

Technology-Skill Complementarity on the Eve of the Industrial Revolution: New Evidence from England (1710-1772)

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This paper revisits the debate over whether the technological changes in eighteenth-century England were complements to skilled workers, or whether they were substitutes, as believed by many. Using an exceptional and comprehensive set of evidence from tax records on apprenticeship indentures from all over Great Britain between 1710 and 1772 I find evidence consistent with the technology-skill complementarity view. Thus, the relative number of new apprentices in the mechanical occupations was increasing throughout the eighteenth century and since the 1730s', a period of accelerated technological changes, the relative tuition paid to be apprenticed to these occupations was increasing as well. Furthermore, a breakdown of the occupations to categories of skill level reveals that the relative number of new apprentices in skilled occupation was continuously increasing. Interestingly, these trends are shown to have taken place in the regions where technological changes had an impact and are not apparent in the London area.

1. Introduction

The British Industrial Revolution, which marks the first transition to sustained growth in history, was a period of great technological change. It began in the eighteenth century with the mechanization of the textile industries, the development of iron-making techniques, the increased use of refined coal, and the introduction of steam power. The aim of this study is to revisit the debate regarding the effect of the technological changes that led to the Industrial Revolution, on the level of human capital, using an exceptional set of evidence that has not thus far been systematically exploited. The existing debate revolves around the question of whether these technological changes were skill-complementary, as many recent models of endogenous economic growth would predict, or whether they were skill-substituting, as much of the historical literature argues.

In recent models of endogenous economic growth, transition to sustained growth is associated with rising returns to education as well as a rapid acceleration in demand for human capital and skill formation. In these models, it is usually assumed that

technological change is skill-biased and therefore, increases the demand for human capital and in the short run produces a skill premium. Although human capital based-growth models were largely developed to explain investment in human capital in modern economies, the mechanism that they offer can be applicable to earlier periods as well. This view was expressed by different scholars, including Jan Tinbergen who shared the first Nobel Prize in Economics in 1969. In his classic book, *Income Distribution*, Tinbergen argued that skill returns always rise when the rate of technological development outpaces the production of new human capital. He viewed the evolution of the wage structure as depending on a race between technological development and educational advance¹. Consistent with this view, Goldin and Katz (1998) showed that capital-skill complementarity was already apparent in the US economy in the beginning of the twentieth century as particular technologies spread².

Nevertheless, there are also many scholars who disagree as to the relevance of these models to earlier periods in history. In particular, the period of the British Industrial Revolution, which is perceived by many as being deskilling in that it substituted highly skilled artisans for physical capital, raw materials, and unskilled labor. The main problem in determining whether the technological changes of the Industrial Revolution were indeed deskilling is the limited amount of available evidence on human capital in the eighteenth century. In fact, there are hardly any studies that focus on this question and empirically examine it. Williamson (1985) and Clark (2005, 2007) are important exceptions in this respect. Williamson showed that there was a significant increase in wage inequality between 1750 and 1850, resulting mainly from a surge in the relative wages of white collar occupations. However, his data has been heavily contested by Feinstein (1988). Clark, on the other hand, argues that there is no evidence to support the view that the Industrial Revolution was skill-complementary. He brings forth three main sets of data in support of his argument. The first two sets show that there was no increase in enrolment rates to primary school (based on Mitch, 1982), nor any increase in male literacy rates at that time (based on Schofield, 1973). The third set of data concerns the skill premium. His data shows that the wages of carpenters relative to those of unskilled day laborers did not change during those

¹ Jan Tinbergen (1975).

² Goldin and Katz (1996).

years, suggesting that technological changes did not induce a significant increase in demand for skilled labor (Figure 2, p. 1309).

However these findings should be viewed with caution. For example, enrolment to primary school and literacy, two basic indicators for human capital in the modern economy, may not be relevant for the eighteenth century when apprenticeship and on-the-job training were the main formal systems for acquiring skills. Apprenticeship either supplemented schooling or was the only form of a child's education. Clark's evidence on the skill premium might be problematic as well since it is based on wages of carpenters coming from the London area, which was less affected by the technological changes that were more relevant for the textile industry in the Midlands. Thus, the main difficulty with the existing literature is that it lacks the set of evidence required for a systematic and comprehensive analysis of the question involved.

To the best of my knowledge, this is the first research to present an extensive set of evidence and to provide a systematic analysis of the effects of technological changes in the eighteenth-century England on the market for skilled labor. It exploits a comprehensive source of data on English apprenticeship derived from indexes of the British Apprentice Tax records kept by the Inland Revenue.³ These records are of exceptional value for the study of apprenticeship in eighteenth-century England as they include information on about 350,000 indentures from all over Great Britain. The study is based on a randomly selected sample of 50,200 observations. The indexes give the name of the apprentice, the name of the master to whom he was indentured, the master's trade, the place where the master lived, and the value of the tuition paid to the master for taking on the apprentice.

The analysis of the data focuses on the production sector, as customary in this literature. It strongly indicates that the technological changes of the early eighteenth century had a significant effect on the demand for highly skilled mechanical workers. These workers include, amongst others, wheelwrights, iron founders, blacksmiths, engravers, goldsmiths, carpenters, wood carvers, coopers, joiners. The effect of technological changes is reflected by the significant increase in the relative number of new apprentices into the skilled mechanical occupations, as well as by the rise in the

³ The indexes were compiled by the Society of Genealogists and are kept together with the apprenticeship books at the National Archives under Series IR 1.

relative tuition since the introduction of textile machinery in the 1730s. Furthermore, the data shows clearly that the absolute number of skilled mechanical workers in England was increasing throughout the eighteenth century, as well as the relative number of these workers vis-à-vis lower skilled workers.

The spatial examination of the data reveals a finding of great significance. The study shows that apprenticeship in London was not affected by technological changes at this early stage of the Industrial Revolution, which mainly concerned the English midlands. While the number of apprentices in the other manufacturing trades shows the exact same trend in both London and the midlands, the number of apprentices in the machine trades shows no trend at all in London, while it increases sharply in the Midlands from the 1730s'. The same applies to the relative tuition paid in the mechanical occupations, which shows no change at all in London while it increases sharply in the Midlands.

Unfortunately, this paper does not include an econometric analysis of the data, mainly because I am still working on the main explanatory variable, which is the measure of technological change in the relevant period. Yet, as I will show below, the analysis of the trends in the number of new apprentices and in the tuition they paid, strongly suggests that the introduction of new machines and the mechanization of the production processes, which grew dramatically in the 1730s' had a positive effect on the stock of highly skilled workers in the English economy, mainly in the mechanical occupations.

The paper is organized as follows: The theoretical framework of the paper is discussed briefly in the following section (2). Section 3 discusses the use of the trends in the relative tuition paid for apprenticeship in different occupations as an indicator for the relative wages for the same occupations. The data and findings are presented in sections 4 and 5 and the last section concludes.

2. Theoretical framework

Skill-biased technical change is manifested by a shift in the production technology that favors skilled over unskilled labor by increasing its relative productivity and,

therefore, its relative demand. Modern growth theory envisions human capital as a critical growth factor. Human capital theory was introduced by Becker (1962), and is a widely-accepted approach for understanding investment in human capital. The models developed in modern growth theory demonstrate that the disequilibrium brought about by technological change raises the demand for human capital. This is because educated individuals have a comparative advantage in adapting to a new technological environment.

The theoretical framework of my analysis is primarily based on the model offered by Goldin and Katz (1998), which conceives of manufacturing as having two distinct stages: (1) machine-installation and machine-maintenance and (2) production and assembly. According to the mechanism they propose, technology and education are always complements in the first stage. The workable capital is then used by the unskilled labor to create the final product in the second stage. Therefore the adoption of technology will alter aggregate demand for skilled labor only if the machine-installation demand for skilled labor is not offset by the production process demand for unskilled labor. In this study I examine in this paper whether there is evidence to support the existence of technology-skill complementarity in the machine-installation and machine-maintenance stage, during the early years of the industrial revolution.

