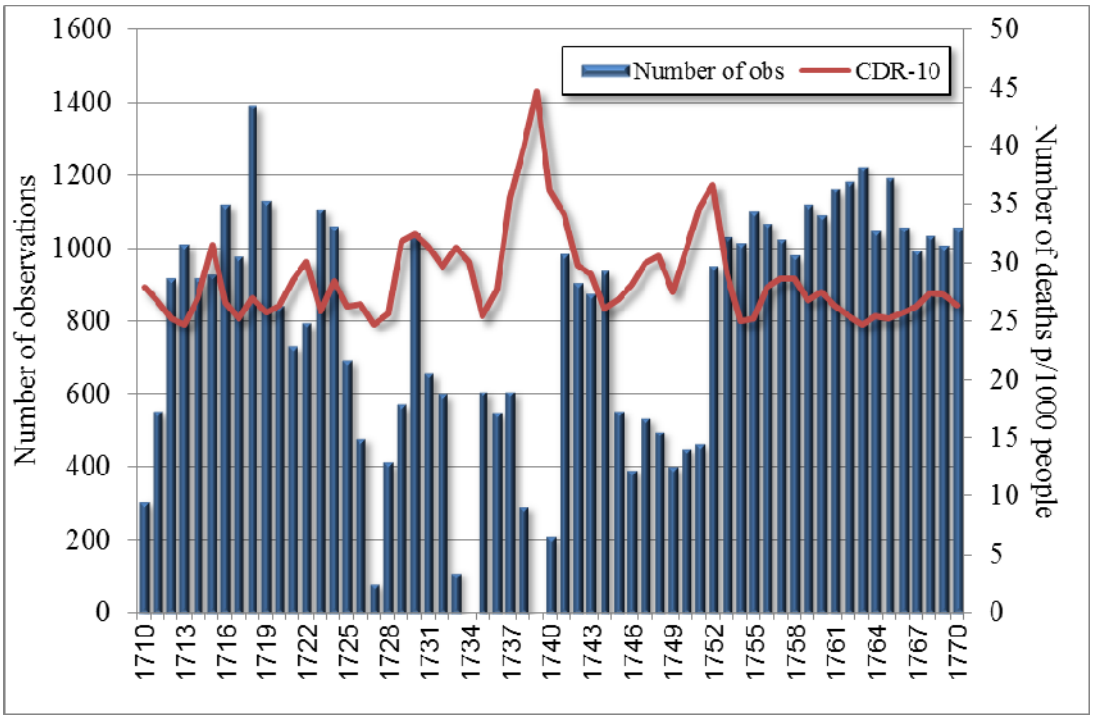
[18] *ibid*

the beginning of the twentieth century, covering the period 1710-1774.[19] In addition to the sums received, the index records the date of the contract, the name, location and trade of the master, and the name and location of the apprentice.

The stamp tax dataset

The analysis that is presented in this paper is based on a stratified random sample of 50,200 entries out of about 300,000 entries in the index of the stamp tax records, registering the duty payment on apprenticeship premiums (payment to the master), covering the period 1710-1774 (14.3%). The sample was constructed so as to keep the proportion of observations of apprentices' surnames beginning with the same letter. For example, apprentices' surnames beginning with the letter ``B" comprise 11% of the entries in the index. This proportion was kept in the sample.

Figure 2: Number of entries in the sample compared to the crude death rate



Source: Feldman and van der Beek 2013, Table A1.

[19] The indexes for the years 1710-1774 are kept with the apprenticeship books at the National Archives, Kew, under Series IR 1. They are also available online at Origins Network, a family history website.

Each observation in the database represents an apprenticeship contract and contains information about the year of the contract, the trade and location of the master and the premium paid by the apprenticeship. After omitting entries from years prior to 1710 and later than 1770, which could be misrepresentative of the year, I am left with about 48,000 observations. Interestingly, as can be observed in Figure2, the distribution of entries over the period is not smooth and contains some serious drops in the number of entries. This is mainly true for the years 1726-1740, and with more moderate drops, for the years 1745-1751. These drops can most probably be explained by exogenous shocks of small pox outbreaks that caused high mortality, mainly among young children.[20] Wrigley and Schofield place this sharp rise in deaths precisely in the years that show a drop in the number of entries: *"…their* (of the deaths) *upsurge in the early eighteenth century owes much to some years exceptionally high mortality in the 1720s and early 1740s, and it is noteworthy that around 1750 the number of deaths sinks back to a level not much higher than had obtained in the last quarter of the seventeenth century."*[21] Figure 2 illustrates both the annual number of entries in the sample, where every entry represents an apprenticeship contract, and the Crude Death Rate (CDR), which represents the number of deaths in England per 1000 people. The CDR is presented with a lag of 10 years in order to examine the actual effect of the deaths 10 years later, when children could potentially become apprentices. The figure shows that indeed, periods of high mortality were followed by a decline in the number of children that had been bound to masters.

