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# Education and Skills during the first Industrial Revolution in England

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## Abstract

We provide evidence that education contributed to England’s Industrial Revolution by increasing upper-tail human capital. Contrary to the prevailing view that schooling was irrelevant to early industrialization, we show that the expansion of schooling lowered barriers to entering apprenticeships in skill-intensive trades. We introduce new parish-level data on 3,000 school foundations, 46,000 charitable bequests, and 350,000 apprenticeship contracts between 1711 and 1805. Using a staggered difference-in-differences design exploiting educational endowments through wills, we show that the expansion of schooling increased apprenticeship training, particularly in occupations requiring reading, writing, and mathematical skills that were crucial for the Industrial Revolution.

Keywords: Education, Skill Formation, Human Capital, Innovation, Industrial Revolution.  
JEL: N13, I21, J24, O14, O33

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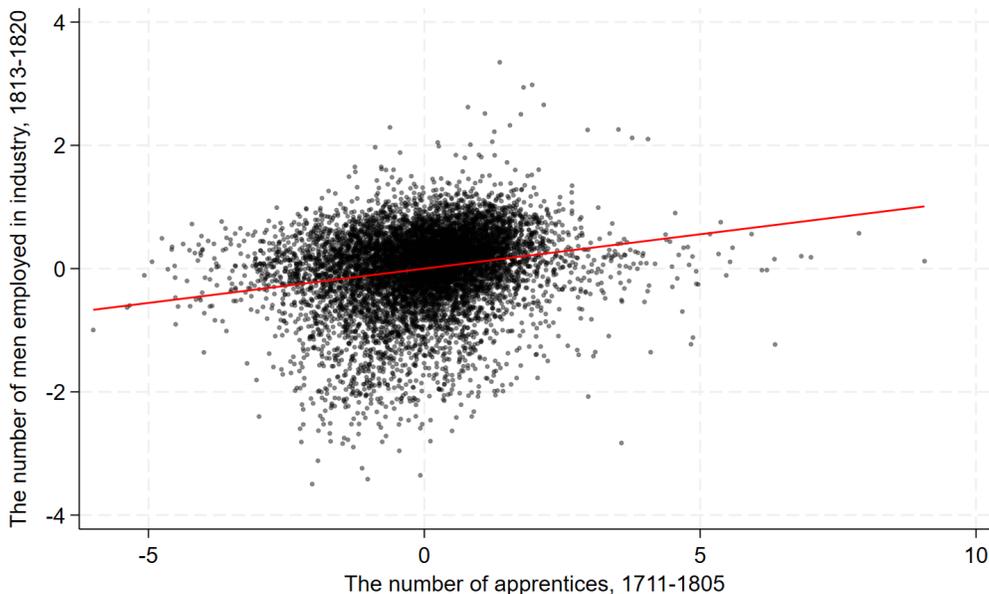
# 1 Introduction

Education is strongly associated with economic growth in the last century ([Hanushek and Woessmann, 2020](#)) and is a key factor for the transition to sustained growth in Unified Growth Theory ([Lucas, 1988](#); [Galor and Moav, 2004](#); [Galor, 2005, 2011, 2022](#)). Yet explanations of the origins of modern economic growth in Britain’s Industrial Revolution generally conclude that education was irrelevant. Unlike later periods of industrialization in the nineteenth and twentieth centuries, the evidence for Britain from 1750–1830 suggests education stagnated at best, while some groups experienced declining levels of literacy and school enrollment, providing ample support for pessimistic interpretations of the contribution of education to the First Industrial Revolution ([Mitch, 1999](#); [Allen, 2003](#); [Mokyr, 2009](#)).

The puzzle presented by the standard view that education did not play a role in the British Industrial Revolution deepens when we consider two points. First, the Industrial Revolution was preceded by two centuries in which both the number of schools and literacy rates sharply increased ([Boucekkine, de la Croix and Peeters, 2007](#); [Cressy, 1980](#)). The number of endowed primary schools increased by about 330% between 1675 and 1750 (from 314 to 1,352) ([Schools Inquiry Commission, 1868](#)). More than half of the English population lived in a parish with an endowed school by 1800. Second, other kinds of human capital — occupational skills, natural philosophy — that were not widely taught at school do feature prominently in current explanations of industrialization. Arguably, an abundant supply of highly skilled artisans was essential for the development, implementation, and diffusion of new technologies ([Mokyr, 2009](#); [Meisenzahl and Mokyr, 2011](#); [de la Croix, Doepke and Mokyr, 2018](#)). As [Figure 1](#) shows, there is a robust association at the local level between the number of apprentices in the eighteenth century, our proxy for ‘upper-tail’ human capital, and the number of men employed in industry in the early nineteenth century, an indicator for the degree of industrialization. This correlation suggests that the accumulation of upper-tail human capital may have been an important mechanism underlying England’s structural

transformation. However, the role of formal education in generating this supply of skills remains unresolved.

Figure 1: The association between the number of apprentices and number of men working in industry at the parish level, 1813–1820



*Notes:* The Figure reports the conditional relationship between the number of fee paying apprentices, 1711–1805, and the number of men employed in industry, 1813–1820, net of all the controls and fixed effects. The full results are reported in Column (2) of Table A.1 in Appendix A. *Sources:* For an overview of our sources see Appendix B.

In this paper we document a novel channel that connects education and the First Industrial Revolution. Specifically, we provide causal evidence that the supply of skilled artisans shifted in response to the expansion of elementary education during the seventeenth and eighteenth centuries. For these children, access to formal schooling lowered the cost of entering apprenticeships in occupations, such as engineering and machine building, where literacy and mathematics — skills they obtained at school — were valuable on the shop floor. Schooling affected both the supply of skilled apprentices and the jobs they pursued: the skills that they gained at school steered youths into a set of occupations that would be particularly valuable for industrialization. We provide a new explanation for the supply of upper-tail

artisans who helped to create the technologies of the First Industrial Revolution, and, to the best of our knowledge, we are the first to demonstrate the contribution of schooling to England’s industrialization.

We introduce new micro-data that allow us to trace the growth of education at the local (parish) level in England from ca. 1550 to 1820. Specifically, we introduce data on the foundation of 2,200 endowed elementary (non-classical) schools focused on practical instruction in reading, writing and arithmetic — the so-called ‘three R’s’ — as well as 800 endowed secondary (grammar) schools offering education beyond the primary level (mostly Latin and Greek). We then complement this with evidence on 46,000 charitable gifts in English parishes, many for educational purposes, which allows us to observe the donations that sustained or expanded schools after their foundation, along with smaller funds for teaching. We link these datasets to individual-level data on apprenticeship training between 1711 and 1805, covering more than 350,000 individuals. The occupation of the master enables us to identify the distribution of training for the upper-tail of skilled artisans.

As a first step, we document a strong relationship between the provision of schooling and the number of skilled artisans training at the parish level between 1786 and 1805. This association is robust to the inclusion of a large set of confounding variables, including controls for early urbanization, geography, and trade potential. Specifically, parishes with a non-classical school in 1786 had 14–20% more apprentices requiring reading, writing and mathematical skills.

To address the endogeneity of schooling we use a staggered difference-in-differences strategy to identify the effect of the foundation of a school or an educational fund on local skilled artisans between 1711 and 1786. We exploit the fact that ca. 60% of school foundations and educational funds were postmortem gifts made through wills. Therefore, we expect the foundation of schooling, and educational charity more broadly, to be unrelated to contemporaneous local shocks. To ensure that the identifying variation only originates from the time when a parish received a school foundation or an educational endowment, we restrict

our difference-in-differences analysis to a sample of ever-treated units. Isolating exogenous variation in school foundations allows us to assess whether the expansion of elementary education shifted the equilibrium skill composition of the workforce in a way consistent with endogenous growth models ([Galor and Moav, 2004](#); [Galor, 2005, 2011](#)).

We find that a school foundation led to a ca. 10% increase in the local number of skilled artisans in occupations requiring reading, writing, and mathematical skills. At the same time, there is no effect on the number of youths entering apprenticeships in other occupations. While these effects indicate that schooling shifted training toward occupations for which skills obtained in school were relevant, they do not by themselves imply that training was directed toward occupations relevant for industrialization. Literacy and numeracy were valuable in a wide range of trades, including commercial and service-oriented occupations that were only weakly connected to the Industrial Revolution. We therefore refine the analysis by focusing on apprentices training for occupations in the secondary sector, where we find a causal effect of schooling that is concentrated in this segment of the workforce.

Finally, if schooling led to an upskilling of the workforce, we also expect schooling to be positively associated with innovation in the long run ([Mokyr, 2009, 2016](#)). We find support for this in a reduced form relationship between non-classical schooling and inventive activity as measured by patents and patent citations from [Nuvolari and Tartari \(2011\)](#) for the 1750–1815 period. Non-classical school foundations are associated with an increase in patenting by 10% after ca. 40 years and by ca. 30% after 60 years.

Taken together, our findings show that the expansion of schooling changed the composition of upper-tail human capital, thereby facilitating technological change during the First Industrial Revolution. Our results therefore offer direct empirical support for growth theories that assign human capital accumulation a key role in the transition from stagnation to sustained growth. By identifying the mechanism linking schooling to structural change, we reconcile the apparent disconnect between Unified Growth Theory and the historical case of England.

The remainder of our paper is structured as follows. Section 2 discusses the main literature to which we contribute. Section 3 provides the historical background on schooling and apprenticeship in early modern England. Section 4 describes our newly constructed datasets on school foundations, charitable bequests, and apprenticeship contracts. Section 5 presents the empirical analysis, combining cross-sectional evidence with a difference-in-differences design. It also evaluates the size of the effects. We then present long-run effects on innovation in Section 5.5. Section 6 explores the robustness of our results. Section 7 concludes.

## 2 Literature Review

We engage with three related literatures. The first examines the empirical relationship between human capital and economic development (Mokyr, 2009; Mitch, 1993, 1999; Squicciarini and Voigtländer, 2015; Becker, Hornung and Woessmann, 2011; Cinnirella and Streb, 2017). Our main contribution to this strand of the literature is to provide new evidence that increases in education contributed to the overall stock of highly skilled artisans needed for the English Industrial Revolution. With this we provide empirical evidence for one key mechanism highlighted in Unified Growth Theory (Galor and Moav, 2004; Galor, 2005, 2011). Our argument builds on Squicciarini and Voigtländer (2015)'s observation that paying attention solely to the *average* level of education of the English workforce may be missing the point. However, where they focus on the knowledge elites, we explore the origins of the artisanal upper-tail. Our analysis is most closely related to Boucekkine, de la Croix and Peeters (2007) who explored the rise of schooling in England as a result of increasing population density, which lifted the profitability of establishing schools and thereby lowering the cost of accessing education. Where Boucekkine, de la Croix and Peeters (2007) concentrate on explaining levels of human capital, we provide evidence for a specific channel linking increased access to schooling to the formation of upper-tail human capital. We argue that industrialization involved a deepening of specialization that required technically adept, highly skilled workers

who could construct and maintain machinery, as well as unskilled workers to operate it. For these highly skilled workers, literacy and mathematical skills acquired at school were valuable elements of the mix of human capital they utilized. We show that increasing the supply of these skills by expanding schooling led to an increase in the supply of skilled workers and that they were concentrated in relevant occupations.

Our analysis differs from most research on the specific contribution of education to the British Industrial Revolution (Mokyr, 2009, 2016; Mitch, 1993, 1999). This has shown that industrialization brought increased demand for unskilled and semi-skilled workers, particularly in areas such as Manchester, Preston and Stockport that were most exposed to the new factories and machines (Sanderson, 1972; de Pleijt and Weisdorf, 2017), leading to stagnation or decline in literacy rates (Laqueur, 1974; Schofield, 1973; Nicholas and Nicholas, 1992; Mitch, 1999) and average years of schooling (de Pleijt, 2018; Humphries, 2010; de Pleijt, Nuvolari and Weisdorf, 2020).<sup>1</sup> These important studies focus on measures of education and working skills *during* the classic period of the Industrial Revolution, whereas we concentrate on the effects of expansion in the decades prior to it. In this, our work fits into a more open debate about the place of human capital as a determinant of English economic growth in the long-run. Some studies find education irrelevant (Allen, 2003), whereas others suggest that it was a primary driver of growth (Madsen and Murtin, 2017; Baten and van Zanden, 2008; De Pleijt and Van Zanden, 2016).

The second body of literature we engage with explores the sources of England’s endowment of skilled workers. In seeking to explain the supply of skilled artisans, our study closely relates to recent discussions of the determinants of the supply of apprentices. These have linked apprenticeship to the institutional endowment of England and Europe (de la Croix, Doepke and Mokyr, 2018; Prak and Wallis, 2019; Wallis, 2025), inventive activity (Zeev, Mokyr and van der Beek, 2017; Feldman and Van der Beek, 2016), and to persistent clusters of skill around geographical endowments that favored water-powered mills (Mokyr, Sarid

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<sup>1</sup>Franck and Galor (2021) find similar patterns for France.

and van der Beek, 2022). Our identification of a relationship between charitably-funded educational provision and apprenticeship instead links the supply of skill to exogenous local developments that shifted the budgetary constraints on families making it easier for them to place children in trades that would turn out to be economically significant during industrialization.