The analysis also relates to a more recent literature, which distinguishes between the effect of technological changes on highly skilled workers and middle skilled workers. Autor, Levy and Murnane (2003), for example, argue that ICT (information and communication technologies) complements the analytical tasks primarily performed by highly educated workers and substituting for routine tasks generally performed by middle educated workers (with little effect on low educated workers performing manual non-routine tasks).

3. The tuition

As opposed to the central role of schooling in today's education, occupational training was far more important in eighteenth century England. Apprenticeship either supplemented schooling or provided the entire formation of a child. It originated in

the guild system of medieval times, however, the basic conditions of apprenticeship were those laid down in the Statute of Artificers of 1563 and lasted until the Elizabethan statute was repealed in 1814. The main clauses of the statute maintained that masters should have no more than three apprentices each, a seven year term was essential before a craft or trade was exercised, and a written indenture was obligatory for non-poor children⁴.

The practice of paying a premium (to which I refer here as *tuition*) arose in the seventeenth century when the optional gift the child brought his new master's wife, was gradually converted into cash. The importance of the tuition in securing an apprenticeship can be seen in bequests made by fathers of young families who left specific sums of money in their wills for this purpose⁵. It is possible to think of different reasons why parents would be interested in paying for their children to acquire skills, yet, the prime reason must be assumed to be future earnings. According to Lane (1996), according to whom future occupational security and earning potential were of prime importance in parents' choice over their wards' or children's life-long career. Thus, "Indenturing children was committing them in an inescapable way to an adult working life perhaps of 30 years or more, in one particular occupation, in prosperous or hard times, when ill or well, even against their own inclinations."⁶

The tuition was primarily designed to cover the masters' maintenance and training costs. While maintenance costs, which included food, shelter and clothing, can be regarded as fixed among trades, training costs must have been very diverse and therefore responsible for a large part of the variation observed in tuitions for different occupations. Since both the apprentice and the master must have ensured the returns from their investment and had no interest in paying more than they were expected to receive, The tuition should be expected to be, on the one hand, either equal or be greater than the net training costs incurred by the master (i.e. the training costs exclusive of the value of the apprentice's labor). On the other hand, it could not have exceeded the present value of future earnings perceived by the apprentice, since in

⁴ Wallis (2008), shows that the term of apprenticeship was in practice shorter than seven years.

⁵ Lane (1996), p. 19.

⁶ Lane (1996), p. 29.

this case he would have preferred to be apprenticed elsewhere. Therefore in equilibrium, the amount of the tuition should be⁷:

$$(1) \quad k_{0,i} - mp_{0,i} \leq prem_{0,i} \leq \sum_{t=1}^T \frac{w_{t,i}}{(1+r)^t}$$

where mp_0 stands for the marginal product of the apprentice's labor during the apprenticeship term, t , the year ($0 =$ apprenticeship term, $1, 2, \dots, T =$ later periods of employment), i the trade, k , the maintenance costs, training costs, damages incurred by apprentice, w , the expected annual wages, and r , marks the market discount rate.

As can be understood from equation (1), the tuition reflects not only changes in k , the net training costs, but also changes in w , the expected annual wages. This implies that exogenous changes in demand by employees had a direct effect on the tuition that apprentices were willing to pay for their training. Yet, guilds could also affect wages by successfully limiting access to apprenticeship⁸. In this case rising tuitions would not indicate a greater incentive to pursue training for children and market wage rates would be misleading.

Clark (2005), however, argues that since guild regulation of crafts was much stronger in cities than in the countryside and since the skill premium he calculated was, if anything, higher in rural areas and small towns than in the largest cities, the decline in skill premiums must reflect underlying trends in the demand for and supply of skills⁹.

An additional difficulty of interpreting changes in the tuition paid for a specific occupation as reflecting changes in demand for that trade may arise from the fact that variation in tuitions reflects differences in training costs, as discussed above. Thus a higher tuition paid in one occupation may merely reflect higher training costs in this occupation. In order to overcome this difficulty I concentrate on the difference-in-difference level, using the changes in the relative tuition paid in different occupations

⁷ The analysis of the premium is based on Becker (1962).

⁸ See for example, Epstein (1998).

⁹ Clark (2005), p. 1316.

over time and place. Since the changes I observe are continuous and vary across areas, they cannot be interpreted as changes in training costs, but rather changes in demand.

4. Data

4.1 Data Source

The main source of data for this paper is the indexes of tax records kept by the Inland Revenue¹⁰. These records are of exceptional value for the study of apprenticeship in eighteenth-century England as they contain information on about 350,000 indentures from all over Great Britain. The indexes summarize information from indentures, which are official contracts between masters and the apprentices they took on, including the year of the contract, the name of the apprentice, the name of the master to whom he was indentured, the master's location and occupation, and, as well as the fee paid to the master (i.e. the *premium*), to which I will refer here as tuition.

According to an act of Parliament in Queen Anne's reign from 1 May 1710, a tax was to be paid by the master not more than one year after the end of the apprenticeship, and was at the rate of 6d in the pound on agreements of £50 or less, plus one shilling for every pound above that sum. No tax had to be paid for fees below one shilling or for contracts that were arranged by parish or public charities, implying that these registers do not include indentures of parish apprentices. In addition, trades which had not existed in 1563 when the *Statute of Apprentices* became law, most notably in the cotton industry, were also not liable to the tax¹¹. The payment of the tax was entered on the reverse of the indenture, which was void without this payment.

The indexes of the original records were typed up as two series, covering the periods 1710-62 (Series 1) and 1763-74 (Series 2), and arranged in alphabetical order according to the apprentice's name. Unfortunately, they do not cover the later period until 1804, when the tax was finally abolished.

¹⁰ The indexes were compiled by the Society of Genealogists and are kept together with the apprenticeship books at the National Archives under Series IR 1. The indexes are also available online at Origins Network, a family history website:

¹¹ The most notable example of this was the cotton industry.

Below is a sample of entries from a typical page in the index, where the first entry reads "Bently Edward Jn. from Mortlake was apprenticed in 1725 to Alex Haslear of Westminster, an attorney and paid a premium of £50."

Figure 1: The format of the abstracts

				430.
11/31	1725	Bently	Edw Jn of Mortlake to Alex Haslear of Westr atty	£50
53/62	1757	Bently	Edw to Marvellous Froud of Holbrook Suff tay	£10 10/
18/12	1747		Edw Edw to Wm Edridge of Stoke Newington bak	£5 5/
48/4	1722		Eliz to Mary Reeve of Erth Coughton Worcs needle	£10
9/169	1723	Bently	Eliz Wm of S Mary Westr to Mary Chabane of S Giles/Flids mart	£9
41/45	1710	Bently	Geo Thos late of Huntington Yks husb to Thos Rycroft of York city translator	£2
44/159	1716	Bently	Geo to Rob Reymes of Norwich w weav	£18
51/180	1752	Bently	Geo to Simson Kay of Bedale curr	£3 8/
18/89	1747		Geo Geo to Isaac Wood of Bradford Yks groc	£63
18/132	1748		Geo Fred to Jas Goddard of S Anns Westr enameller	£1
49/15	1724		Hen Dan to Jn Smedley of Blackburn fustian	£40
52/35	1754		Hen to Thos Abrahall of Little Dean Glos shoe	£5 10/
20/199	1756		Isaac to Thos West of Reading clock	£20
12/158	1731		Jas Jas of Endfield Mx to Wm Willford cit & m'tay	£10
6/67	1718		Jas Jas dec to Jos Simcoe cit & glism	£5
7/1	1718		Jn Jn of Ebisham Warws to Ric Harrison of Birmingham found	£5
5/15	1716		Jn Jn cit & cordw to Jos Walker cit & vint	£10
41/51	1710		Jn Rebecca dec to Dan Chambers of Kidderminster Worcs stuff weav & clth & Mary his wife	£3