Masters' trades have been classified into occupational groups, using two alternative methods. The first uses the occupational information system, HISCO (Historical International Classification of Occupations), a system that offers information on occupations in the past, for example: occupational titles from countries and languages around the world, descriptions of the content of the work, images, and mainly, it allows coding occupational titles into a classification system that containing 76 major occupational groups and 296 minor groups, as well as groups of social class (HISCLASS).[22] The second method uses occupational groups from relevant literature,

[20] I am grateful to Joel Mokyr for pointing out demography as a possible of explanation.

[21] Wrigley and Schofiel 1981, p. 162

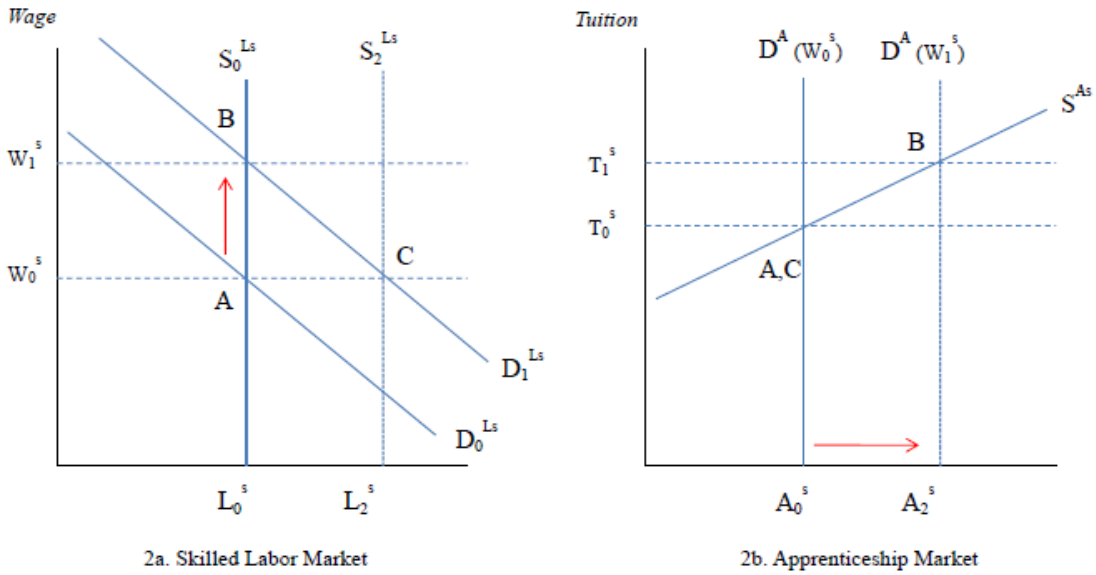
[22] Van Leeuwen, Maas and Miles 2002

mainly the ones in Williamson (1982), which are also consistent in most cases with the ones in Bowley and Wood (1898-1910).[23] This classification has the advantage of being more convenient for the purpose of presentation and comparison, as well as containing occupational groups that are of interest for the purpose of this analysis. For example, skilled in building trades, skilled in shipbuilding, textile trades, engineer, machine and instrument makers, etc. An elaborated list of the occupational groups and the occupations they include can be found in Feldman and van der Beek 2013, Table A1.

Framework of Analysis

The two variables of interest in this analysis are the annual number of new apprentices and the average tuition paid, in each occupation. These variables can be viewed as proxies for changes in the demand for skills and their supply in the labor markets.