Finally, our study provides further evidence on the religious causes of economic changes. Researchers have identified several possible channels by which religion could influence human capital (Mokyr, 2016; Becker, Rubin and Woessmann, 2024). Becker and Woessmann (2009), for example, argue that investments in education followed the Protestant Reformation as reading of the Bible in vernacular increased the demand for literacy skills. A number of other studies have shown how religious practices or communities have generated increases in human capital (Akçomak, Webbink and ter Weel, 2016; Botticini and Eckstein, 2012) or, conversely, lowered it (West and Woessmann, 2010; Squicciarini, 2020). We provide suggestive evidence that religiously-inspired investments in education in eighteenth century Britain shaped access to skilled work in ways that facilitated industrialization.

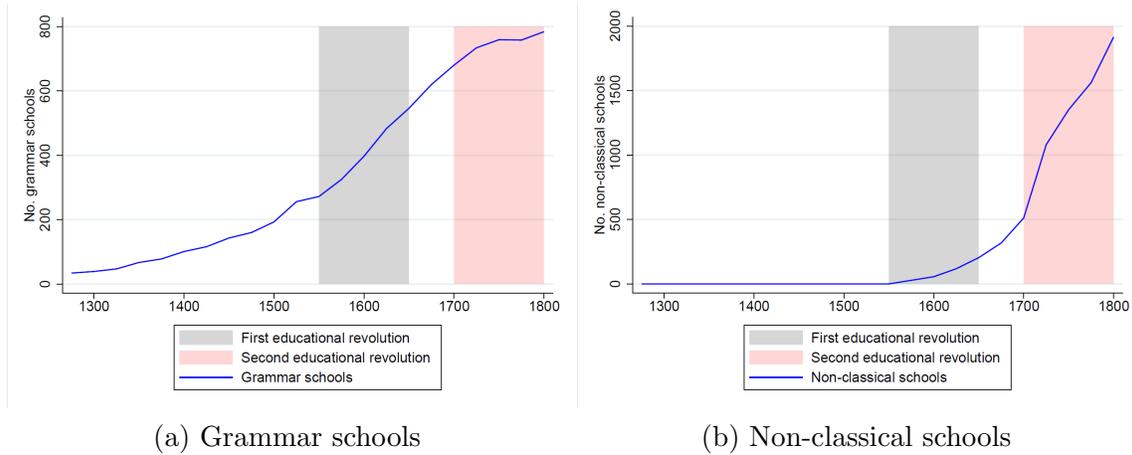
### **3 Historical context**

This Section discusses the development of schooling in England in the three centuries before the Industrial Revolution.

#### **3.1 Education in England after the Reformation**

The Reformation, and particularly the dissolution of the monasteries between 1536 and 1541, profoundly reshaped English schooling. The seizure of religious assets and the closure of monasteries and chantries removed many of the existing sources of schooling. While many grammar schools were refounded, some were not, and others lost funding (Slack, 1999, 18-19; Simon, 1994). Although it is the universities that saw the most dramatic

Figure 2: The Two ‘Educational Revolutions’, 1270–1800



(a) Grammar schools

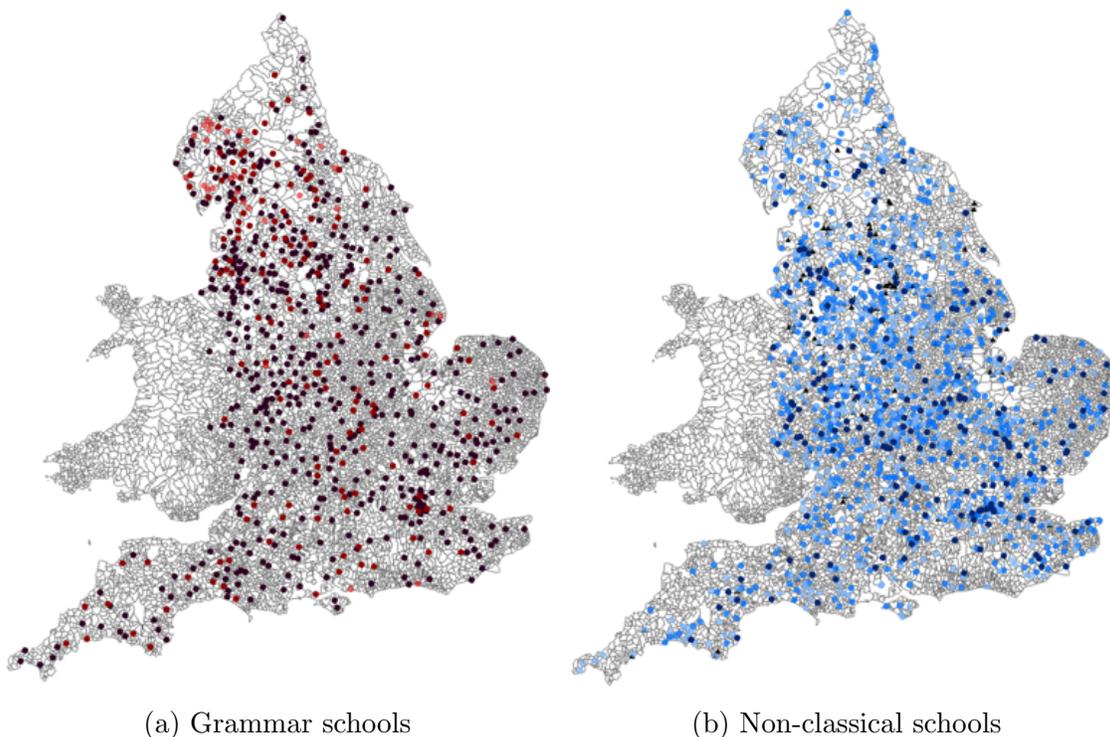
(b) Non-classical schools

*Notes:* Panel (a) shows the number of grammar schools; Panel (b) the number of non-classical schools.  
*Source:* SIC (1868).

‘educational revolution’ (Stone, 1964), the later sixteenth century saw a surge in grammar school foundations that replaced many of those which had been lost, as Figure 2 shows. This was fuelled by a substantial stream of charitable gifts from wealthy individuals, often nobility or merchants, with around 25% of all charitable giving directed towards education (Jordan, 1959). Grammar school attendance still required fees from most, but scholarships for poorer students were often available, usually for local boys. Reading, writing, and Latin grammar formed the core of the curriculum. Grammar schools were largely intended to strengthen the quality of the clergy. However, they also trained literate lay administrators and professionals (Slack, 1999, 26). Most English market towns had a permanent, endowed grammar school by the early seventeenth century (Jordan, 1959; O’Day, 1982, 30).

Elementary education did not attract the same generosity. The growth in grammar and university students implied a growth in elementary education, but this was not matched with public or private funding. Many elementary schools were relatively ephemeral private enterprises operated by single teachers (O’Day, 1982, 28-29). Established elementary schools were rare, and charitable funding was limited (Stone, 1964; Jewell, 1998, 27-28). Yet, even among artisans and small farmers, it was increasingly common in the sixteenth century

Figure 3: The spatial distribution of schools in 1650, 1725 and 1800



*Notes:* Panel (a) shows the spatial distribution of parishes with provision for grammar schooling in 1650 (dark-red dots), locations that got provision for grammar schooling between 1650 and 1725 (medium-red dots), and those who got a school between 1725 and 1800 (light-red dots). Panel (b) depicts parishes with provision for non-classical schooling for three points in time: Dark-blue dots are locations in 1650; Medium-blue dots are new locations up to 1725, and light-blue dots are new locations up to 1800. *Source:* SIC (1868).

to pay for at least a few years of schooling (Spufford, 1981). The Protestant emphasis on scripture reinforced the social and economic value of literacy, stimulating educational investment (Becker and Woessmann, 2009). The social extent of parental ambition was expressed in 1652 by James Howell: ‘every Man strains his Fortunes to keep his Children at School: the Cobler will clout it till Midnight, the Porter will carry Burdens till his Bones crack again’ (Jewell, 1998, 8).

Signs of a shift in the school curriculum towards teaching more obviously economically useful material do appear in the seventeenth century. New ‘non-classical’ schools were established that emphasized vernacular literacy and mathematics, and taught commercial, mercantile and navigational skills, such as double-entry bookkeeping, trigonometry and modern

languages, instead of Latin and Greek. Initially, these schools were largely set up in or around London for fee-paying students. Over the seventeenth and eighteenth centuries, it also became increasingly common for grammar schools to add non-classical subjects, such as mathematics and modern languages, to their curriculums (Tompson, 1971, 59-72).

### 3.2 The charity school revolution

In the later seventeenth century, elementary education began to attract the interest of elite and middle class philanthropists in Britain. From the 1680s, a wave of new elementary schools for the poor were founded by private philanthropy (Jones 1964; Hume 1982, 123; Rogers 1971, 52). The suddenness and scale of this movement is visible in the second panel of Figure 2 and better merits the title of ‘revolution’ than the earlier expansion analysed by Stone (1964). As well as benefiting from large legacies in wills, these schools were often supported by groups of middle-class subscribers — clergy, small traders, artisans — who contributed annually to their upkeep, sometimes nominating students. The subscribers usually restricted their benevolence to the local poor of the parish. In Birmingham’s Blue Coat School, for example, 88% of students came from the two local parishes (Foster, 2019, 53).

Surviving records — often fragmentary — indicate that the students ‘came, for the most part, from families of the respectable and deserving poor... small shopkeepers, craftsmen, or unskilled workers in more or less regular employment’, not the workhouse (Tomkins, 1997; Payne, 2006, 389; Foster, 2019). In London, the earliest elementary charity school was established in Whitechapel in 1680 by the will of the parish rector, Ralph Davenant. By 1704, there were 54 schools in the city and by 1711, there were 112 (Rose, 1991, 36). In Kent, the number of parishes with schools rose from 32 in 1660 to 172 parishes by 1807 (Hume, 1982). In some Kent parishes, perhaps half of poor children could be accommodated (Hume, 1982, 132). In Oxford, places existed for around 42% of boys and around 18% of girls (Tomkins, 1997, 57).

This ‘Charity School Movement’ had several roots (Armytage, 1964; Jones, 1964). The

major driver came from the Society for the Promotion of Christian Knowledge (SPCK), founded in the 1690s. It promoted the establishment of charity schools for the poor to counter the rise of the non-conformist Protestantism that was threatening the Anglican church's position after the religious settlement of 1688. Charity schools were intended to 'reassert the influence of the Church of England among the lower orders of society' (Rose, 1991, 44). As William Dawes argued in 1713, these schools would 'shut out Heresy and Schism' (Rose, 1991, 44). Political order was another important goal. To many, education offered a way to establish social discipline among the poor and prevent the risk of rebellion (Jones, 1964; Paglayan, 2024, 4). As the senior judge Sir John Eardley Wilmot suggested in the eighteenth century, 'obedience is one of the capital benefits arising from a public education' (O'Day, 1982, 207). Finally, arguments that providing education to the poorest would improve their economic prospects were a common theme in enlightened thought in this period (Mokyr, 2009, 36; Mokyr, 2016, 235-236; Webster, 1975, 209-11). As James Harrington argued when including universal schooling in his utopian text *Oceana*, 'he that can read and use his pen has some convenience by it in the meanest vocation' (Harrington, 1992). In many cases, these goals overlapped. John Allen, the founder of the Warrington Blue Coat School in 1677, sought 'to rescue such poor Children from Ignorance and Vitious courses of living and to make them fit for Apprenticeship ... [which] is certainly the best way to make them good servants to God and their Masters' (Gomez, 1987, 274).

The initial surge in philanthropy for elementary education in the eighteenth century led to a well-documented wave of school foundations.<sup>2</sup> The evidence we present on charitable donations over the rest of the century shows that elementary education remained a major interest among donors. Although little information on subscriptions survives, schools often attracted legacies repeatedly. By 1818, 165,433 children were studying in charitably endowed

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<sup>2</sup>The SPCK ceased to update its annual record of charity schools after 1723, turning its attention to overseas missions (Jones, 1964, 24). This has been interpreted by some historians as indicating a decline in the schooling movement, and some schools did struggle to maintain subscriptions after their initial period of enthusiasm (Langford, 1989, 130-132). However, the new evidence on charity we present overturns this view.

schools, almost all receiving their education for free: in England 50% of enrolled students attended schools with some form of charitable subsidy or endowment, while in Wales the figure was 44% ([Select Committee on Education of Poor, 1819](#); [Mitch, 1982](#), 1171, 1275).