4.2 Sample

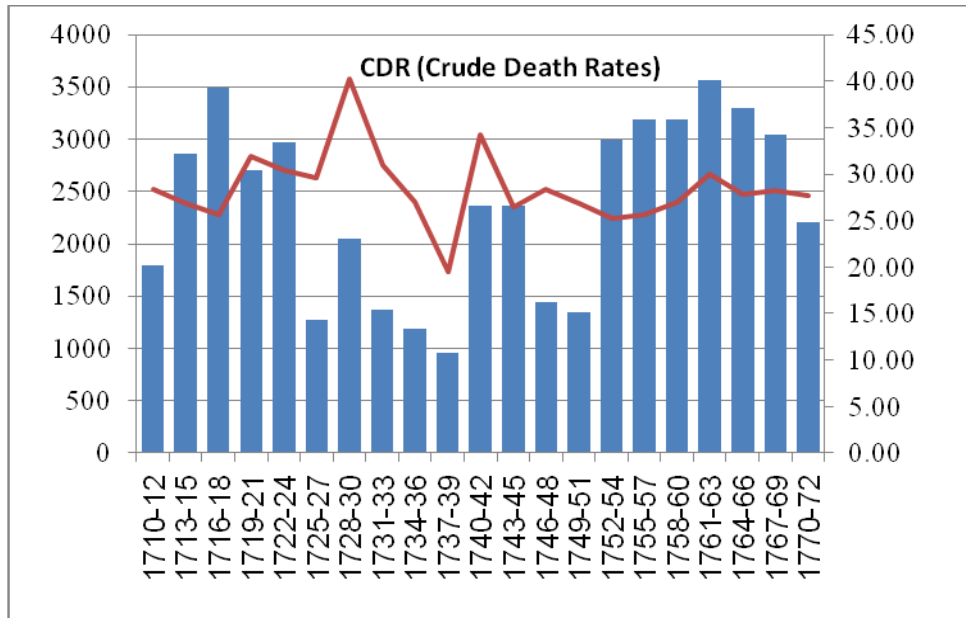
The study is based on a randomly selected sample of 50,200 observations, where every observation is an apprenticeship contract entry that includes information on the year of the contract, the name of the apprentice, the name, location and occupation of the master, and, the tuition that has been paid by the apprentice (see figure 1)¹². In the text I refer to each observation as a 'new entrant to apprenticeship'. Figure 2 depicts the distribution of observations of over the years. As the figure shows, the distribution is not uniform. There is a sharp decline in the number of new entrants in the years 1725-1750, reaching less than 1000 observations in the years 1737-1739. As suggested by the red line representing the Crude Death Rates (number of deaths per 10,000 people), this decline can be explained by a "demographic crisis" caused by a small pox outbreak during the first half of the eighteenth century, which caused a high mortality in these years, mainly among young children¹³. Wrigley and Schofield place this sharp rise in deaths precisely in the years in which our data shows a decline in the

¹² 156 observations were omitted because the year wasn't mentioned or was unreadable. Another 400 observations were omitted for the years before 1710 (4) and after 1772 (396) due to their small number.

¹³ I am grateful to Joel Mokyr for pointing out demography as a possible path for exploration.

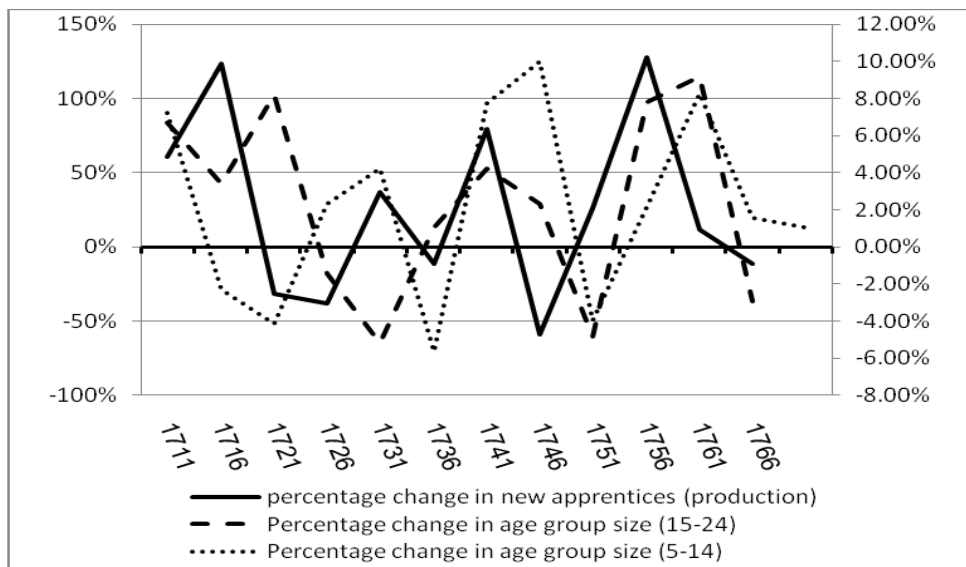
number of apprentices: "...their (*the deaths*)' upsurge in the early eighteenth century owes much to some years exceptionally high mortality in the 1720s and early 1740s, and it is noteworthy that around 1750 the number of deaths sinks back to a level not much higher than had obtained in the last quarter of the seventeenth century".¹⁴

Figure 2: Distribution of observations: 1710-1772



Source: Table 1; Wrigley & Schofield, 1981, Table A3.1.

Figure 3: Percentage change of new apprentices and of age-group size



Source: Table 1; Wrigley & Schofield, 1981, Table A3.1.

¹⁴ Wrigley & Schofield, 1981, p. 162

The close correlation between demographic trends and entry to apprenticeship is reinforced in Figure 3, where the change in the number of new entrants to apprenticeship is plotted along-side with changes in the size of the relevant age groups for entering apprenticeship, i.e., 5-14, and 15-24. At least until the forty's, it is clear that any change in the 5-14 age group size is followed by a change in the same direction in the number of apprentices. Importantly, no sign of a bias of this decline in the number of new apprentices towards a specific economic sector, or a specific region in England, has been identified.

4.3 Data Construction

Since the study requires data on industry as well as on skill composition, masters' occupations have first been coded using the occupational information system, HISCO (Historical International classification of Occupations), which is both international and historical, and simultaneously links to existing industry categories used in the present¹⁵. The HISCO codes were then recoded into measures of social class and social level, which are available through the HISCO system as well. These measures include three skill classes for the production occupations: skilled, low-skilled, and unskilled. The main occupations that compose each of these skill categories are listed in Table A1 in the appendix.

The analysis of the data was conducted both on the industry-year level and on the skill category-year level. In both cases the outcomes of interest are the relative number of new apprentices, and the relative tuition that was paid. These are used as indicators for the supply and demand of skilled labor.

¹⁵ The subsidiary HISCO-classification PRODUCT utilizes version 1.0 (draft) of the United Nations Central Product Classification at the two digit level, copyright United Nations, 1998.

5 Findings

5.1.1 The Production Sector

The average number of new apprentices and the amounts they paid as tuition are summarized in Table 1 by economic sector. As the table shows, the average tuition that was paid for apprenticeship was about £20. This amount stayed relatively stable throughout the period, despite the sharp declines in the number of entrants (Figure 4)¹⁶. Yet the variation in tuition levels between the different economic sectors was enormous. For example, while children who were apprenticed to masters in the sales sector paid an average tuition of £52, or £31 to masters in the professional sector, children apprenticed to masters in the production sector paid an average tuition of £12.