Figure 3: Demand for skilled labor and changes in the number of apprentices



Thus, as depicted in Figure 3, assuming that the number of skilled workmen is inelastic, an exogenous increase in the relative demand for skilled workmen (or for a group of workers with specific skills) from D_0^{LS} to D_1^{LS}, raises the relative wages of these workers from W_0^S to W_1^S in the short run, moving us from an equilibrium such

[23] A series of publications contained in articles in the J.R.S.S. between 1898 and 1910.

as in point A, to point B in the skilled labor market. These higher wages increase the present values of the stream of incomes viewed by potential workers and as a result, increase the demand for acquiring the relevant occupations from $D^A(W_0^S)$ to $D^A(W_1^S)$, moving us to an equilibrium in point B in the apprenticeship market. Note that at this point tuitions will increase, depending on the elasticity of supply of the apprenticeship institution, and the number of apprentices in the relevant occupations increases from A_0^S in the initial period to A_2^S, the number of workers required to satisfy the higher demand for skilled workmen. Once these apprentices join the labor force we reach the long run equilibrium in the skilled labor market (point C), in which the supply of skilled workers reaches S_2^{LS}, the number of skilled workmen increases to L_2^S and the wages move back to W_0^S.

Note that the span of the short-run, in which a skill premium exists, depends on the elasticity of supply in the market for apprentices. If the apprenticeship institution in eighteenth century England was efficient, as claimed by recent economic historians, we might not be able to observe rising wages and tuitions, yet, as Figure 3 clearly demonstrates, we will still observe an increase in the number of apprentices.[24] This explains why I concentrate in this article on changes in the composition of occupations to which they were bound, as a proxy to the changes in the demand for this occupation in the labor markets.

The share of 'high-quality workmen'

Since it is difficult to assess whether the tax was uniformly imposed on masters in different sectors, and whether it was easier to avoid tax payments if you were a merchant or an attorney, I do not relate to the absolute share of each sector. Rather, I look into the changes in the relative share of each sector (and of the occupations within sectors), assuming that if there was a bias in tax collection it was constant over time.

Even if we assume the existence of a bias in tax collection, it is evident that the largest share of apprentices in Eighteenth century England was bound to masters in the

[24] See Humphries 2003, 2010 as well as Mokyr 2009.

manufacturing trades. The share of such apprentices comprises almost 80% of the observations, rising from 76.8% in the 1710s' to 82.2% in the 1760s (see Table 1). The following two sectors are the service sector (barbers, shopkeepers, doctors, attorneys, bankers, etc.), and the sales sector (including different type of merchants, sellers and shop owners), each comprising about 10% of the observations. The administration and agricultural trades come last, comprising less than 1%.

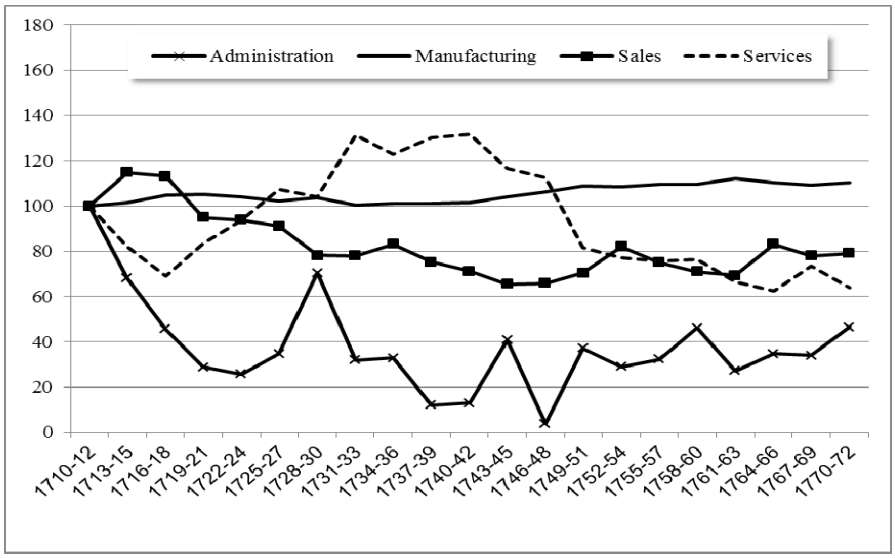
Table 1: Distribution of observations by economic sector: 1710-1770

Economic sector		1710-20	1721-30	1731-40	1741-50	1751-60	1761-70
Administration	(no. of obs)	101	52	17	27	68	70
	(share in %)	1.09%	0.77%	0.48%	0.42%	0.71%	0.65%
Agriculture	(no. of obs)	28	20	8	25	44	40
	(share in %)	0.30%	0.30%	0.23%	0.39%	0.46%	0.37%
Production	(no. of obs)	7106	5209	2662	4971	7778	8803
	(share in %)	76.82%	76.93%	75.13%	77.50%	81.16%	82.17%
Sales	(no. of obs)	1140	679	318	491	829	944
	(share in %)	12.32%	10.03%	8.98%	7.66%	8.65%	8.81%
Services	(no. of obs)	875	811	538	900	865	856
	(share in %)	9.46%	11.98%	15.18%	14.03%	9.03%	7.99%
Whole Sample	(no. of obs)	9250	6771	3543	6414	9584	10713

Source: Feldman and van der Beek 2013, Table A1.