Elementary charity schools often shared the interest in the economic benefits of schooling that had motivated earlier non-classical schools.<sup>3</sup> Practical skills such as needlework, spinning and knitting were taught alongside religious and academic content. Writing and arithmetic became more common over time ([Hume, 1982](#), 139). Some charity schools were more ambitious and covered advanced subjects such as navigation and geometry ([Payne, 2006](#)). The Green Coat School in Greenwich taught children to ‘read, write and cast merchants’ accounts’ and made them ‘capable of the art of navigation’ ([Hume, 1982](#), 138). Navigation also featured at the Blue Coat schools in Chester and Chistleton in Lancashire ([Robson, 1966](#), 38).

When they completed their studies, students might be given funding to secure an apprenticeship or helped to find a position. Boys from Birmingham’s Blue Coat School mainly became clerks to attorneys (13%) or apprentices to brass founders (10%) and gun makers (9%), both upper-tail artisanal trades ([Foster, 2019](#), 235). None went into the city’s large, but low-skilled trades of nailmaking or pinmaking. As this example highlights, human capital was also important to the expansion in commercial services that ran alongside the growth in highly-skilled manufacturing in this period.

The effect of the long-run expansion in education can be seen clearly in the growth in literacy in England from around one in ten literate males in 1550, to one in four by 1650, and one in two by 1750 ([Cressy, 1980](#)). Levels of literacy in Britain may not stand out against its peers at the time of the Industrial Revolution ([Reis, 2005](#)), but relative to two centuries earlier they show a marked improvement.

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<sup>3</sup>These charity schools were also counted among the non-classical schools by the Schools Inquiry in the nineteenth century.

### 3.3 Schooling and apprenticeship

Schooling and vocational training are commonly treated separately in studies of human capital. This ignores the complementarities between the two stages of learning. Securing the returns from investments in education involved more than simply attending a school. For most non-agricultural jobs it required a further investment in training to gain vocational skills, usually through a formal apprenticeship (Wallis, 2025).

Children usually progressed from school into apprenticeship. The standard elementary school curriculum was completed around the age of fourteen, which was the age when private apprenticeships usually started (Wallis, Webb and Minns, 2010). New apprentices were expected to possess the general skills taught at school — reading and writing, especially — if they were needed for the occupation they were entering. Contracts for apprenticeship almost never specify that the apprentice was to be taught to write (Wallis, 2025). The ability to read, write and calculate were valuable skills for artisans, allowing access to the increasing body of technical literature, the implementation and adjustment of designs, the maintenance of business records and so on. At a wider level, the interaction between artisans and enlightened innovators and engineers emphasized by Mokyr relied on their ability to articulate and communicate ideas. Masters demanded these skills for a reason.

The need for children seeking apprenticeships to possess general skills varied between occupations. In his 1747 guide for parents who were considering what career their children might pursue, Robert Campbell identified which jobs required mathematical ability, drawing skills, reading and writing or physical strength from those being apprenticed into them (Campbell, 1747; Justman and van der Beek, 2015). Some, such as the baker ‘requires more Strength than is ordinarily to be met with in younger Years’. Others were more demanding:

‘An Engineer requires a very mechanically turned Head, and should be versed in all the Laws and Principles of Mechanics, and what is called the Mechanic Powers, as he is employed in making all Engines of Force...The Theory of Mechanics

is soon learned, but a Man whose Hand can execute what his Head invents, is likely to prove a much better Engineer, than he who has only the Theory: Theory and Practice joined make the compleat Workman in this and all other Branches of Trade' ([Campbell, 1747](#), 249).

The result of this combination of school-based and vocational training was that skilled workers who had served apprenticeships as millwrights or machine makers possessed both their vocational skills and 'a good knowledge of arithmetic, geometry, and theoretical as well as practical mechanics' ([Musson, 1969](#), 211).<sup>4</sup>

The importance of apprenticeship as a channel for training was beginning to change in the late eighteenth century. Alternative forms of on-the-job training emerged within firms as companies grew larger. Task specialisation and new machines meant that a larger share of manufacturing roles required a narrower and, arguably, shallower set of skills. These changes were having a visible effect on the share of youths being apprenticed at county and city level by the 1790s ([Wallis, 2025](#), 35-43), but the changes were not yet large. Many high-skill occupations still relied on apprenticeship for training, and some, such as machine building, bucked the trend and saw growing numbers of apprentices.

Both schooling and apprenticeship involved costs for parents and their children. Unless their place was funded through charity, schools charged fees.<sup>5</sup> Access to apprenticeships also often required the payment of a fee, known as the premium, to the master who would employ and train the youth. In addition, both incurred opportunity costs, absorbing time that might have been spent in productive activities. For apprentices, whose terms of service extended into their early twenties, these opportunity costs could be large.

The existence of these direct and indirect costs allows us to make several predictions about the effect of an increase in the supply of free or subsidised schooling on apprenticeship. First,

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<sup>4</sup>Direct prosopographical evidence on the schooling of artisans, even those of some note, is rare. [Meisenzahl and Mokyr \(2011\)](#) could only obtain information on the schooling of 37 individuals in their sample of 533 tinkerers born before 1800.

<sup>5</sup>Many schools, particularly secondary schools, accepted a mixture of scholarship and fee-paying students.

we would expect the reduction in the cost of education to lead more families to be able to fund apprenticing a child, affecting training on the extensive margin. Second, because the utility of academic skills such as literacy and mathematics in specific occupations varies, we would also expect this to affect the distribution of apprentices across occupations. A larger share should enter occupations that need prior schooling as a complementary preparation. This would lead to a shift towards upper-tail skilled occupations. Indeed, if the impact is mainly through the skill mix, we may see a negative effect on apprenticeships without academic skill requirements.

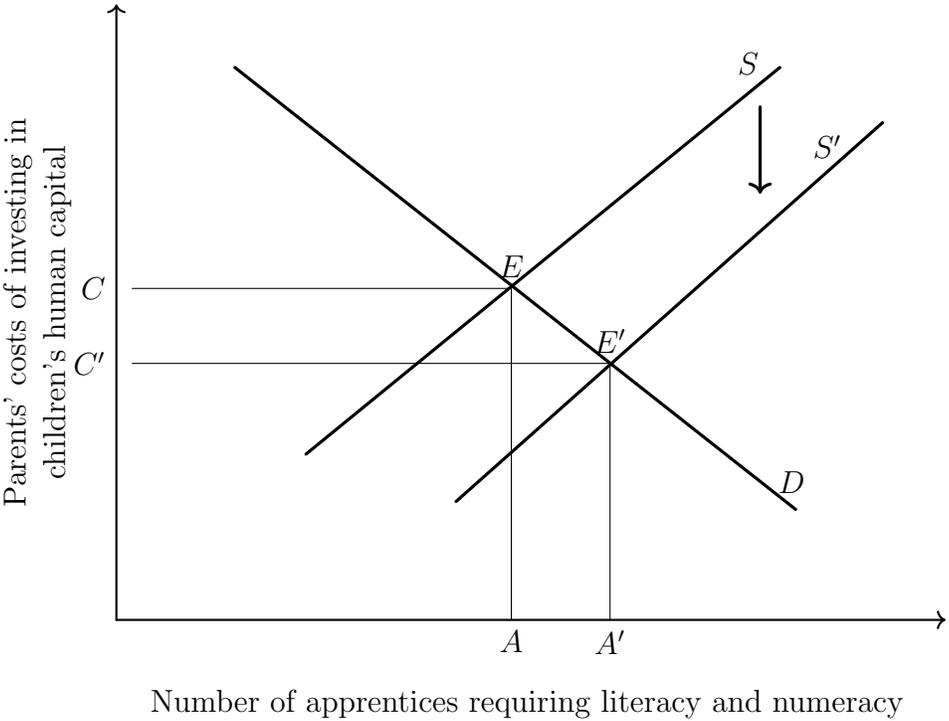


Figure 4

Notes: See text.

To illustrate these mechanisms, Figure 4 presents a simple conceptual framework linking the rise of schooling to apprenticeship training. The vertical axis represents the parents' cost of investing in children's human capital, while the horizontal axis shows the number of apprentices requiring reading, writing, and mathematical skills. Families' decision to invest

in apprenticeship depends on the total cost of schooling, apprenticeship fees, and foregone earnings. The upward-sloping supply curve ( $S$ ) captures the willingness of families to invest in training at different cost levels, while the downward-sloping demand curve ( $D$ ) reflects the limited capacity of masters to take on apprentices. The foundation of a school constitutes a positive supply shock, as it provided free instruction in reading, writing, and arithmetic for children born in the parish and, in many cases, also covered apprenticeship premiums. This substantially lowered the effective cost of education for families and shifted the supply curve from  $S$  to  $S'$ , as more households were able to afford investment in their children's training. As a result, the equilibrium moved from point  $E$  to  $E'$ , where the cost of education fell from  $C$  to  $C'$  and the number of apprentices requiring skills obtained in school rose from  $A$  to  $A'$ .

## 4 Data

In this Section, we introduce our datasets in detail, beginning with schooling and apprenticeship, before briefly describing the patent data we use to proxy innovation.

### 4.1 The Schools Inquiry Commission

Our datasets on non-classical and grammar schools are derived from the 22 volume *Schools Inquiry Commission* (SIC) Report ([Schools Inquiry Commission, 1868](#)). The Commission was formed in 1864 under the chairmanship of Lord Taunton to investigate the state of schooling across England and Wales. Its Report includes detailed information on the location, foundation, and endowment of ca. 2,200 endowed non-classical schools, and ca. 800 endowed classical (grammar) schools.

To classify non-classical and classical schools, the SIC used schools' founding charters. If this prescribed classical instruction (grammar or Latin) or preparing boys for university, the school was identified as classical. If, instead, the founding charter prescribed 'reading, writing and arithmetic' or preparing boys for apprenticeships, it was listed as a non-classical

school. Non-classical schools include the many ‘national’, ‘blue coat’, ‘yellow’, ‘hospital’, ‘dissenting’, and ‘friends’ schools. The datasets are presented in Figures 2 and 3 and already discussed in Section 3. In what follows, we use the information on the location of the schools. We can, however, approximate the relative importance of the schools using (i) income from endowments in the 1860s, and (ii) the founding dates of schools. Both are included in the SIC Report, and reported on in Appendix D.

## 4.2 The Gilbert Returns on Charities

To capture smaller, less durable schools and educational funds we introduce a second dataset based on a Parliamentary survey of charitable funds for the poor carried out in 1786 ([United Kingdom. House of Commons, 1816](#)). The Report, generally known as the *Gilbert Returns*, records over 46,000 charitable endowments from across England, including more than 4,500 gifts for education of the poor. It lists all known endowments by parish, giving the name of the donor, the year made, the intended purpose of the gift, and the sums given. Additional information on the dataset is given in Appendix E.

Figure 5 shows the spatial distribution of the number of charitable funds in each parish in 1786. It should be mentioned here that the rate of linkage between the reported parishes and the parish GIS is lower in parts of the north west of England where large parishes are often subdivided into townships and chapelries.

The *Gilbert Returns* allow us to observe smaller educational gifts as well as larger legacies. Small gifts were often enough to pay for a teacher in a parish for a period, but usually not sufficient to endow a permanent school. These gifts would have provided a short-run increase in educational provision in a parish.<sup>6</sup> Apart from education, the *Returns* include information on charitable funds for other purposes. It was common for money to be left to feed and clothe the poor or to pay for the church, for example. A number of charitable legacies were

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<sup>6</sup>The median educational gift of £55 would have approximately paid the salary of one teacher for 3 1/2 years [Williamson \(1982\)](#). See Appendix E.



Figure 5: The number of charitable funds in 1786

*Notes:* The figure shows the spatial extent of parishes matched to the Gilbert data as well as the number of Gilbert charitable funds per parish. As shown, there were 7,008 parishes were able to successfully link to a location. The minimum number of charitable funds is 1, the mean is 4.7, and the maximum is 240. *Source:* Gilbert 1816.

directly intended to help pay for apprenticeship premiums. For the purposes of our analysis as conducted below, we have classified all funds into nine categories based on the purpose prescribed by the donor: apprenticeship, education, hospitals, church, loans, poor, roads, fuel, and other.

Apart from gifts for education, we will focus on 34,500 charitable funds that provided direct monetary relief to the poor. This information allows us to estimate whether relaxing the budget constraints for poor households had an effect on the number of skilled artisans. In the absence of such an effect, we can conclude that the impact of free schooling

operates primarily through the education channel rather than through income effects (see Section 5.2.3).

### 4.3 Apprenticeship

Apprenticeship was the main mechanism through which vocational training was provided in the eighteenth century. Our data on apprenticeship is derived from the Stamp Tax registers, which list all apprentices nationwide whose masters had paid a tax of 2.5–5% on the premium (training fee) they received from their apprentice’s family or sponsors. The surviving registers run from 1710 to 1804 and contain the records of over 500,000 apprentices (Minns and Wallis, 2013). Additional information on the dataset and a map showing all training locations is given in Appendix F.