Table 1: Summary of Statistics by Economic Sector¹⁷

Economic sector	No. of new entrants	Percentage	Average of tuition (in Shillings)
ADMINISTRATIVE AND MANAGERIAL WORKERS	468	1%	621.6
AGRICULTURAL, ANIMAL HUSBANDRY AND FORESTRY WORKERS, FISHERMEN AND HUNTERS	506	1%	157.4
CLERICAL AND RELATED WORKERS	491	1%	703.9
PRODUCTION AND RELATED WORKERS, TRANSPORT EQUIPMENT OPERATORS AND LABOURERS	36481	76%	241.6
PROFESSIONAL, TECHNICAL AND RELATED WORKERS	3444	7%	1286.7
SALES WORKERS	4841	10%	1047.8
SERVICE WORKERS	1713	4%	281.7
Total	47944	100%	404.1

As I mentioned earlier, this study focuses on the production sector, as is standard in the literature that deals with responses of the labor markets to technological changes. There are, however, additional justifications for this choice. As Table 1 shows, the production sector comprises the largest number of new apprentices within the sample (76%). It is followed by the commercial sector (10%), the professional sector (including mainly pharmacists, surgeons, attorneys, and artists), and the services,

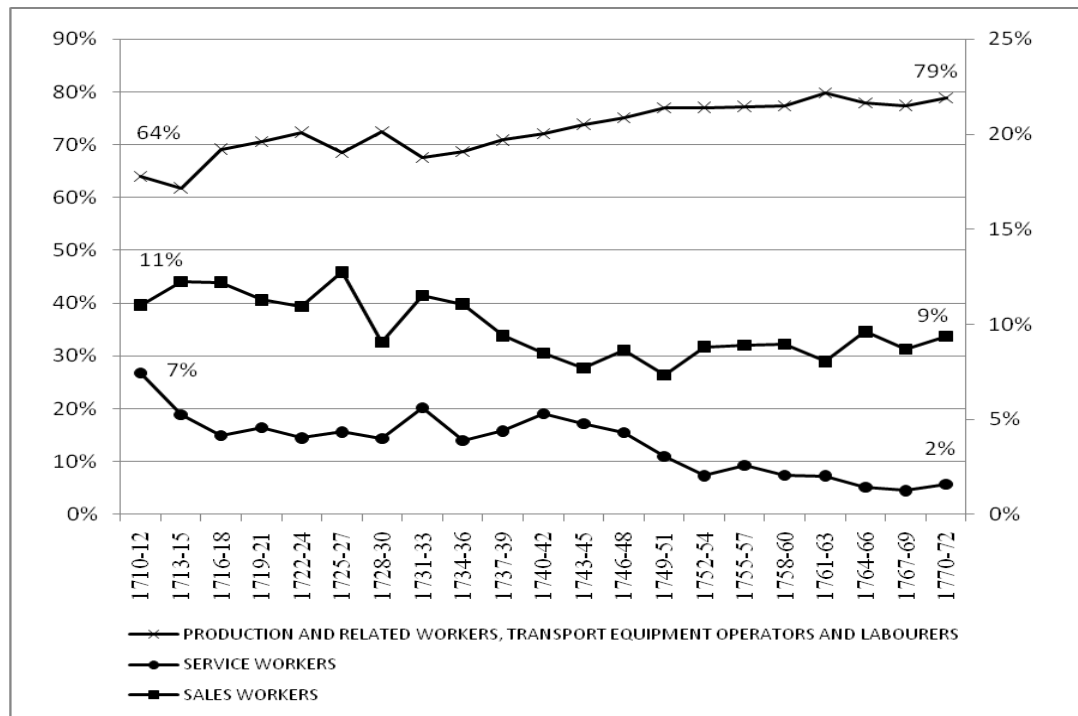
¹⁶ Note that the number of new entrants is from the sample and does not represent their number in the population, which is 7 times these numbers.

¹⁷ For 1278 observations no occupation was mentioned.

administrative and clerical sectors (4%, 1%, 1%). Last, the agricultural sector, which accounts for less than 1% of the observations, and is obviously under-represented in this data source. In addition, there are many reasons to believe that the production sector is, in effect, the sector that is best representative of the real economy in this sample, as it is the one that is less likely to be significantly biased by tax exemption, also due to its size.

The relative number of new apprentices in the production sector, which was around 30 percent of the new apprentices in the sample, grew continuously since the 1730s', reaching 80 percent of the apprentices in 1770s', while most of the other sectors in the economy were, in effect, shrinking (Figure 4).

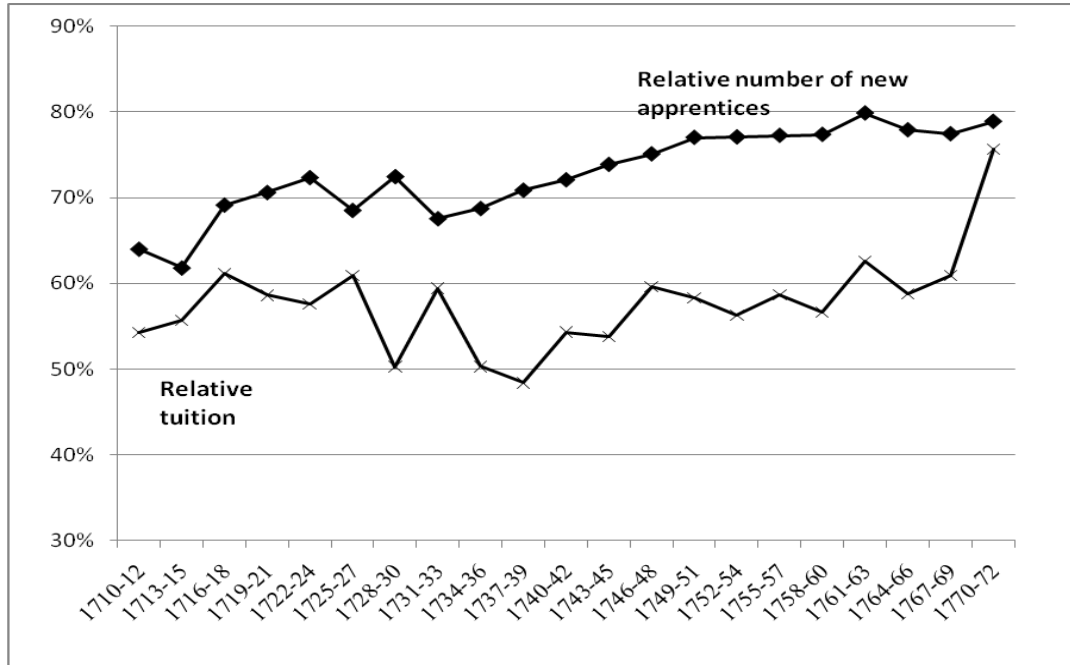
Figure 4: The relative number of new apprentices in different sectors



Meanwhile, the relative tuition that was paid to masters in the production sector, which is depicted along with the relative number of new apprentices in Figure 5, shows a small increase as well, mainly since the mid 1730s'. This finding could suggest that the demand for apprenticed workers in the production sector was growing relative to the other sectors with the beginning of mechanization in the 1730s'. Furthermore, the increase in tuition would suggest that the demand was growing faster than the supply of new apprentices. Nevertheless, since we are not sure as to the

level of representativeness of all the sectors in the sample, it is not possible to conclude that this was indeed the case.

Figure 5: The relative tuition and number of new apprentices in production



5.1.2 Cross Industry Trends

A breakdown of the relative number of new apprentices by the main production industries appears in Figure 6. Most importantly, the number of new apprentices in the "Machinery Fitters, Machine Assemblers and Precision-Instrument Makers" industry was clearly growing during the period. This industry, which includes highly skilled workers that were directly defined as machine and instrument makers (e.g. clock makers, movement makers, wheelwrights, shipwrights, etc.), comprised 6-7 percent of the new apprentices in the beginning of the period and reached 9% in its end. In most of the other production industries no particular trend beyond the general increase in the number of new apprentices in the production sector can be observed.

The exception is, of course, in the "Spinners, Weavers, Knitters, Dyers and Related Workers" industry. The relative number of apprentices to these occupations declined sharply, by 8 percent, in the beginning of the period, and then increased moderately. This decline, which was clearly a result of the mechanization of the spinning industry,

is very interesting as the workers in this industry are all categorized as lower skilled. The significant increase in the number of apprentices in the "Food and Beverage Processors" industry could be an outcome of an increase in living standards, yet, it remains to be explained. It is important to note that almost all the occupations in this industry are categorized as skilled.