Apart from a rise in the agricultural trades, which cannot be statistically supported given the small annual number of observations in each year, manufacturing was the only sector in which the share of skilled labor was continuously rising throughout the century.

Figure 4: Index of apprentices' share by economic sector (100=1710-12)

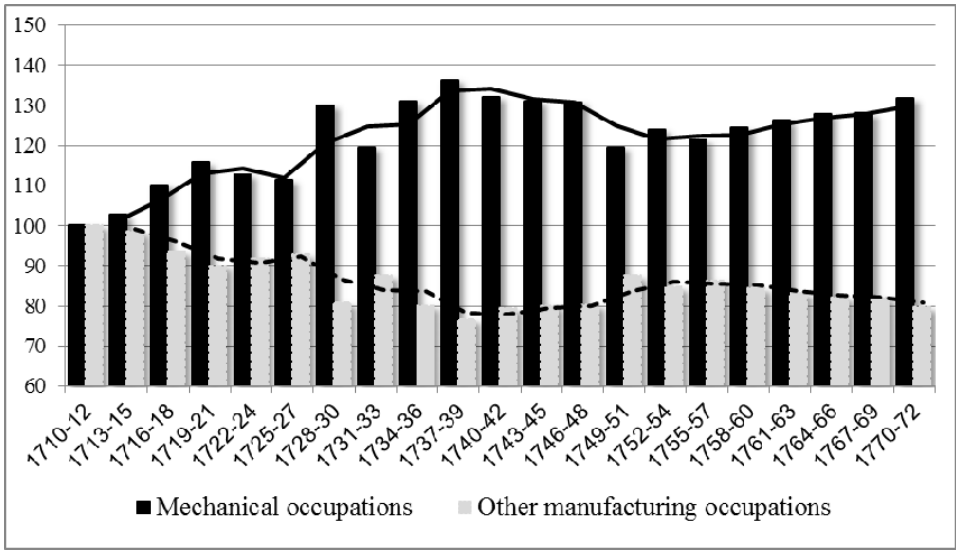


Source: Stamp tax registers

Figure 4 depicts an index that has been calculated to measure the changes in the share of apprentices in each economic sector, indicating the rising share of skilled labor in manufacturing.

Nevertheless, this relative increase in the share of skilled labor in manufacturing is not definite, and it depends on the representativeness of the tax registers in all the sectors. That is, it is not clear to what extent the changes in the share of tax registers in the elite occupations (mainly in trade and services), represents the changes in share of apprentices in these occupations, due to the possibility that the magnitude of tax evasion in these occupations changed over time. Yet changes in composition within the manufacturing sector, which is believed to be representative over time, are informative in the sense that they do represent changes in the real economy. To explore this question I decomposed the manufacturing sector in the first stage into two groups: mechanical and non-mechanical occupations, to test whether more parents wished their children to obtain a mechanical occupation in a period of technological change. Mechanical occupations include, for example, carpenters, joiners, coopers, turners, coach-makers, smiths, braziers, wheelwrights, and ship builders. Non-mechanical occupations include masons, tillers, weavers, tailors, bakers, dyers, and painters.