The Stamp Tax is the best available indicator on investments in occupational human capital in this period. However, it is still imperfect. Three limitations may affect our results. First, for some years the registers are entirely or partially lost. We therefore have to restrict our empirical analysis to periods with complete coverage, which means that we exclude the periods 1721–22, 1726–40, and 1746–52. Second, for much of the period the data only reports the location of the master, not the apprentice. Apprenticeship was increasingly localised in the eighteenth century, and urban data show that almost three-quarters of apprentices were from the same place as their master by the end of the century. Nonetheless, some apprentices would still have migrated to train, and so been affected by conditions in different parishes. Third, the Stamp Tax only applied when a taxable premium was paid. Around one half of apprenticeships did not involve a premium. More importantly, *no* tax was payable on premiums paid by the poor law or by charity. Apprenticeships without premiums and poor law apprenticeships were concentrated in lower-income occupations and are less of a concern here (Minns and Wallis, 2013). However, indentures supported by charity funds are a greater problem (Wallis, 2025). The impact is likely to be limited, however, as charitable funding was usually limited to £5–£10; too little to access to higher-priced and higher-skilled

apprenticeships.

## 4.4 Measuring skills

The Stamp Tax registers give information on ca. 2,080 different occupations, which allows us to study how apprenticeship training was distributed across skill requirements. Rather than classifying occupations directly as belonging to the upper-tail, we focus on the skills that apprentices were expected to possess upon entry. This reflects our interest in whether the expansion of schooling shifted training toward occupations for which reading, writing, and arithmetic were valuable.

Information on skill requirements is drawn from [Campbell \(1747\)](#), a detailed guide to occupations aimed at parents planning their children’s careers. Campbell discussed whether apprentices entering a trade were expected to possess skills in literacy (reading and writing abilities) and arithmetic. The internal consistency of Campbell’s classifications has been demonstrated by [Justman and van der Beek \(2015\)](#), and his work has been widely used to study skill requirements in early modern occupations.

Among apprenticeships recorded in the Stamp Tax registers, 395 occupations required literacy skills and 118 required mathematical skills. These categories overlap, as some occupations demanded both literacy and numeracy, while others required neither of these skills. A full list of occupations and their skill classifications is provided in [Appendix G](#).

## 4.5 Patents

In [Section 5.5](#) we explore the relationship between schooling and innovation. We use patent numbers and citations from the period of the First Industrial Revolution 1750–1850 from [Nuvolari and Tartari \(2011\)](#) as our proxy for innovation. This is an imperfect measure, as patent citations omit innovations that were not patented but kept secret or not found worth patenting ([Moser, 2005](#)). Yet, in the absence of other proxies for innovation, such

as exhibits, during this time period, patents remain a standard proxy for innovation during the Industrial Revolution (Khan and Sokoloff, 1993; Nuvolari, Tartari and Tranchero, 2021; Rosenberger, Hanlon and Hallmann, 2024). Patents closely track the timing of the English Industrial Revolution, as Figure 16 in Appendix H shows.

## 5 Empirical analysis

What is the relationship between the increases in schooling, apprenticeship training and innovation in industrializing England? We employ three empirical approaches. In Section 5.1 we start by examining the cross-sectional association between schooling and skilled artisans at the parish level. Second, in Section 5.2, we establish causality for which we employ a staggered difference-in-differences design based on school foundations and educational charities that were established through wills. In this Section we also provide placebo tests using shocks from purely monetary charity. In Section 5.3 we analyze the shift to trades requiring reading, writing, and arithmetic. Then, as a third step, we discuss the magnitude of the effects we find in Section 5.4. Finally, we explore the long-run effect of schooling on innovation in 5.5.

### 5.1 The relationship between schools, charities and apprenticeship training

We start with a cross-sectional analysis of the relationship between the number of charities, the presence of schools, and the number of apprentices in training. Since our data on charitable bequests ends in 1786, we restrict the analysis to training in the period 1786–1805. This date aligns reasonably well with most views on when the industrial revolution started, meaning that these are the young workers we are most interested in. Specifically, we estimate the following equation:

$$Apps_{i,1786-1805} = \alpha + \beta_1 School_{i,1786} + \beta_2 Charity_{i,1786} + X'_i \mu + \Omega_c + \varepsilon_i, \quad (1)$$

where  $Apps_{i,1786-1805}$  represents the number of apprentices training in parish  $i$  between 1786 and 1805,  $School_{i,1786}$  is an indicator variable that captures the presence of a non-classical school in parish  $i$  in 1786, and  $Charity_{i,1786}$  captures the number of charitable bequests for education (and other purposes) in parish  $i$  by 1786. In Table 5.1 we distinguish between (i) all apprentices, (ii) those requiring reading and writing skills, (iii) those needing arithmetic skills, and finally (iv), those requiring reading, writing and mathematical skills.

$\Omega_c$  represents county fixed effects, while  $\varepsilon_i$  is the error term for parish  $i$ . Our set of controls ( $X'_i$ ) is a vector of geographical and pre-industrial characteristics of parish  $i$ . Our geographical controls include the quality of agricultural land, proximity to a river, latitude, longitude, average rainfall, terrain ruggedness, parish size, and average temperature. We also account for whether the parish bordered Scotland or Wales, had access to the sea, or contained carboniferous rock strata (as a proxy for coal deposits). To capture pre-industrial characteristics, we control for access to a port or a Roman road, the presence of a cathedral, and distances to the nearest monastery in 1535 and the nearest town in 1680. A detailed description of our control variables can be found in Appendix B, and summary statistics can be found in Appendix J. Given the skewed distribution of many variables and the presence of zeros, we apply the inverse hyperbolic sine transformation ( $\text{arcsinh}$ ) to all variables that are not indicator variables. To adjust for differences in population size, we control for 1801 parish population levels (Wrigley, 2011).

We apply several more restrictions to ensure the robustness of our results. First, we restrict the sample to parishes included in the *Gilbert Returns* (see Section 4.2), focusing our analysis on locations with a reported charity. Second, 6.8% of non-classical schools have an unknown foundation date, and 20.5% of parishes have at least one charity with an unspecified purpose. We therefore include indicator variables to control for missing information. Finally,

we report standard errors clustered at the hundred level.<sup>7</sup> Appendices K and L show our results are robust to (i) using the [Chen and Roth \(2024\)](#) approach to model decreasing returns and avoid scale-dependence in the inverse hyperbolic sine transformation, and (ii) spatial unit roots ([Becker, Boll and Voth, 2025](#)).

Appendix I also presents results for grammar schools. Traditionally, grammar schools did focus on the teaching of classics. However, throughout the eighteenth century, a significant number of grammar schools changed their curriculum to also include practical subjects ([Tompson, 1971](#)). The exact timing and location of these changes is impossible to quantify within the scope of this project. However, results from Appendix I show that the overall number of grammar schools was also positively associated with growth in the number of apprentices.

Were there more youths becoming apprentices during the Industrial Revolution in parishes with access to schooling? Columns (1)–(3) of Table 5.1 present our estimates for the overall number of apprentices. In Columns (4)–(12), we focus on the association with apprentices requiring literacy and numeracy skills. For each category of apprentices, we first estimate the association between the presence of a non-classical school in a parish in 1786 and the apprenticeship outcome. Next, we explore the association with charitable funds: i.e. funds to pay for apprenticeship premiums, funds for education, and funds for the poor. We control for other types of charity funds – i.e. hospitals, church, loans, roads, fuel and ‘other’ – but do not report coefficients in our Tables. Finally, in Columns (3), (6), (9) and (12) we present the fully specified model incorporating both schools and charitable funds.

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<sup>7</sup>We omit London, which combines high levels of schooling and apprenticeship, to avoid bias from its unique economic position during the early modern period.

Table 5.1: The association between schooling and apprenticeship, 1786–1805

	Apprentices			Reading and writing			Mathematics			Reading, writing, mathematics		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Non-classical school, 1786	0.207*** (0.0451)		0.189*** (0.0456)	0.193*** (0.0413)		0.177*** (0.0418)	0.151*** (0.0386)		0.138*** (0.0387)	0.159*** (0.0368)		0.148*** (0.0370)
Non-classical school, date unknown	-0.0308 (0.109)		-0.0438 (0.110)	-0.0101 (0.104)		-0.0244 (0.103)	-0.129 (0.104)		-0.140 (0.103)	-0.111 (0.104)		-0.122 (0.103)
Apprenticeship charity		0.0476 (0.0432)	0.0462 (0.0431)		0.0345 (0.0408)	0.0331 (0.0408)		0.00885 (0.0386)	0.00783 (0.0385)	0.00364 (0.0379)		0.00253 (0.0378)
Educational charity		0.100*** (0.0296)	0.0854*** (0.0300)		0.0781*** (0.0279)	0.0642** (0.0282)		0.0770*** (0.0242)	0.0671*** (0.0241)	0.0657*** (0.0235)		0.0548** (0.0235)
Poor Relief charity		-0.00177 (0.0158)	-0.000544 (0.0157)		0.0120 (0.0140)	0.0132 (0.0139)		0.00182 (0.0129)	0.00257 (0.0127)	0.00548 (0.0124)		0.00632 (0.0123)
Other charities	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Unknown	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Pre-development	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geography	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6938	6938	6938	6938	6938	6938	6938	6938	6938	6938	6938	6938
R-squared	0.53	0.53	0.53	0.47	0.47	0.47	0.40	0.40	0.40	0.38	0.38	0.38

Notes: All reported variables are transformed by the inverse hyperbolic sine function, except for indicator variables. Standard errors are robust to control for heteroscedasticity. \* Significant at 10%; \*\* significant at 5%; \*\*\* significant at 1% level.

The results in Table 5.1 indicate that parishes with a school saw substantially more apprentices in all four categories. The endogeneity inherent to accumulations of schooling makes it tricky to interpret the coefficients, but the diverse set of controls included allows us to make a tentative estimation. The presence of a non-classical school was associated with an increase of roughly 19% in the number of apprentices relative to parishes without a school.<sup>8</sup> Interestingly, we obtain similar results for all four categories of apprentices: there is no obvious difference between the effect of schooling on all apprentices and on those entering occupations for which reading, writing, and arithmetic skills were required.

Interestingly, Table I.1 in Appendix I shows that the increase in apprentices associated with parishes having a grammar school was around 55%. The larger coefficients for grammar schools may reflect differences in scale. Grammar schools were, on average, substantially larger than non-classical schools. By the 1860s, when data first becomes available, the average annual income from the endowment of a grammar school was £259 (based on 633 observations), 3.8 times greater than the average £68 income for a non-classical schools (based on 1,227 observations). This ratio is not far from the difference we observe in their respective correlation with apprenticeship.

Among the various types of charities considered, only charities for education are significantly associated with apprenticeship training at the 1% level. However, the coefficient of educational charities is around half the size of that for schools (around 5% compared to 10% for non-classical schools). The reduction in the size of the coefficient when we consider charities alongside schools suggests that part of the effect of education-related charities may be channeled through (or absorbed by) the presence of a formal school.

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<sup>8</sup>The inverse hyperbolic sine ( $\operatorname{arcsinh}$ ) function approximates a log transformation for sufficiently large values.

## 5.2 Causality and mechanisms: Panel results

The previous Section established a positive relationship between schooling and skilled artisans at the local level. However, school foundations might simply reflect the demand for education, which could itself be driven by early industrialization. In this Section, we therefore exploit variation in schooling in a staggered difference-in-difference design to address endogeneity. In doing so, we focus on (i) school foundations and educational charity from wills, and (ii) restrict our analysis to a sample of ever-treated units. To distinguish the effect of education from monetary support, we also run a placebo test with purely monetary charities for the poor.

### 5.2.1 Empirical framework

As a first step, we distinguish school foundations and educational charity from wills from deeds and legacies. This exploits the nature of early modern charitable endowments. The system was entirely private and relied on money left by rich benefactors, e.g. by deeds, subscription, or wills. The motivation behind these donations was religious as well as altruistic and directed at the public good (see discussion in Section 3). When schools were founded through wills (unlike deeds or subscriptions) the timing of the endowment was determined by the moment of death of a donor. Historical statistics on the death of famous people provide a close approximation to that of rich benefactors and [De la Croix and Licandro \(2015\)](#) show that deaths were widely distributed across different ages, as we would expect in a period in which many deaths were the result of infectious diseases.<sup>9</sup>

We argue that the choice to endow schools through wills was still endogenous to other local factors, for example demand for education. However, the timing itself was determined exogenously by the death of the donor. Therefore, our identification strategy is based on the following observation: *Where* to endow a school was plausibly influenced by local factors,

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<sup>9</sup>Out of the sub-sample of famous people in the eighteenth century, 90% died between ca. 35 and 85 years of age, 80% died between ca. 45 and 80 years, and 50% died between ca. 52 and 75 years.

but *when* to endow it was exogenous, at least within a certain time window. We implement this logic in (i) a staggered difference-in-differences design and (ii) a stacked difference-in-differences design. For both approaches, we restrict our analysis to ever-treated units, thereby only exploiting variation from the timing of adoption. The staggered difference-in-differences design allows us to estimate the long-run effect of schooling, while the stacked difference-in-differences design is built around narrow intervals around a donor’s death event. In what follows, we use the staggered difference-in-differences design as our main specification and report the more demanding stacked difference-in-differences regression in Section 6.1.