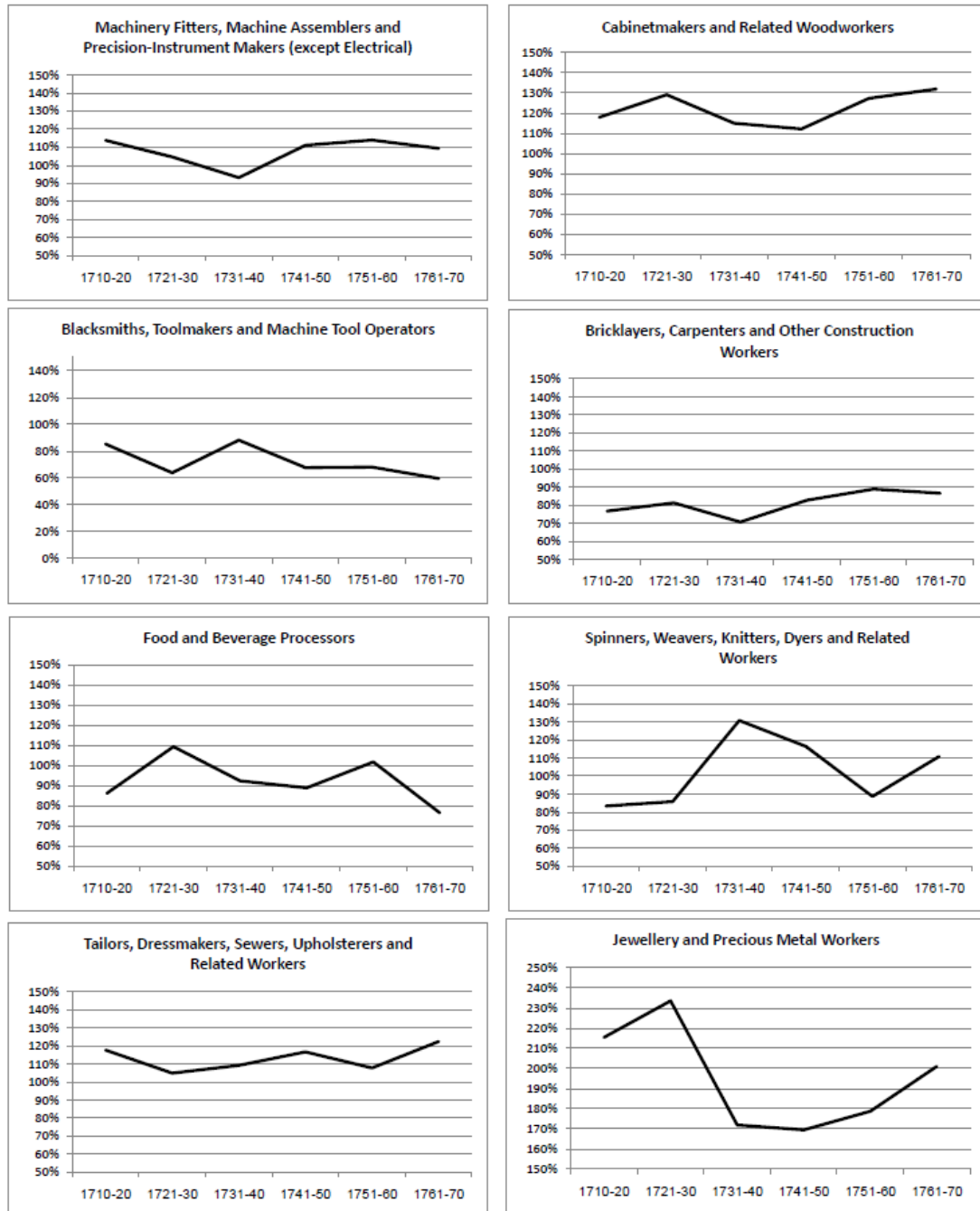
Figure 6: The relative number of new apprentices by industry



Source: Table A2.

The trends in the relative tuition perform an interesting change in the 1730s' in most of the industries.

Figure 7: The relative tuition by industry



In the three industries that are most closely related to machinery, the "Machinery Fitters, Machine Assemblers and Precision-Instrument Makers", the "Bricklayers, Carpenters and Other Construction Workers", and the "Cabinetmakers and Related Woodworkers" industries, the relative tuition declined until the 1730s' and then

increased again. This pattern may be indicative of the shocks in demand in the 1730s', which pushed tuition out of equilibrium in the short run.

5.1.3 Trends in Specific Occupations

The classification of occupations into industries conceals specific occupations, which were also of relevance to machine construction and maintenance. There is much anecdotal evidence according to which the technological changes that were taking place increased the demand for skills necessary to the machine production and maintenance industry. S. D. Chapman, for example, referring to the increase in demand in the cotton factories, which needed skilled labor to operate and maintain the new machinery, contends that: *"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"*¹⁸.

The machine making sector faced an even more difficult problem in that it required experienced workmen of every kind. According to Musson and Robinson (1960), who focused on the sources of engineering, the result of this situation was that many craftsmen moved to the cotton industry from other trades, due to the higher wages that they offered. The following correspondence between Matthew Boulton and James Watt, and Peter Ewart, an engine erector in Manchester from the 1790's, from whom they asked to find skilled metal workers illustrates this point¹⁹: *"Ewart reported that it was almost impossible to get good millwrights, turners, and filers; he himself was having to "make shift with Joiners and Carpenters...The very few general good filers and turners that are here, are all engaged for a term of years in the different Cotton Mills." He mentioned, however, two watch-tool makers in London whom they might be able to get. The wages of engineering workers in Manchester were "almost 1/2*

¹⁸ Chapman (1972), p. 54.

¹⁹ Boulton and Watt's partnership was formed in 1775 to exploit Watt's patent and had a monopoly on steam engine construction.

higher" than in Birmingham: "there is not a hand that is good for anything can be had here for less than 17 or 18 Shill.p. week"²⁰.

A deeper look into few of these occupations, for which there is a large enough number of observation, carpenters, smiths and joiners, provides interesting insights. Carpenters are a very good example of an occupation for which both the demand and supply were clearly increasing sharply, mainly in the 1730s' (see Figure 8). The relative number of new apprentices to this occupation increased from 5 percent in the beginning of the period to 10 percent in its end. The relative tuition, which was 60 percent in the beginning of the period, increased to 80 percent in the 1730s'.

The case of joiners and smiths however, is less clear. The relative number of new apprentices to these occupations stayed almost unchanged (around 4-5 percent), the relative tuition to become joiners increased by about 10 percent from the beginning of the period to its end and that of smiths stayed stable throughout the period. Note that this only implies that the number of new apprentices in these occupations did not increase by more than the general trend in the production sector.

Figure 8: The relative number of new apprentices and tuition - carpenters



To overcome the aggregation problem in the industry level analysis, I also classified the occupations in the production sector into two categories, of which the first includes the occupations that are most relevant in machine construction and maintenance (mainly wheelwrights, iron founders, blacksmiths, whitesmiths, engravers, goldsmiths, silversmiths, carpenters, carvers, coopers, turners, joiners,

²⁰ From Musson and Robinson (1960), p. 220.

etc.), and the second category includes all the other occupations. Interestingly, the number of new apprentices in the mechanical occupations nearly tripled between the beginning and the end of the period (from 396 to 966), while their number in the other occupations remained practically unchanged.