Figure 5: Mechanical vs. non-mechanical manufacturing occupations

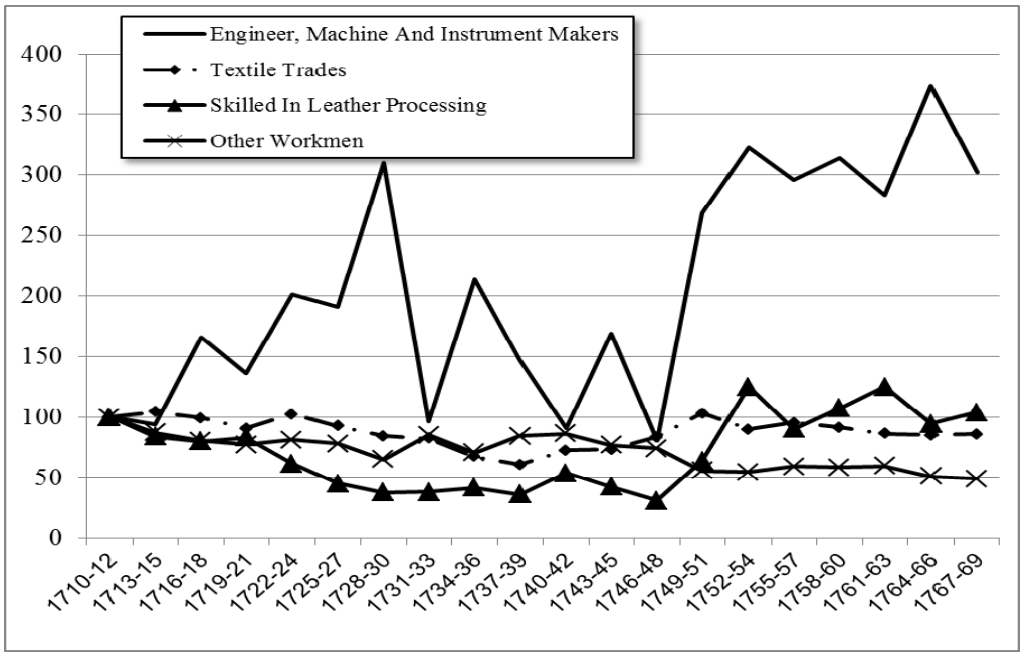


Source: Feldman and van der Beek 2013, Table A1.

As shown in Figure 5, the mechanical occupations, which accounted for 40% of the apprentices in manufacturing at the beginning of the period, accounted for 50% by the late 1730s and on, an increase of about a third.

Interestingly, this substantial rise in demand for mechanical occupations towards the middle of the eighteenth century was not characteristic of all the mechanical occupations. It was in fact the occupations of the 'high-quality' workmen identified by Mokyr as critical to Britain's industrial precocity that seem to have been in growing demand. Figures 6a and 6b show that indeed, the share of the group of occupations classified here as 'Engineer, Machine and Instrument Makers' was rising significantly during this period.

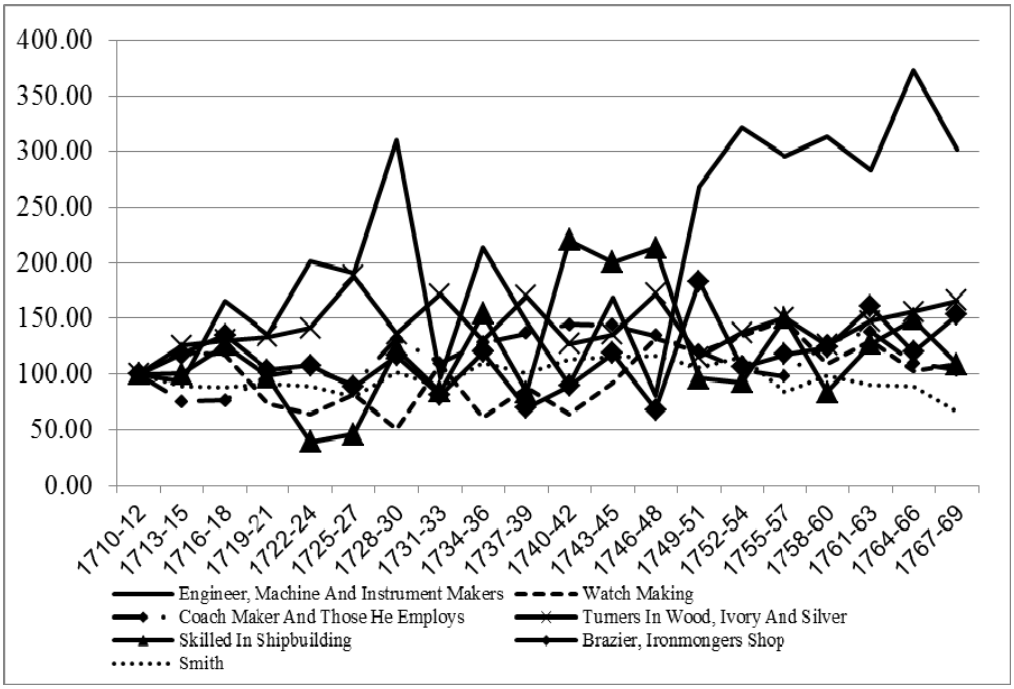
Figure 6a: Changes in the share of engineers, machine and instrument makers vs. the non-mechanical occupations



Source: Feldman and van der Beek 2013, Table A1.