To ensure that we only capture variation from wills, we additionally restrict our sample to units that received endowments through wills but that never received endowments through other forms of legacies (direct endowments, gifts, etc.). Therefore, the identifying variation only derives from the timing of a will, driven by the donor’s death. Here, we argue that the uncertainty in the timing of death would have made it difficult to employ school charities through wills to respond to demand shocks. Instead, we argue that within-parish timing of educational charity depended on the available stock of altruistically minded potential rich donors.

We estimate the following model:

$$\text{Apprent}_{it} = \sum_{\tau \in [-10, 20]} (\beta_{\tau} \cdot \text{Legacy}(E_{ie})_{it} \cdot \mathbb{1}(t - E_{ie} = \tau)) + \gamma_i + \alpha_t + \varepsilon_{it} \quad (2)$$

where the outcome  $\text{Apprent}_{it}$  denotes the number of apprentices entering occupations identified as requiring reading and writing, or mathematical skills, or the intersection of these two in parish  $i$  and two-year period  $t$ . To capture potentially decreasing returns to education, our outcome variable is transformed using the inverse hyperbolic sine function (Bellemare and Wichman, 2020). The treatment variable is defined as the staggered treatment of a legacy creating a non-classical school or educational charity in parish  $i$  at event time  $E_{ie}$ . Through this, we capture the effects of the foundation of a school or the supply of teaching.

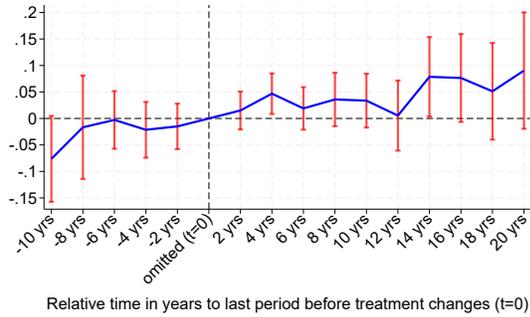
The treatment is measured ordinally. Given that the Gilbert data on educational charities ends in 1786, we estimate our sample for two-year periods within 1710–1784 (refer to data Section 4). The model includes parish and two-year-period fixed effects,  $\gamma_i$  and  $\alpha_t$ . We estimate the model using the estimator proposed by [de Chaisemartin and d’Haultfoeuille \(2024\)](#) and [de Chaisemartin et al. \(2024\)](#). Section 6.2 presents additional robustness checks for alternative transformations of the outcome variable and for compositional bias.

### 5.2.2 Results: The effect of educational legacies

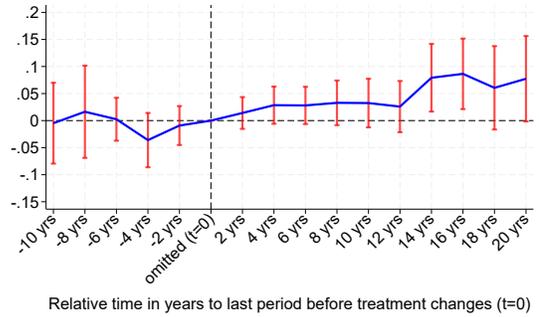
Our results in Section 5.1 suggest that schooling had a positive effect on the formation of highly skilled artisans. We therefore begin by testing whether school foundations and educational charity led to higher apprenticeship numbers in highly-skilled occupations. Figure 6 presents the effect of a new educational legacy on apprentices requiring (i) reading and writing, (ii) arithmetic, and (iii) skills in both reading, writing, and arithmetic from Equation 2.

The results in Figure 6 support our hypothesis. We find that the foundation of a non-classical school or an educational charity by a legacy had a long-run effect on the formation of skilled artisans. After 15 to 20 years, an additional non-classical school or educational charity led to a ca. 10% local increase in apprenticeships in occupations needing reading, writing, and mathematics. We find that the effects built up gradually over time, as we would expect given the time needed to start and properly run a school. Yet, for apprenticeships requiring reading and writing, a significant increase of ca. 5% is already visible within 4 years post treatment.

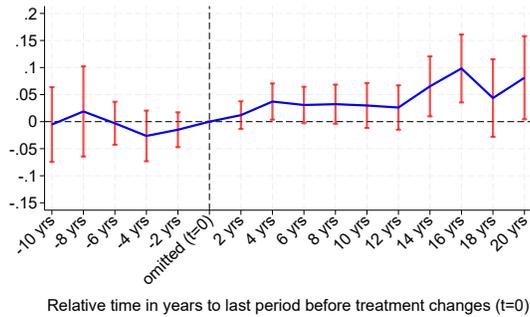
Did this also translate into compositional changes within apprenticeships leading to an overall upskilling of the workforce? Figure 7 presents the effect of school foundations and educational charities on occupations that did not require reading, writing and/or arithmetic. We do not find significant effects for either of the specifications. We take this as evidence that overall, the effects of schooling were neutral for low-literacy/numeracy occupations and



(a) Needing reading and writing



(b) Needing arithmetic skills



(c) Needing reading, writing and arithmetic skills

Figure 6: The effect of educational legacies on highly skilled artisans

*Notes:* Difference-in-differences results for the foundation events of non-classical schools and educational charities within a [10,20] pre- and post-treatment year window. Estimated using the estimator from [de Chaisemartin et al. \(2024\)](#). The unit of analysis is the parish  $\times$  two-year period level. Treatment is provided by the ordinal number of school foundations. Standard errors are clustered at the parish-level.  $N = 18,003$ . 90% confidence intervals provided.

positive for high-literacy/numeracy occupations. Hence, we conclude that schooling led to an upskilling of the workforce.

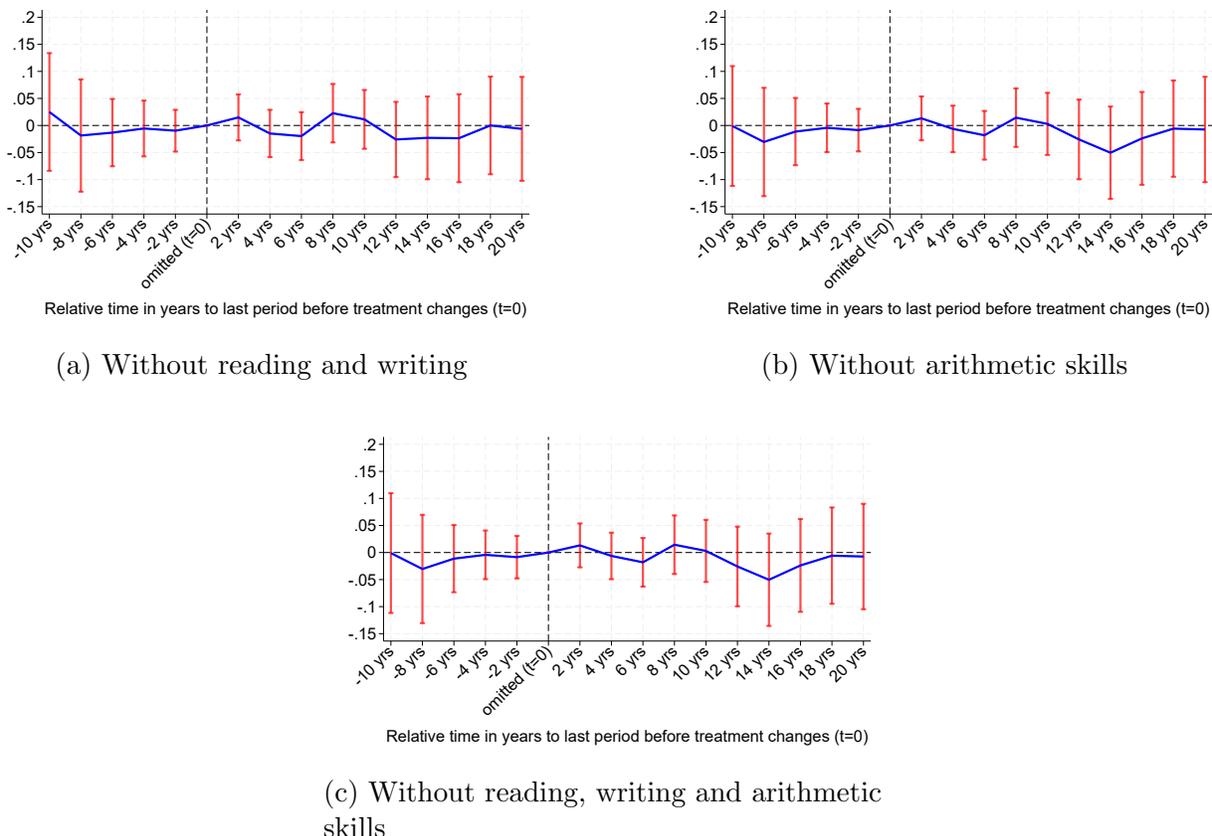


Figure 7: The effect of educational legacies on other occupations

*Notes:* Difference-in-differences results for the foundation events of non-classical schools and educational charities within a [10,20] pre- and post-treatment year window. Estimated using the estimator from [de Chaisemartin et al. \(2024\)](#). The unit of analysis is the parish  $\times$  two-year period level. Treatment is provided by the ordinal number of school foundations and educational legacies from wills. Standard errors are clustered at the parish-level.  $N = 18,003$  90% confidence intervals provided.

Altogether, our baseline results provide causal support for the previous cross-sectional findings of an association between the supply of schooling and the formation of skilled artisans. The increase in non-classical schooling that occurred in England in the eighteenth century directed artisans towards occupations requiring reading, writing, and arithmetic — abilities that would have been crucial for the Industrial Revolution (see Section 5.3).

### 5.2.3 Income effects and education

The previous Section provided evidence of a causal effect of schooling on the numbers of youths entering apprenticeships in occupations requiring literacy or numeracy. As discussed before, a characteristic of most schools was that they offered a number of free places for boys born and/or residing in the parish. So far, our interpretation was that the educational content of schooling mattered. But free schooling also provided a subsidy to those families who benefited from it. Could it also have been this income effect that increased entry into skilled apprenticeships?

To test this alternative channel, we explore whether other forms of charitable legacies increased entry to apprenticeship. The charity data includes information on 34,500 charities for the poor, which primarily consisted of direct monetary transfers or food doles that would have eased poor families' budget constraints. If it was family income that explained the effect of charity and schooling on apprenticeship then this other form of charitable help should also have enabled families to send more children to school and to bear the opportunity and direct costs of apprenticeship.

Figure 8 presents the estimated effect of direct financial transfers for the poor on entry into apprenticeships. Treatment is defined by the ordinal number of charities for the poor. As before our sample is defined as all places that ever received charities through wills but not through other more endogenous forms of charities (e.g. gifts or direct transfers). We do not find evidence for an income effect on training, with coefficients estimated relatively precisely around zero.

We conclude that monetary transfers did not lead to an increase in youths entering apprenticeships requiring literacy or numeracy by relaxing families' budget constraints. Therefore, the absence of a monetary channel from charity to apprenticeship entries suggests that educational charities mainly influenced skill formation through the content of the schooling they provided.

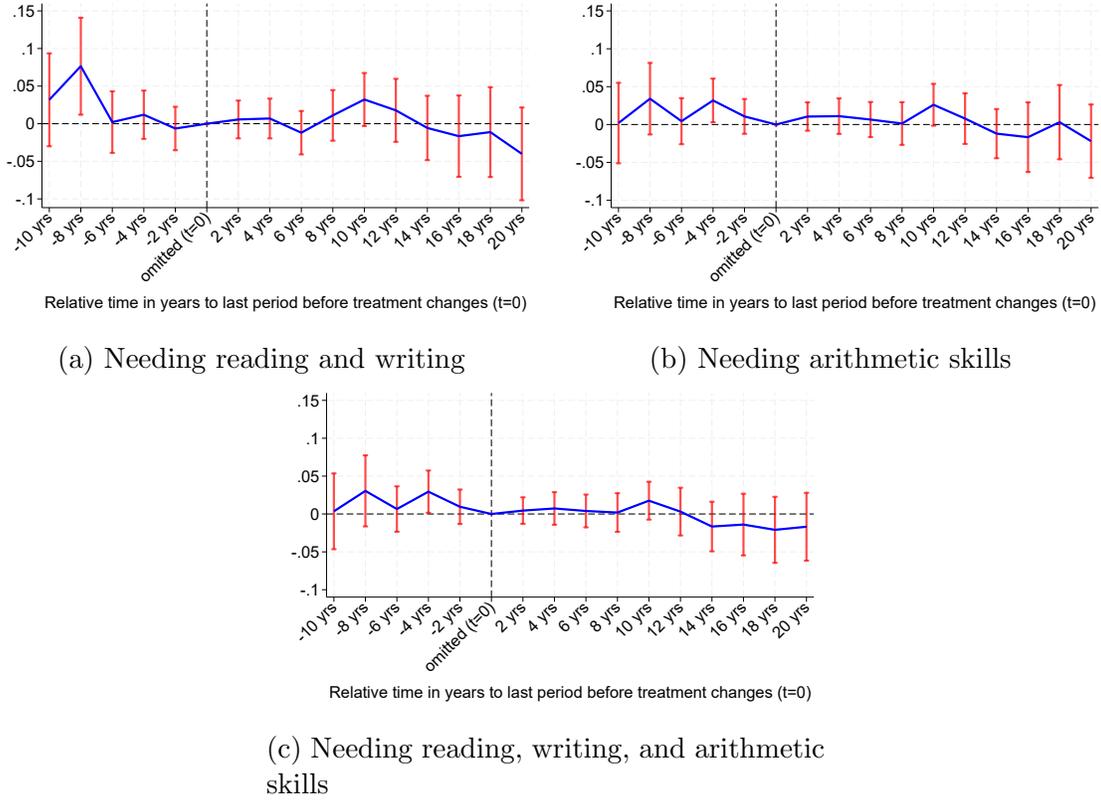


Figure 8: Placebo: The effect of charities for the poor on different groups of apprentices  
*Notes:* Difference-in-differences results for charities for the poor within a [10,10] pre- and post-treatment year window. Estimated using the estimator from [de Chaisemartin et al. \(2024\)](#). The unit of analysis is the parish  $\times$  two-year period level. Treatment is provided by the ordinal number of charities for the poor. The outcomes are transformed using the inverse hyperbolic sine transformation ( $\text{arcsinh}$ ).  $N = 34,992$ . Standard errors are clustered at the parish-level. 90% confidence intervals provided.