Figure 9: The relative number of new apprentices: mechanical vs. other

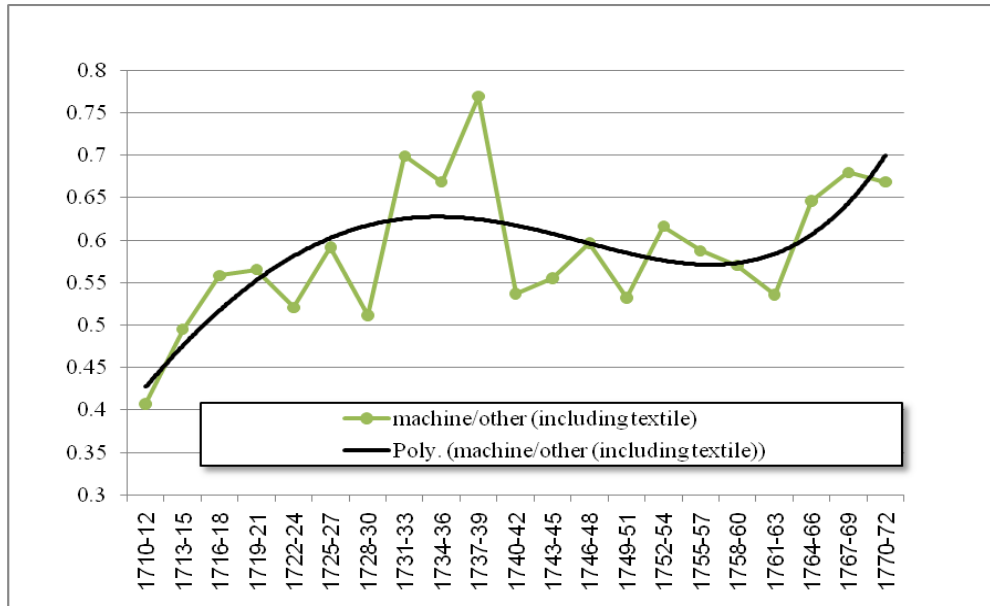
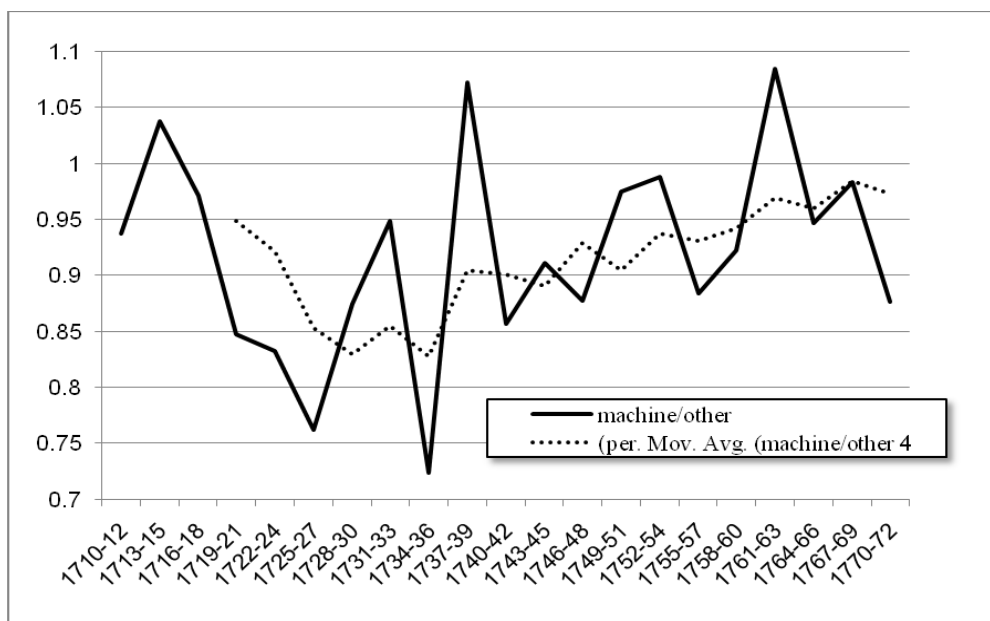


Figure 10: The relative tuition: mechanical vs. other



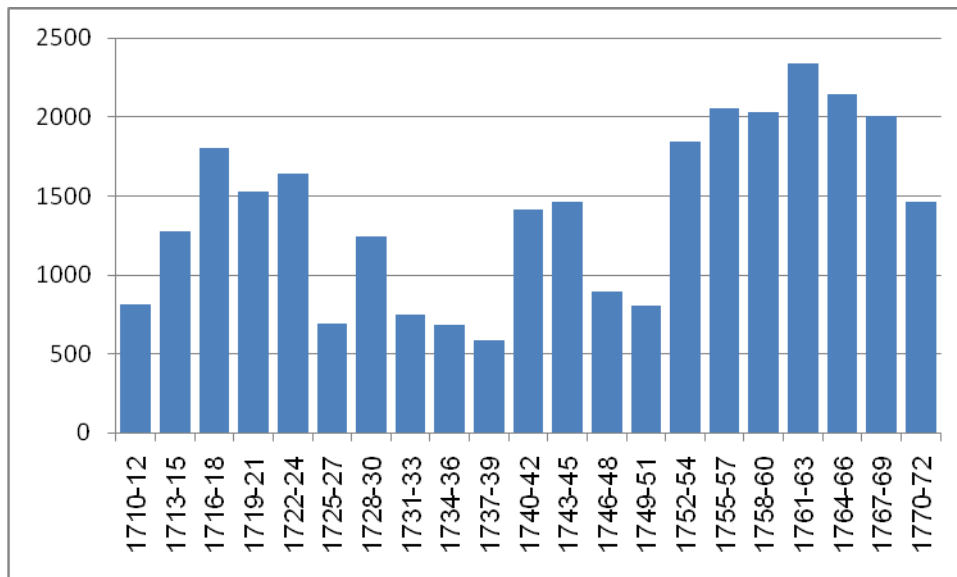
As Figure 9 shows, the relative number of new apprentices in the mechanical occupations increased by more than 25%, relative to the other occupations, from 40% to 67%. As in the cross industry analysis, according to this classification the relative tuition in the mechanical occupations began to rise in the 1730s' while it was in fact decreasing in the occupations (Figure 10).

Thus, the figures presented here are highly suggestive of empirical support for the hypothesis that the technological changes of the eighteenth century increased the demand and the supply of skilled mechanical workers in England.

5.1.4 Cross Skill Trends

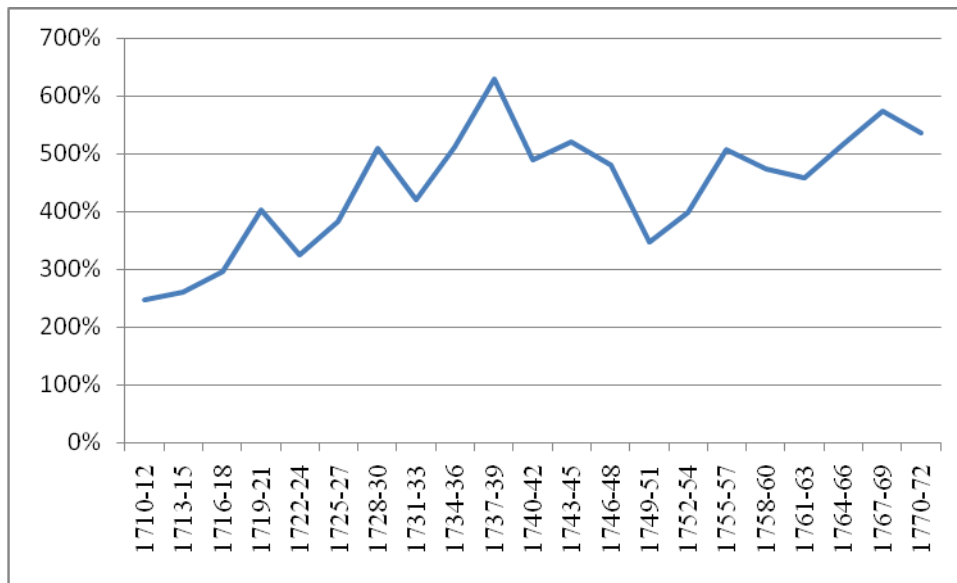
An examination of the changes in the stock of skilled labor (to be), in eighteenth century England, reveals a finding of great significance. Figures 6 and 7 depict the number of new apprentices in occupations that are categorized as skilled according to the HISCLASS system, between 1710 and 1772, and their number relative to that in lower skilled occupation²¹.