The share of this group, which contains many of the occupations specified by Mokyr (wheelwrights, millwrights, spectacle makers, instrument maker, plough-wrights, pump-makers, stocking-frame makers, etc.), increased not only relative to the share of apprentices in the non-mechanical occupations (textile, leather processing and others), but also relative to the share of other mechanical occupations. The non-mechanical share of apprentice remained practically unchanged, while the other mechanical shares were increasing, but not by as much as the share of the 'high-quality' mechanical occupations.

Figure 6b: Changes in the share of engineers, machine and instrument makers vs. other mechanical occupations

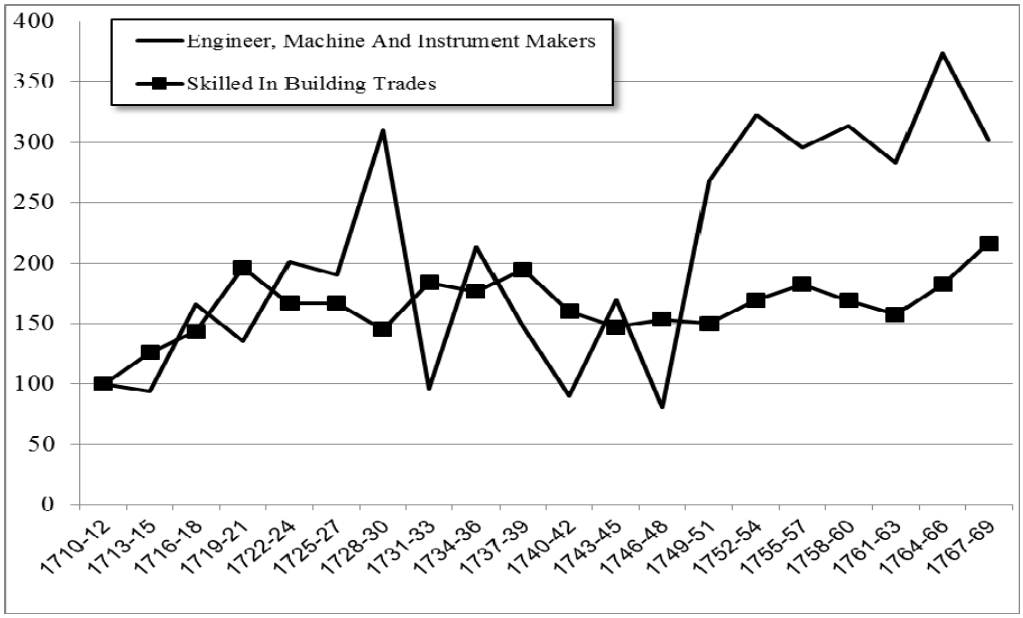


Source: Feldman and van der Beek 2013, Table A1.

Studies that advance the idea that human capital did not play any role in the process of the industrial revolution, base their claims, amongst other studies, on Clark's work (2005, 2007). In these studies Clark shows that the relative wages of carpenters to those of unskilled day laborers in the building trades did not change significantly during the eighteenth century, implying that there was no increase in the relative demand for skilled workers as a result of the technological changes. These studies may, nevertheless, be misleading. First, as discussed in the previous sections, the skill premium is a short run phenomenon, which depends on the responsiveness of the supply of skilled workers. Thus, the skill premium may remain constant even in the presence of an increase in demand for skilled workers relative to that for unskilled workers. Another important reservation regarding Clark's argument was raised by Mokyr and Voth (2010) who questioned the relevancy of the wage series, which is based mainly on evidence from southern England and consists of wages of workmen in the building trades.[25] Figure 7 shows that the demand for building trades – as a group - was not affected by the Industrial Revolution, while the demand for those specialized in machine manufacturing was strongly affected by it.

[25] Mokyr and Voth, Understanding Growth in Europe, 1700-1870: Theory and Evidence 2010, p. 25.