### 5.3 The shift to trades requiring reading, writing, and arithmetic

So far, our analysis has provided evidence that the growth in the supply of schooling in England, particularly the foundation of grammar and non-classical schools, shifted training to occupations requiring reading, writing, and arithmetic. What types of occupations demanded these abilities?

As discussed in Section 2, a key insight from the literature on human capital formation is that technological change did not depend on the average level of human capital in the workforce, but on the ‘density in the upper-tail of professional knowledge’. Specifically, industrialization was supported by a growing class of highly skilled mechanical workers who

were capable of implementing, adapting, and improving new technologies (Mokyr, 2002, 2009, 2016; Hanlon, 2025). Mokyr and co-authors emphasize that the supply of high-quality workmen, such as wrights, carpenters, joiners, turners, engineers, mechanics, and instrument makers, was central to technological change (Mokyr, 2002; Mokyr and Voth, 2010). These highly trained workers — referred to as ‘tweakers’ by Meisenzahl and Mokyr (2011) — were essential for the implementation and use of new technologies, thereby helping to bring about the Industrial Revolution (Feldman and Van der Beek, 2016; Zeev, Mokyr and van der Beek, 2017).

Our empirical analysis distinguishes apprenticeships requiring literacy and numeracy, skills that were taught at non-classical and grammar schools. However, the presence of literacy and numeracy alone does not imply that training was directed toward occupations that contributed to industrialization. If schooling mainly shifted training toward occupations where literacy was useful for basic accounting or record keeping, the implied link to industrialization would be weaker than if it shifted training toward the mathematically-demanding crafts that developed industrial machinery.

To assess whether the shift in training we observe aligns with the upper-tail mechanism emphasized by Mokyr, we therefore examine which occupations appear within our skill categories. Table 5.2 lists the most frequent occupations among trades requiring reading, writing, and arithmetic. The table reveals a clear pattern. Among trades requiring mathematics in particular, the most frequent occupations include carpenters, smiths, wrights, shipwrights, masons, and clock- and watchmakers. These occupations closely align with the set of highly skilled mechanical trades highlighted in the upper-tail human capital literature (Meisenzahl and Mokyr, 2011).

The table therefore suggests that the expansion of schooling was associated with increased training in occupations belonging to the artisanal upper-tail. At the same time, it also makes clear that, especially among occupations requiring literacy only, a substantial share of apprentices trained for service- and commerce-oriented trades that are not directly associated

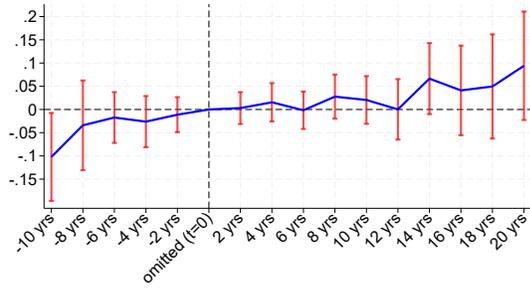
with industrialization.

Table 5.2: Skills required for the most common trades

Category	Most frequent occupations
Reading and writing	Cordwainer (38,816), Carpenter (27,131), Smith (13,520), Attorney (13,054), Grocer (10,177), Cooper (9,913), Surgeon (8,811), Shoemaker (7,381), Barber (7,220), Draper (5,524)
Mathematics	Carpenter (27,287), Smith (11,881), Joiner (11,356), Grocer (10,177), Shipwright (6,790), Clock and Watch maker (5,009), Merchant (4,797), Mercer (4,180), Wright (3,493), Mason (3,318)
Both reading, writing, and mathematics	Carpenter (27,131), Smith (11,881), Grocer (10,177), Clock and Watch maker (5,009), Merchant (4,797), Mercer (4,180), Wright (3,493), Apothecary (616), Draper (616), Gun maker (234)

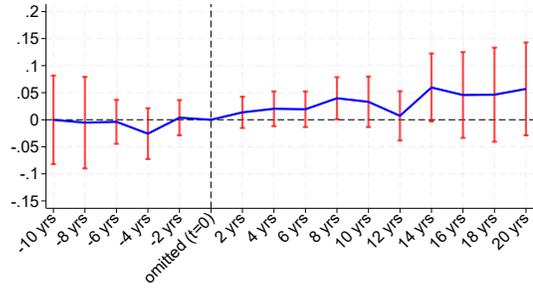
*Notes:* The table lists the most frequent occupations within each skill category. Frequencies are drawn from the Stamp Tax records and aggregate occupational and spelling variants where applicable. ‘Wright’ combines wright, millwright, and square wright; ‘Smith’ combines smith, blacksmith, whitesmith, copper smith, and goldsmith; ‘Clock and Watch maker’ combines clock maker, watch maker, and clock and watch maker; ‘Carpenter’ combines carpenter, house carpenter, and ship carpenter. Categories are determined by cross-referencing trades with those requiring literacy and mathematical skills.

To further document the link between schooling and the formation of upper-tail skills relevant for the technical changes of the Industrial Revolution, we therefore extend the analysis by restricting the sample to apprentices training for occupations in the secondary sector. In doing so, occupations such as cordwainers, grocers, merchants, attorneys, coopers, surgeons, barbers, and drapers are excluded. The results are reported in Figure 9 and closely resemble those in Section 5.2, although at a smaller, but still relevant, magnitude. Appendix section N presents results for the retail and service sectors. For the retail sector, we find an upskilling effect in reading, writing, and arithmetic, similar to the previous results from Figure 7. For the service sector, we do not find evidence of a significant upskilling.



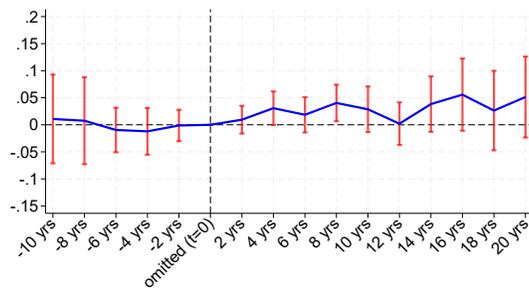
Relative time in years to last period before treatment changes (t=0)

(a) Needing reading and writing



Relative time in years to last period before treatment changes (t=0)

(b) Needing arithmetic skills



Relative time in years to last period before treatment changes (t=0)

(c) Needing reading, writing, and arithmetic skills

Figure 9: Results for the secondary sector

*Notes:* Difference-in-differences results for the foundation events of non-classical schools and educational charities within a [10,20] pre- and post-treatment year window. The outcome captures apprentices working in the secondary sector. Estimated using the estimator from [de Chaisemartin et al. \(2024\)](#). The unit of analysis is the parish  $\times$  two-year period level. Treatment is provided by the ordinal number of school foundations and educational legacies from wills. Standard errors are clustered at the parish-level.  $N = 18,003$  90% confidence intervals provided.

## 5.4 Magnitude

The revolution in elementary schooling that we document in Section 3 fundamentally transformed the availability of practical schooling in England. Outside London, only 14% of apprentices in the 1710s trained in parishes that had had a non-classical school or educational charity in 1680, when the educational revolution began. This quadrupled to 52% of apprentices trained after 1786. If we consider grammar schools as well, we see a rise from 37% to 63% in the share of apprentices in parishes with either a grammar school, non-classical school or educational charity.

To consider whether this large expansion of schooling accounts for a meaningful share of the changes in the supply of skilled artisans in the decades leading up to the Industrial Revolution, we study the extent of compositional changes in the apprenticeship data.

Apprenticeship was used for a wide array of occupations, and not all had much need for book learning, or much potential for improvements in productivity. Figure 10 separates the shares of apprentices entering different groups of occupations by the capabilities required. It shows a marked increase of around 20% to 30% in apprentices entering trades that required literacy, arithmetical skills, or both, over the eighteenth century. These are significant changes, given that the first phase of the Industrial Revolution was a gradual process limited to only a few industries (Crafts and Harley, 1992). These numbers show that English apprentices were increasingly shifting into occupations requiring the literacy and numeracy that could be most easily obtained in school. As shown before, these included the most common occupations from which the core group of ‘tweakers’ were drawn (Meisenzahl and Mokyr, 2011). Hence, the shift into more literate and numerate occupations deepened the supply of the types of skilled artisans Mokyr and others have identified as particularly relevant for industrialization.

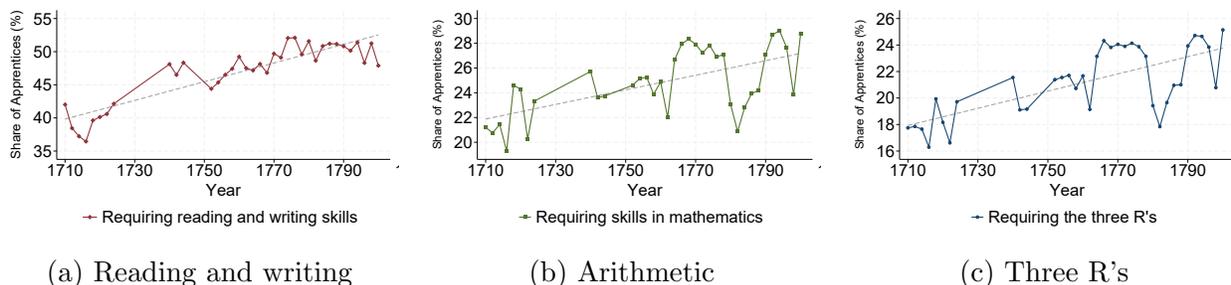


Figure 10: Trends in the skill-composition of apprentices

*Notes:* The figure reports the share of apprentices entering occupations that required (a) reading and writing skills, (b) arithmetic skills, and (c) all of these together. *Source:* See Section 4.3 and Appendix F.

How much of the shift in training was due to this increase in schooling? Our difference-in-differences estimates show that a school foundation or endowments increases the number of apprentices in occupations that require literacy or numeracy by approximately 10% in the treated parish. In the matched sample for 1786–1805, 62% of all apprenticeships took place in parishes with at least one endowed non-classical school or educational charity. Ignoring, general equilibrium effects, this implies an increase in the national stock of literate/numerate artisans of roughly 6% ( $0.62 \cdot 0.10$ ). In comparison, the share of literate/numerate apprentices nationally increased by ca. 20 to 30% (Figure 10). Given that the total number of apprenticeships was broadly constant throughout the eighteenth century, it follows that schooling can roughly explain 25% of the observed compositional shift towards apprenticeships in occupations that required these capabilities.

We can therefore conclude that the shift to apprenticeships in occupations requiring literacy/numeracy was not only driven by demand from industrialization but also by supply shocks from schooling.

It should be stressed that these numbers are likely to be lower-bound estimates of the impact of schooling on the compositional shift towards apprenticeships in occupations needing literacy or numeracy. There are two main reasons for this. First, we only estimate the effect of schooling for the parish where a school was located. However, as explained in

Section 4.3, some children from neighboring parishes could also have attended.<sup>10</sup> Moreover, after finishing school, pupils could have migrated to different places to enter an apprenticeship. Hence, besides their direct effect on the local parish, schools would also have raised the level of skills available in the wider apprenticeship market. We are unable to estimate these spillover effects within the current setting, making it likely that we underestimate the impact of schooling.