Figure 11: The number of new apprentices in skilled occupations



²¹ Skilled according the HISCLASS classification system.

Figure 12: The number of new apprentices in skilled vs. lower skilled occupations



These figures show very clearly that the number of children that were apprenticed into skilled occupation within the production sector was growing all along the eighteenth century, both in levels and in relative terms.

5.1.5 Cross Area Trends

The spatial examination of the data reveals a finding of great significance. It shows that apprenticeship in London was not affected by technological changes at this early stage of the Industrial Revolution, which mainly concerned the English midlands. While the relative number of new apprentices in the other occupations shows the exact same trend in both London and the midlands, the number of apprentices in the mechanical occupations shows no trend at all in London, while it increases sharply in the Midlands since the 1730s'. (Figure 13). The same applies to the relative tuition paid in the mechanical occupation. It shows no change at all in London while it increases sharply in the Midlands.

**Figure 13: The relative number of new apprentices: mechanical vs. other
And Midlands vs. London**

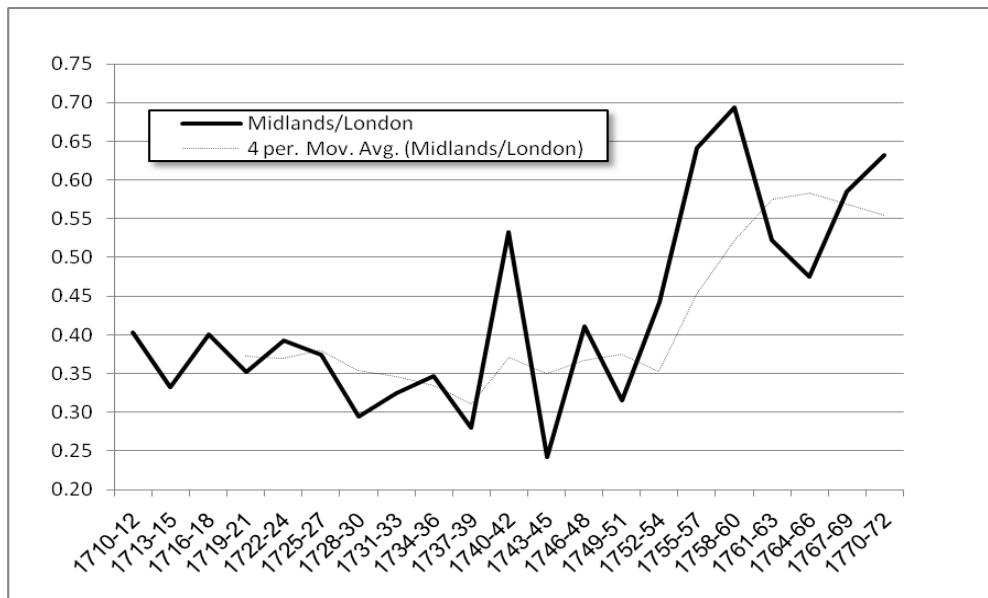
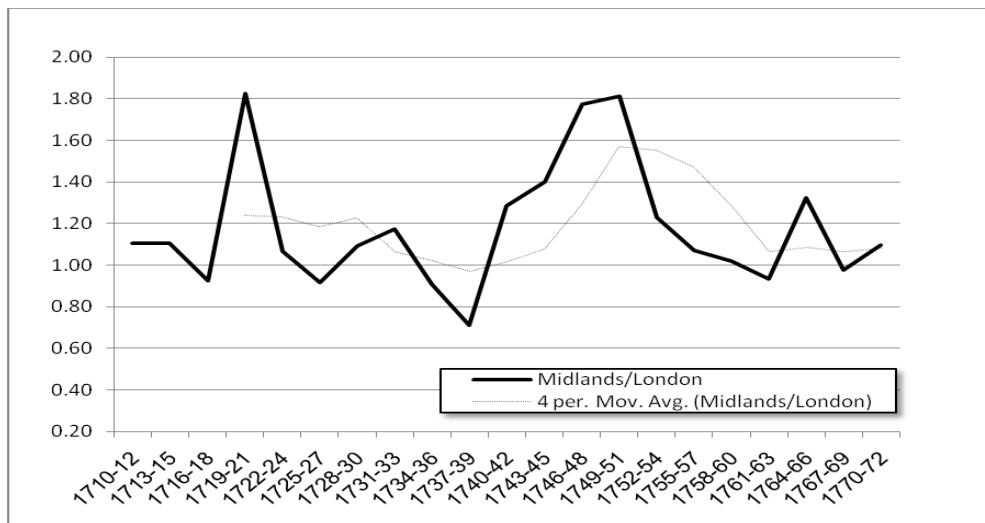


Figure 12: The relative tuition: mechanical vs. other and Midlands vs. London



6 Conclusions

Although this data requires further examination, it strongly indicates that the technological changes of the early eighteenth century had a significant effect on the demand for highly skilled workers in the machine-producing occupations. This effect

is reflected by the significant increase in the tuition paid to be apprenticed in these trades since the 1730s'.

Furthermore, the data shows that the number of skilled mechanical workers in England was increasing throughout the eighteenth century. This finding, which is interesting in itself, provides support to the argument in endogenous growth models, that technological change is always skill-complementary. This finding may also suggest that, as claimed recently by Joel Mokyr, the Industrial Revolution took place in England because England had a highly skilled workforce that could implement and construct new machines at a relatively low cost²².

Another significant finding is that London was not affected by technological innovations during the eighteenth century. This suggests that evidence concerning trends in the skill premium in eighteenth-century England, which is based on wages from the London area, may be misleading.

²² Mokyr (2009)

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Appendices

Table A1: Skilled, low-skilled and unskilled occupations by industry

Industry	Skill level (HISCLASS)	Matched occupation (HISCO)
Blacksmiths, Toolmakers and Machine Tool Operators	Lower skilled workers	Forging Press Operator Other Metal Grinders, Polishers and Tool Sharpeners Polisher Striker
	Skilled workers	Blacksmith Blade forger Buckle maker Chain maker Cutler Edgetool maker Farrier File cutler File cutter File maker Filesmith Forgeman Fork maker Gun barrel welder Gun lock filer Gun maker Gunsmith Hinge maker Horse nail maker Lock maker Locksmith Other Blacksmiths Other Blacksmiths, Toolmakers and Machine-Tool Operators Other Toolmakers, Metal Pattern Makers and Metal Markers Saw maker Scissorsmith Shovel maker Smith Toolmaker
Bricklayers, Carpenters and Other Construction Workers	Lower skilled workers	Builder Lath render Master builder Other Construction Workers Other Plasterers Other Roofers Paviour Plasterer Slate and Tile Roofer Slater Thatcher
	Skilled workers	Boat maker Boatbuilder Bricklayer Carpenter Glazier Joiner Joiner (wood) Master carpenter Other Carpenters, Joiners and Parquetry Workers Ship's Carpenter Stonemason Stonemason (Construction)
Cabinetmakers and Related Woodworkers	Lower skilled workers	Stock maker Turner Wood Turner Wood-Lathe Setter Operator Woodworker
	Skilled workers	Bellows maker Cabinetmaker Carver Case maker Chair maker Coach maker Cooper Pipe maker Tobacco pipe maker Wheel maker Wine cooper Wood Carver Wooden Pattern Maker

Table A1: Skilled, low-skilled and unskilled occupations by industry (cont.)