Figure 7: Engineers, machine and instrument makers vs. building trades

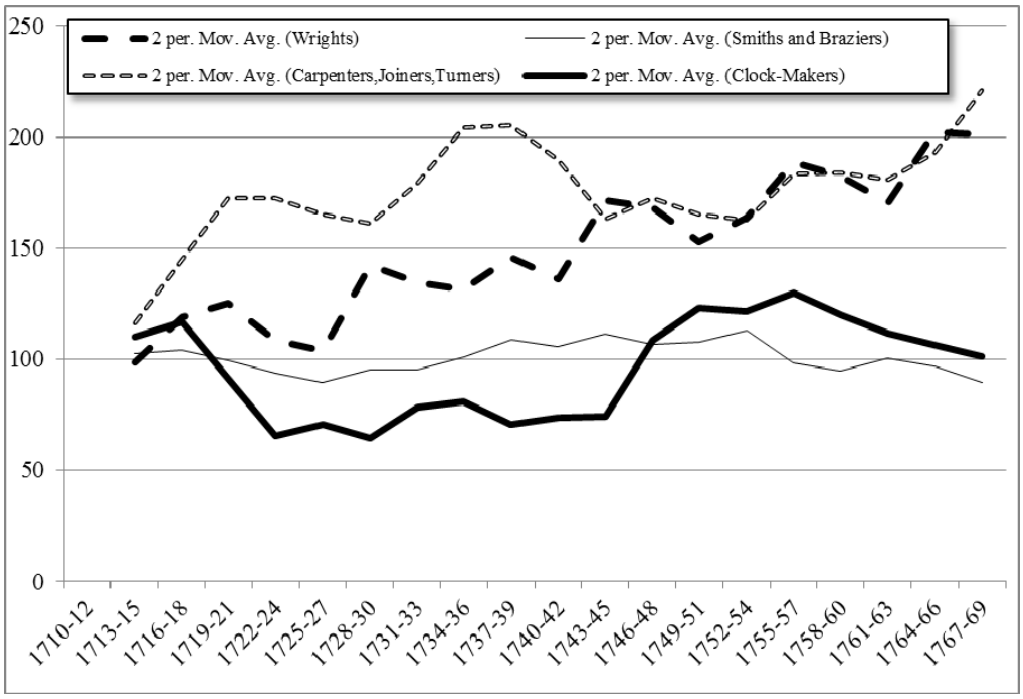


Source: Feldman and van der Beek 2013, Table A1.

To ensure that I am identifying the right type of occupation, I decompose the occupational groups and look into the changes in share of specific occupations that were relevant to mechanization. For example, Wrights account for about 90% of the group 'Engineers, Machine and Instrument Makers' (e.g. millwrights, wheel wrights, plough-wrights), as well as the occupational group 'Skilled in Shipbuilding'. Carpenters and joiners, which are relevant mechanical occupations, are comprised in 'Skilled in Building trades', and smiths can also be find in other groups, including 'Armorers'.

Decomposing the groups and looking into the specific occupations indicates that indeed, there was an increasing demand for wrights throughout the eighteenth century; however, Figure 8 shows that a shock in the demand for carpenters, joiners and turners also occurred in the first half of the century but the demand for clock makers does show an increase in the half of the century, however this change only brings us back to the share of apprentices in clock making in the beginning of the century. The demand for those specialized in metal, however, stays stable all through the period, as expected.

Figure 8: Changes in the share of 'high-quality workmen'



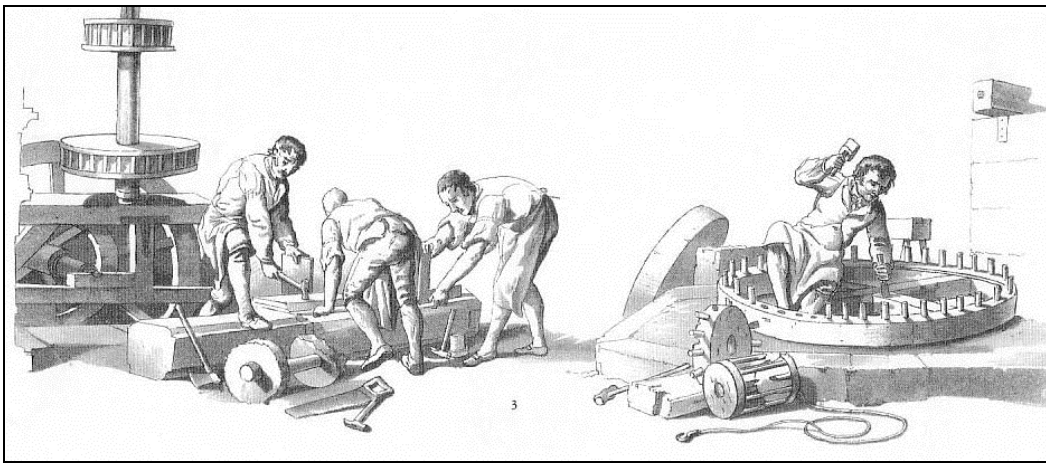
Source: Feldman and van der Beek 2013, Table A1.