Second, we may be missing some of the most important periods of school foundations in our analysis. As discussed in Appendix F, the Stamp Tax registers contain gaps, which disproportionately affect the period before 1750 – precisely the decades in which many non-classical schools were founded and endowed by wills. If we assume decreasing returns to schooling, then it is plausible that earlier schools, often the first school in a parish or region, would have had larger effects.

It is also important to make clear that we only observe one part of the expansion of schooling in this period. The scope of our difference-in-differences analysis covers endowed non-classical schools, not grammar schools or purely fee-paying schools. While traditionally grammar schools focused on teaching Latin, they increasingly expanded their curriculum to include mathematical and vernacular languages during the eighteenth century (see Section 3). By the 1860s, 42% of grammar schools had moved to such an expanded curriculum, potentially making a further contribution to the skilled workforce.<sup>11</sup>

Altogether, there are good reasons to interpret our results as lower-bound estimates. Overall, our analysis documents that schooling was relevant for the compositional change in apprenticeships entering occupations that required literacy or numeracy. Without disputing the importance of demand-side forces, we document a relevant role of the supply of schooling for skill formation and occupational choice before and during the early Industrial Revolution.

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<sup>10</sup>Furthermore, in places without non-classical schools basic education could still have been taught informally, either within families or through private teachers that we do not capture in our data.

<sup>11</sup>According to the SIC reports 21 had become national schools, 143 non-classical schools, 164 semi-classical schools, and 120 elementary schools. It is impossible to reconstruct the timing of the curriculum changes for the whole of England, but for Lancashire, see [Tompson \(1971\)](#).

## 5.5 The long-run effect of schooling on innovation

So far, we have provided evidence on the effect of education on the formation of a highly-skilled artisans during the Industrial Revolution. This expanding workforce had the set of skills that were needed to apply the useful knowledge of the Industrial Enlightenment to the challenges of expanding manufacturing (Mokyr, 2002). If this was in fact the case, we would expect the increase in the supply of non-classical schooling to have contributed to industrialization and innovation as well. In this Section, we therefore explore whether long-run patterns in local patenting activity are broadly consistent with this prediction.

### 5.5.1 Empirical framework

To capture long-run trends in innovation, we rely on patent data widely employed as proxy for innovation (Griliches, 1990; Nuvolari and Tartari, 2011; Moser, 2016; Billington and Hanna, 2020; Koschnick, 2025). However, note that patents are prone to bias from industries that relied on secrecy instead of patenting (Moser, 2005). For this analysis, we assume that there was no systematic relationship between school foundations and the adoption of secrecy instead of patents.

We estimate the staggered difference-in-difference model in Equation 2 with aggregate patent numbers and patent citations from Nuvolari and Tartari (2011) as the outcome variables. Our treatment is the ordinal number of non-classical school foundations through wills between 1750 and 1815. Here, we only use variation in treatment from the foundation of non-classical schools, since our charity dataset ends in 1786, which is too early to capture long-run trends in patenting. Likewise, we use 1750 as our starting point since we lack patent variation before that date (see Figure 17). We end our analysis in 1815, when our data on non-classical schools effectively comes to an end.

As before, patents and patent citations are transformed using the hyperbolic sine transformation ( $\text{arcsinh}$ ). However, because patents were not reported at the parish level if the

place of registration was a town or city, we adopt  $100\text{km}^2$  hexagons as an alternative unit of analysis. Appendix H shows the distribution of schools, charities, and patents across England at the  $100\text{km}^2$  hexagon-level.

Identification relies on the same timing-based variation in school foundations as in the previous sections. Given the longer horizons considered here and the potential for spatial spillovers in innovation, this assumption is more demanding, and the results should therefore be interpreted as suggestive evidence.

### 5.5.2 Results

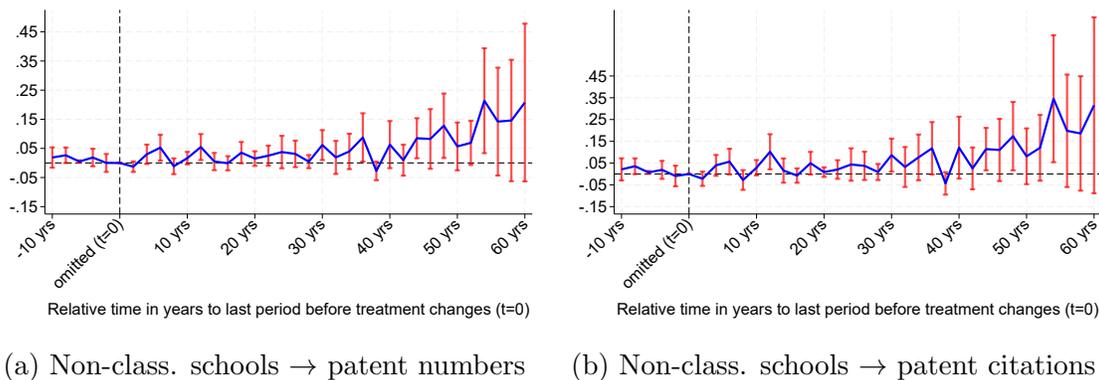


Figure 11: Non-classical school foundations and long-run innovation

*Notes:* Difference-in-differences results estimated using the estimator from de Chaisemartin et al. (2024). The unit of analysis is the hexagon  $100\text{km}^2 \times$  two-year period level. Treatment is provided by the ordinal number of non-classical schools. The outcomes are transformed using an inverse hyperbolic sine transformation ( $\text{arcsinh}$ ). The time frame is 1750–1815.  $N = 12,845$ . Standard errors are clustered at the  $100\text{km}^2 \times$  hexagon-level. 90% confidence intervals provided.

The results are reported in Figure 11. Following the foundation of a non-classical school, we observe a significant increase in patent numbers and citations by  $\sim 10\%$  after ca. 40 years. Then, over time, we observe an even larger increase, up to  $\sim 20\%$  in patent numbers and up to  $\sim 30\%$  in patent citations after ca. 60 years. Hence, it seems that it took a generation before schooling would have been associated with increase in innovation as captured through patenting.

Note that the analysis does not rule out alternative explanations, including spatial real-

location of inventive activity, or educational charity through wills as a response of long-run development. Nevertheless, the timing and direction of the estimates are consistent with the mechanism documented in the previous Sections: the expansion in schooling increased the supply of literate and numerate artisans, which facilitated the adoption, adaptation, and incremental improvement of new technologies (Mokyr, 2002). Therefore, we interpret the patent results as complementary evidence to the previous findings of the formation of a highly skilled workforce through the expansion of schooling. Our findings are also in line with evidence from other historical settings linking education to industrialization and innovation (Becker, Hornung and Woessmann, 2011; Cinnirella and Streb, 2017).

## 6 Robustness

We perform a series of robustness tests for our main results, including the use of a stacked difference-in-differences approach, and a variety of alternative specifications of treatment and outcome variable. The current Section summarizes our results.

### 6.1 Stacked difference-in-differences

We first present a more demanding stacked difference-in-differences approach (Cengiz et al., 2019) that only exploits variation from donor’s deaths within narrow time periods. The full regression model and results are presented in Appendix O.

The stacked difference-in-differences approach also makes it possible to isolate the effect of school foundations and separate it from smaller forms of educational charity.<sup>12</sup> Hence, for each school foundation  $T_i$ , we create stacks around a narrow time frame,  $[t_i - \tau, t, t_i + \tau]$  within which we expect that real uncertainty existed about the timing of death. Clean

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<sup>12</sup>When isolating the effect of treatment, the stacked difference-in-differences approach only requires clean controls to not experience a change in educational charity throughout the small time period of each stack window. In contrast, the previous staggered difference-in-differences approach compares comparisons across all time periods. Hence, isolating the effect of schools from educational charity would have required us to exclude all units ever receiving educational charity, which would lead to sample collapse.

controls units are defined as ever-treated units that that did not experience a change in school treatment during time frame  $[t_i - \tau, t, t_i + \tau]$ . We further require clean controls units not to receive school foundations through other means than wills or educational charity within the same time frame. Applying fully saturated fixed effects at the stack level, we only perform comparisons within each individual stack, thus only exploiting variation from the random timing of death.

We first present results for 22 year (12 pre- and 10 post treatment) stack windows. Despite the more demanding specification, we find significant results for all our baseline specifications for apprentices with skills in reading and writing, arithmetics, and reading, writing and arithmetics. Effect sizes range between 3% and 5% (see Appendix Figure 20), slightly larger than the effects found in section 5.2.

Next, we also report the robustness of our results for 10 year (6 pre- and 4 post treatment) stack windows. The estimated coefficients are similar to the previous results from the 22 year stack window specification. Note that results are not significant for apprentices requiring arithmetic skills. However, the coefficient size is highly similar to the previous specification.

Since we only exploit variation from the timing of donor's death within very narrow stack window, we argue that the timing of the treatment shock is as good as random, thereby alleviating concerns about school foundations responding to demand side factors.

Overall, the results from the stacked difference-in-differences approach are consistent with the main results and show that non-classical school foundations led to the formation of highly skilled craftsmen in trades that required literacy, numeracy, and mathematical skills.

## 6.2 Alternative specifications

In the following, we conduct an additional range of robustness tests to account for a possible divergence of linear pre-trends (see Abadie et al., 2025), different transformations as alternatives to the natural logarithm with zeroes, as well as potential bias from missing periods in the apprenticeship data.

First, we test for the presence of linear pre-trends. While the previous difference-in-differences results have shown stable pre-trends within the log-linear difference-in-differences model from Equation 2, this does not imply an absence of linear pre-trends (see [Abadie et al., 2025](#)). In Appendix Section P, we demonstrate the stability of our results for a model with linear outcomes. We do not find evidence of pre-trends. Moreover, we find a similar dynamic of treatment effects in the linear specification.

Next, we address recent criticisms of the hyperbolic sine transformations as an alternative to the natural logarithm in the presence of zeros ([Chen and Roth, 2024](#)). Specifically, we address concerns about the scale dependence of the inverse hyperbolic sine transformation by explicitly modeling the trade-off between the extensive and intensive margin following [Chen and Roth \(2024\)](#). The transformation is further described in Appendix Q. Estimating the difference-in-differences model with this transformation yields almost identical results to our baseline results.

Lastly, we consider potential bias from gaps in the apprenticeship data. Our collection of apprenticeship records misses entries for the years 1721–22, 1726–40, and 1746–52. (see data Section 4). Throughout all previous specifications, we adopt the approach recommended by [de Chaisemartin et al. \(2024\)](#) where we explicitly model the missing periods to allow for correct time comparisons.<sup>13</sup> However, difference-in-differences comparisons across missing years, especially in the presence of national trends in the outcome, might still give rise to compositional bias. In Appendix Section R, we therefore restrict our model to the period of 1754–1784 for which we have the complete set of apprenticeship records across all years. Reassuringly, we find that results are very similar to our baseline results for the full period.

Altogether, we show that our results are not driven by our choice of specification, the way in which we transform the outcome variable, or compositional effects.

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<sup>13</sup>As a conservative solution, we pass the estimator both the outcome and treatment as missing (see [de Chaisemartin et al., 2024](#)).

## 7 Conclusion

This paper has revisited the role of schooling in England’s First Industrial Revolution. While the prevailing literature emphasizes stagnation in literacy and schooling, our analysis shows that the expansion of education in the seventeenth and eighteenth centuries contributed to the rise of a highly skilled artisanal ‘upper-tail’. Drawing on novel parish-level data on school foundations, charitable bequests, and apprenticeship contracts, we have demonstrated that access to schooling lowered the barriers to entering trades that required literacy, numeracy, and mathematical skills. Our empirical strategy, exploiting the timing of post-mortem educational bequests, supports a causal link between charitable investments in schooling and subsequent increases in apprenticeship training, with persistent effects on local supply of artisans. Our analysis moreover provides suggestive evidence that our mechanism is compatible with trends in innovation in the long run.

Our results show that schooling contributed to an upskilling of the artisanal English labor force. Schooling can plausibly account for more than 25% of aggregate changes in the skill composition of apprenticeships. Hence we conclude that the skills apprentices had acquired at school contributed to the Industrial Revolution. Reading, writing and mathematics were crucial for bridging the gap between savants, entrepreneurs, and tinkerers on the shopfloor, and enabled artisans to access new technological knowledge codified in technical journals and periodicals, such as those published by the Society of Arts ([Howes, 2020](#)) or local provincial societies ([Schofield, 1957, 1963](#); [Cinnirella, Hornung and Koschnick, 2025](#)).

More broadly, our findings identify an underappreciated channel through which human capital shaped the transition to modern economic growth. The interplay between formal schooling and vocational training expanded the supply of skilled artisans essential for the adoption and implementation of new technologies. We thereby connect the early modern educational revolution to the technological changes of the First Industrial Revolution.