Industry	Skill level (HISCLASS)	Matched occupation (HISCO)
Chemical Processors and Related Workers	Lower skilled workers	Other Chemical Processors and Related Workers Other Crushers, Grinders and Mixers Saltmaker
Food and Beverage Processors	Lower skilled workers	Confectioner Other Brewers, Wine and Beverage Makers Slaughterer Sugar baker Sugar boiler
	Skilled workers	Baker Baker, General Bread Baker Brewer Butcher Grain Miller Malster
Glass Formers, Potters and Related Workers	Lower skilled workers	Brick and Tile Kilnman Brickmaker Glasscutter Glassmaker Potter or Related Clay and Abrasive Former Tile maker
	Skilled workers	Chinadecorator Gilder Glassblower Potter Printer
	Unskilled workers	Other Glass and Ceramics Painters and Decorators
Jewellery and Precious Metal Workers	Skilled workers	Gem Cutter and Polisher Goldbeater Goldsmith Goldsmith and Silversmith Jeweller Other Jewellery and Precious Metal Workers Precious Metal Leaf Roller Whitesmith
Labourers Not Elsewhere Classified	Unskilled workers	Labourer Silkman Workman
Machinery Fitters, Machine Assemblers and Precision-Instrument Makers	Skilled workers	Clockmaker Engineer Instrument maker Machine maker Machinery Fitter Optical Instrument Maker and Repairer Other Watch, Clock and Precision Instrument Makers Precision Instrument Maker Textile Machinery Fitter Assembler Watch case maker Watch finisher Watchmaker
Material Handling and Related Equipment Operators, Dockers and Freight Handlers	Skilled workers	Rigger
	Unskilled workers	Packer Porter
Metal Processors	Lower skilled workers	Brass founder Brazier Caster Ironworker Plater Wire drawer
	Unskilled workers	Other Metal Drawers and Extruders
Metal Processors Total		
Miners, Quarrymen, Well Drillers and Related Workers	Lower skilled workers	Coal miner Quarryman
	Unskilled workers	Other Miners and Quarrymen
Painters	Lower skilled workers	Painter and Glazier
	Skilled workers	Coach painter Japanner Watch gilder
Paper and Paperboard Products Makers	Lower skilled workers	Boxmaker Cardboard Lining-Machine Operator
	Unskilled workers	Other Paper and Paperboard Products Makers
Plumbers, Welders, Sheet Metal and Structural Metal Preparers and Erectors	Lower skilled workers	Welder, General
	Skilled workers	Coppersmith Plumber

Table A1: Skilled, low-skilled and unskilled occupations by industry (cont.)

Industry	Skill level (HISCLASS)	Matched occupation (HISCO)
		Tinker Tinsmith
Printers and Related Workers	Skilled workers	Bookbinder Cailico printer
Production and Related Workers Not Elsewhere Classified	Lower skilled workers	Basket Maker Basketmaker Brush maker Candle Maker Other Tanners and Fellmongers
	Skilled workers	Musical Instrument Maker or Tuner Other Musical Instrument Makers and Tuners Rubber Stamp Maker Taxidermist
Shoemakers and Leather Goods Makers	Lower skilled workers	Leather Cutter Leather Goods Maker Leather Goods Maker, General
	Skilled workers	Cordwainer Harness maker Other Leather Goods Makers Saddler Saddler and Harness Maker Shoemaker Shoemaker, General Whip maker
Spinners, Weavers, Knitters, Dyers and Related Workers	Lower skilled workers	Bleacher Bleacher, Dyer or Textile Product Finisher Carpet maker Carpet Weaver (Hand or Machine) Cloth Weaver (Machine, except Jacquard Loom) Clothier Cotton weaver Cotton worker Dyer Engine weaver Fabrics Repairer Fibre Carder Fibre Comber Fibre Picker Flax dresser Framework knitter Gold lace spinner Gold thread spinner Hackler flax Hosiery Knitter (Hand) Jacquard Weaver Knitter Lace Weaver (Hand or Machine) Lacemaker Linen weaver Other Bleachers, Dyers and Textile Product Finishers Other Spinners, Weavers, Knitters, Dyers and Related Workers Other Weavers and Related Workers Other Weaving- and Knitting-Machine Setters and Pattern-Card Preparers Pattern maker Ribbon weaver Rope Maker Silk dyer Silk throwster Silk weaver Spinner Spinner, Thread and Yarn Stocking maker Stocking weaver Tape weaver Textile Bleacher Textile Calender Operator Textile Fuller Textile Washer Twine spinner Twister Warper Weaver Wheel Turner Winder

Table A1: Skilled, low-skilled and unskilled occupations by industry (cont.)

Industry	Skill level (HISCLASS)	Matched occupation (HISCO)
		Woolcomber Woolen weaver Woolsorter Worsted weaver Yarn Dyer
	Unskilled workers	Other Fibre Preparers Other Spinners and Winders
Stone Cutters and Carvers	Lower skilled workers	Other Stone Cutters and Carvers Stonecutter
	Skilled workers	Mason Stone Carver (Hand)
Tailors, Dressmakers, Sewers, Upholsterers and Related Workers	Lower skilled workers	Bagmaker Fancy trimmer Fustian cutter Garment Hand Sewer (except Leather and Fur) Glover Hand and Machine Sewer, General Leather Garment Hand Sewer Mattress Maker Other Sewers and Embroiderers Other Tailors, Dressmakers, Sewers Pattern Maker or Cutter Trimming maker
	Skilled workers	Corset maker Dresser Embroiderer, Hand or Machine Embroideress Furrier Hat Maker Hat Maker, General Hatter Milliner Other Tailors and Dressmakers Sail maker Sail, Tent and Awning Maker Stay maker Tailor Tailoress Upholsterer
Tanners, Fellmongers and Pelt Dressers	Lower skilled workers	Fellmonger Flesher etc Leather Currier Leather dresser Leather Dyer and Stainer Other Pelt Dressers Other Tanners and Fellmongers Skinner Tanner
	Skilled workers	Taxidermist
	Unskilled workers	Hide Splitter
Transport Equipment Operators	Lower skilled workers	Carman Carrier Carter Coachman Higgler Horse driver
	Unskilled workers	Lighterman Other Ships' Deck Ratings, Barge Crews and Boatmen Sailor
Wood Preparation Workers and Paper Makers	Lower skilled workers	Other Paper Makers Paper stainer Papemaker Sawyer
	Unskilled workers	Other Wood Treaters

Table A2: Number of new apprentices by industry

Industry*	1710-20		1721-30		1731-40		1741-50		1751-60		1761-70	
	N	% of Total	N	% of Total	N	% of Total	N	% of Total	N	% of Total	N	% of Total
Blacksmiths, Toolmakers and Machine Tool Operators	473	7%	334	7%	193	7%	380	8%	492	6%	449	5%
Bricklayers, Carpenters and Other Construction Workers	911	14%	708	14%	468	17%	627	13%	1092	14%	1292	15%
Cabinetmakers and Related Woodworkers	391	6%	319	6%	249	9%	431	9%	486	6%	671	8%
Chemical Processors and Related Workers	68	1%	52	1%	34	1%	49	1%	24	0%	37	0%
Food and Beverage Processors	638	10%	521	10%	296	11%	638	13%	826	11%	918	11%
Jewellery and Precious Metal Workers	167	2%	73	1%	84	3%	85	2%	124	2%	170	2%
Machinery Fitters, Machine Assemblers and Precision-Instrument Makers	471	7%	320	6%	191	7%	396	8%	699	9%	805	9%
Plumbers, Welders, Sheet Metal and Structural Metal Preparers and Erectors	134	2%	80	2%	61	2%	79	2%	109	1%	169	2%
Shoemakers and Leather Goods Makers	876	13%	780	16%	417	15%	752	15%	1194	16%	1431	17%
Spinners, Weavers, Knitters, Dyers and Related Workers	1078	16%	619	12%	207	7%	444	9%	864	11%	809	9%
Tailors, Dressmakers, Sewers, Upholsterers and Related Workers	1065	16%	892	18%	426	15%	761	16%	1232	16%	1320	15%
Tanners, Fellmongers and Pelt Dressers	198	3%	116	2%	47	2%	84	2%	133	2%	140	2%
Grand Total	6708	100%	5030	100%	2762	100%	4860	100%	7609	100%	8593	100%

* Includes only industries with more than a total of 100 observations.