Thus, the findings in this paper are consistent with Mokyr's view of the relevancy of specific skills to the Industrial Revolution, showing that indeed, the occupations that were most significantly affected by the mechanization and technological changes of the Industrial Revolution in its first stages were wrights, carpenters, joiners and turners.

Wrights were in fact already identified by Musson and Robinson (1960) as the most relevant class of workmen to machine manufacturing, far before the eighteenth century. Their claim was that machines existed before the Industrial Revolution and were constructed by specialized wood and metal workmen, but that mill wrights were of particular importance in this business. In their words: *"Power-driven machinery was not a new thing in the eighteenth century. There had long been wind, water, and horse mills for grinding corn, fulling cloth, working blast furnaces, hammers, and rollers in iron works, and driving drainage engines in mines or fenland districts. There had long been specialized metal workers: ironfounders, brassfounders, blacksmiths and whitesmiths, locksmiths, clockmakers, instrument makers, etc. There must also have been specialization in the making of such primitive textile machines as spinning wheels, hand*

looms, and knitting frames… Almost anyone, in fact, who was used to working in wood or metal might be employed to make machinery or set up millwork….At a fairly early date, however, a special class of millwrights emerged, who were of particular importance in setting up the early mills and factories, and from whom sprang many of the early engineers."[26]

Figure 8: Millwrights repairing a mill



Source: W.H. Pyne, Microcosm or a pictoresque delineation of the arts, agriculture and manufactures of Great Britain. London 1806

What do we know about this class of workmen? The eighteenth-century millwright was described by W. Fairbairn (himself originally a millwright) as *'a kind of jack-of-all-trades, who could with equal facility work at the lathe, the anvil, or the carpenter's bench. . . . He could handle the axe, the hammer, and the plane with equal skill and precision; he could turn, bore, or forge…'* [27] They fall into the HISCO category 'Machinery Erector and Installer' and are defined as follows: *"Erects and installs, in place of use, machinery and other mechanical equipment".*[28] As to their education, it is interesting to note that according to Musson and Robinson millwrights generally had a good knowledge of arithmetic, geometry, and theoretical as well as practical mechanics: *"It appears, in fact: that these millwright-engineers were not-as is often*

[26] Musson and Robinson 1960, pp. 210-211.

[27] W. Fairbairn, *A Treatise on Mills and Millwork,* **(2** vols.; London, 1861-63), I, v-vi. as cited in Musson and Robinson 1960, p. 211.

[28] Van Leeuwen, Maas and Miles 2002

suggested-rough, empirical, illiterate workmen, but had usually acquired somehow a fairly good education or training."[29]

Conclusions

This article uses various historical sources of evidence to challenge the common view among scholars that technological changes were skill substituting in eighteenth century England, despite the scarce and scattered evidence for this period. It demonstrates through wages books from textile mills, labor contracts from Bolton and Watt's engine shop, advertisements in newspapers, as well as a comprehensive set of data on apprenticeship contracts that mechanical workmen were in high demand during the second half of the eighteenth century. They were employed both in the new textile mills and in the rising machinery sector. The exceptional and comprehensive set of evidence from the stamp tax registries enabled us to observe the distribution of skills that young people in England acquired since the beginning of the century and to trace their response to the great changes that were taking place throughout the century up till 1770. We show that the early technological changes of the eighteenth century were complementary to mechanical skills, mainly to those skills relevant to machine production and maintenance, including carpenters, joiners, joiners, braziers, clock makers and mainly, wrights. This finding is consistent with Meisenzahl and Mokyr's argument that the 'high quality workmanship' that helped create the industrial revolution was such was able to *"follow the blueprint with a high level of accuracy, carry out the instructions embodied in the technique, and to have the ability to install, operate, adapt, and repair the machinery and equipment under a variety of circumstances"*.[30]

[29] Musson and Robinson 196), p. 211.

[30] Meisenzahl and Mokyr 2012, p.3

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