## References

- Abadie, Alberto, Joshua Angrist, Brigham Frandsen, and Jörn-Steffen Pischke.** 2025. “Harvesting Differences-in-Differences and Event-Study Evidence.” National Bureau of Economic Research Working Paper 34550.
- Akçomak, İ Semih, Dinand Webbink, and Bas ter Weel.** 2016. “Why Did the Netherlands Develop So Early? The Legacy of the Brethren of the Common Life.” *The Economic Journal* 126 (593): 821–860.
- Allen, Robert C.** 1988. “The price of freehold land and the interest rate in the seventeenth and eighteenth centuries.” *Economic History Review* 33–50.
- Allen, Robert C.** 2003. “Progress and poverty in early modern Europe.” *Economic History Review* 56 (3): 403–443.
- Alvarez-Palau, Eduard J., and Oliver Dunn.** 2019. “Database of historic ports and coastal sailing routes in England and Wales.” *Data in Brief* 25: 104188.
- Andersen, Thomas Barnebeck, Jeanet Bentzen, Carl-Johan Dalgaard, and Paul Sharp.** 2017. “Pre-Reformation Roots of the Protestant Ethic.” *The Economic Journal* 127 (604): 1756–1793.
- Armytage, W. H. G.** 1964. *Four hundred years of English education*. Cambridge: University Press.
- Asch, Kristine.** 2006. “The 1:5 Million International Geological Map of Europe and Adjacent Areas.”
- Baten, Joerg, and Jan Luiten van Zanden.** 2008. “Book Production and the Onset of Modern Economic Growth.” *Journal of Economic Growth* 13 (3): 217–235.

- Becker, Sascha O., and Ludger Woessmann.** 2009. “Was Weber Wrong? A Human Capital Theory of Protestant Economic History\*.” *The Quarterly Journal of Economics* 124 (2): 531–596.
- Becker, Sascha O., Erik Hornung, and Ludger Woessmann.** 2011. “Education and catch-up in the Industrial Revolution.” *American economic journal. Macroeconomics* 3 (3): 92–126.
- Becker, Sascha O, Jared Rubin, and Ludger Woessmann.** 2024. “Religion and growth.” *Journal of Economic Literature* 62 (3): 1094–1142.
- Becker, Sascha, Patrick Boll, and Hans-Joachim Voth.** 2025. “Spatial Unit Roots in Regressions: A Practitioner’s Guide and a Stata Package.” CEPR CEPR Discussion Paper DP19880, Paris and London.
- Bellemare, Marc F, and Casey J Wichman.** 2020. “Elasticities and the inverse hyperbolic sine transformation.” *Oxford Bulletin of Economics and Statistics* 82 (1): 50–61.
- Billington, Stephen, and Alan Hanna.** 2020. “That’s classified! Inventing a new patent taxonomy.” *Inventing a New Patent Taxonomy (May 1, 2020)*.
- Botticini, Maristella, and Zvi Eckstein.** 2012. *The chosen few: how education shaped Jewish history, 70-1492*. Princeton: Princeton University Press.
- Boucekkine, Raouf, David de la Croix, and Dominique Peeters.** 2007. “Early Literacy Achievements, Population Density, and the Transition to Modern Growth.” *Journal of the European Economic Association* 5 (1): 183–226. Publisher: Oxford University Press.
- Buringh, Eltjo, Bruce M. S. Campbell, Auke Rijpma, and Jan Luiten van Zanden.** 2020. “Church building and the economy during Europe’s ‘Age of the Cathedrals’, 700–1500 CE.” *Explorations in Economic History* 76: 101316.

- Campbell, Richard.** 1747. *The London Tradesman: Being an Historical Account of all the Trades, Professions, Arts, Both Liberal and Mechanic.* International Tool Catalog Library. Public Domain Mark 1.0, digitized by Google.
- Cengiz, Doruk, Arindrajit Dube, Attila Lindner, and Ben Zipperer.** 2019. “The effect of minimum wages on low-wage jobs.” *The Quarterly Journal of Economics* 134 (3): 1405–1454.
- Chen, Jiafeng, and Jonathan Roth.** 2024. “Logs with zeros? Some problems and solutions.” *The Quarterly Journal of Economics* 139 (2): 891–936.
- Cinnirella, Francesco, and Jochen Streb.** 2017. “The role of human capital and innovation in economic development: evidence from post-Malthusian Prussia.” *Journal of Economic Growth* 22 (2): 193–227. Publisher: Springer.
- Cinnirella, Francesco, Erik Hornung, and Julius Koschnick.** 2025. “Flow of Ideas: Economic Societies and the Rise of Useful Knowledge.” *The Economic Journal* 135 (669): 1496–1535.
- Clay, Christopher.** 1974. “The price of freehold land in the later seventeenth and eighteenth centuries.” *The Economic History Review* 27 (2): 173–189.
- Crafts, Nicholas FR, and C Knick Harley.** 1992. “Output growth and the British industrial revolution: a restatement of the Crafts-Harley view.” *Economic History Review* 703–730.
- Cressy, David.** 1980. *Literacy and the social order : reading and writing in Tudor and Stuart England.* Cambridge: Cambridge University Press.
- de Chaisemartin, Clément, and Xavier d’Haultfoeuille.** 2024. “Difference-in-differences estimators of intertemporal treatment effects.” *Review of Economics and Statistics* 1–45.

- de Chaisemartin, Clément, Diego Ciccia, Xavier D’Haultfœuille, Felix Knau, Mélitine Malézieux, and Doulo Sow.** 2024. “Event-Study Estimators and Variance Estimators Computed by the `did_multiplegt_dyn` Command.” *Paper draft*.
- De la Croix, David, and Omar Licandro.** 2015. “The longevity of famous people from Hammurabi to Einstein.” *Journal of Economic Growth* 20: 263–303.
- de la Croix, David, Matthias Doepke, and Joel Mokyr.** 2018. “Clans, guilds, and markets: Apprenticeship institutions and growth in the preindustrial economy.” *The Quarterly Journal of Economics* 133 (1): 1–70.
- de Pleijt, Alexandra, Alessandro Nuvolari, and Jacob Weisdorf.** 2020. “Human Capital Formation During the First Industrial Revolution: Evidence from the use of Steam Engines.” *Journal of the European Economic Association* 18 (2): 829–889.
- de Pleijt, Alexandra M.** 2018. “Human capital formation in the long run: evidence from average years of schooling in England, 1300–1900.” *Cliometrica* 12 (1): 99–126.
- de Pleijt, Alexandra M., and Jacob L. Weisdorf.** 2017. “Human capital formation from occupations: the ‘deskilling hypothesis’ revisited.” *Cliometrica* 11 (1): 1–30.
- De Pleijt, Alexandra M., and Jan Luiten Van Zanden.** 2016. “Accounting for the ”Little Divergence”: What drove economic growth in pre-industrial Europe, 1300?1800?” *European Review of Economic History* 20 (4): 387–409. Publisher: Oxford University Press.
- Feldman, Naomi E., and Karine Van der Beek.** 2016. “Skill choice and skill complementarity in eighteenth century England.” *Explorations in Economic History* 59: 94–113.
- Fernihough, Alan, and Kevin Hjortshøj O’Rourke.** 2021. “Coal and the European Industrial Revolution.” *The Economic Journal* 131 (635): 1135–1149.
- Foster, Julie.** 2019. “Did education promote social mobility within the working class in Birmingham?” PhD diss. University of Birmingham.

- Franck, Raphaël, and Oded Galor.** 2021. “Technology-Skill Complementarity in Early Phases of Industrialisation.” *The Economic Journal* 132 (642): 618–643.
- Galor, Oded.** 2005. “From Stagnation to Growth: Unified Growth Theory.” In *Handbook of Economic Growth*, Vol. 1, edited by Philippe Aghion and Steven N. Durlauf, 171–293. Elsevier.
- Galor, Oded.** 2011. *Unified growth theory*. Princeton: Princeton University Press.
- Galor, Oded.** 2022. *The Journey of Humanity: The Origins of Wealth and Inequality*. New York: Dutton.
- Galor, Oded, and Omer Moav.** 2004. “From Physical to Human Capital Accumulation: Inequality and the Process of Development.” *The Review of Economic Studies* 71 (4): 1001–1026.
- Gomez, Francis Gerald.** 1987. “The endowed schools of Lancashire from the seventeenth to the early nineteenth century.” Unpublished.
- Griliches, Zvi.** 1990. “Patent Statistics as Economic Indicators: A Survey.” *Journal of Economic Literature* 28 (4): 1661–1707.
- Hanlon, W Walker.** 2025. “The rise of the engineer: Inventing the professional inventor during the Industrial Revolution.” *The Economic Journal* ueaf023.
- Hanushek, Eric A., and Ludger Woessmann.** 2020. “Chapter 14 - Education, knowledge capital, and economic growth.” In *The Economics of Education (Second Edition)*, edited by Steve Bradley and Colin Green, 171–182. Academic Press.
- Harrington, James.** 1992. *The commonwealth of Oceana ; and, A system of politics*. Cambridge: Cambridge University Press.

- Howes, Anton.** 2020. *Arts and Minds: How the Royal Society of Arts Changed a Nation*. Princeton: Princeton University Press.
- Hume, R.** 1982. “Educational Provision For The Kentish Poor 1660 1811: fluctuations, trends.” *Southern History* 4: 123–144.
- Humphries, Jane.** 2010. *Childhood and child labour in the British Industrial Revolution*. Cambridge: Cambridge University Press.
- Jewell, Helen M.** 1998. *Education in early modern England. Social history in perspective*. Houndmills [England: Macmillan Press.
- Jones, M. G.** 1964. *The charity school movement: a study of eighteenth century Puritanism in action*. London: F. Cass.
- Jordan, W. K.** 1959. *Philanthropy in England, 1480-1660. A study of the changing pattern of English social aspirations*. London: George Allen & Unwin.
- Justman, Moshe, and Karine van der Beek.** 2015. “Market forces shaping human capital in eighteenth-century London.” *The Economic History Review* 68 (4): 1177–1202.
- Keibek, Sebastiaan.** 2017. “The male occupational structure of England and Wales 1600-1850.” PhD diss. University of Cambridge.
- Kelly, Morgan, Joel Mokyr, and Cormac Ó Gráda.** 2023. “The Mechanics of the Industrial Revolution.” *The Journal of Political Economy* 131 (1): 59–94.
- Khan, B Zorina, and Kenneth L Sokoloff.** 1993. ““Schemes of practical utility”: entrepreneurship and innovation among “great inventors” in the United States, 1790–1865.” *The Journal of Economic History* 53 (2): 289–307.
- Knowles, D., and R. N. Hadcock.** 1971. *Medieval Religious Houses: England and Wales*. London: Longman.

- Koschnick, Julius.** 2025. “Did a feedback mechanism between propositional and prescriptive knowledge create modern growth?” arXiv:2512.16587.
- Langford, Paul.** 1989. *A polite and commercial people : England, 1727-1783*. Oxford: Oxford University Press.
- Langton, John.** 2000. “Urban growth and economic change : from the late seventeenth century to 1841.” In *The Cambridge urban history of Britain, vol. 2: 1540-1840*, edited by Peter Clark. Cambridge: Cambridge University Press.
- Laqueur, Thomas W.** 1974. “Literacy and Social Mobility in the Industrial Revolution in England.” *Past & Present* , (64): 96–107. Publisher: [Oxford University Press, The Past and Present Society].
- Lucas, Robert E.** 1988. “On the mechanics of economic development.” *Journal of Monetary Economics* 22 (1): 3–42.
- Madsen, Jakob B., and Fabrice Murtin.** 2017. “British economic growth since 1270: the role of education.” *Journal of economic growth* 22 (3): 229–272. Place: New York Publisher: Springer Science + Business Media.
- McCormick, Michael, Guoping Huang, Gabriele Zambotti, and Jeffrey Lavash.** 2013. “Roman Road Network (version 2008).” *Dataset*, DARMC Scholarly Data Series, Data Contribution Series #2013-5.
- Meisenzahl, Ralf, and Joel Mokyr.** 2011. “The Rate and Direction of Invention in the British Industrial Revolution: Incentives and Institutions.” In *The Rate and Direction of Inventive Activity Revisited*, edited by Josh Lerner and Scott Stern, 443–479. Chicago: University of Chicago Press.

- Minns, Chris, and Patrick Wallis.** 2013. “The price of human capital in a pre-industrial economy: Premiums and apprenticeship contracts in 18th century England.” *Explorations in Economic History* 50 (3): 335–350.
- Mitch, David.** 1993. “The Role of Human Capital in the First Industrial Revolution.” In *The British Industrial Revolution: An Economic Perspective*, edited by Joel Mokyr, 267–307. Boulder: Westview.
- Mitch, David.** 1999. “The Role of Education and Skill in the British Industrial Revolution.” In , 2 edition, 241–279. United Kingdom: Routledge.
- Mitch, David Franklin.** 1982. “The Spread of Literacy in Nineteenth-Century England.” ISBN: 9798644973873.
- Mokyr, Joel.** 2002. *The gifts of Athena: Historical origins of the knowledge economy*. Princeton: Princeton University Press.
- Mokyr, Joel.** 2009. *The enlightened economy : an economic history of Britain, 1700-1850*. New Haven: Yale University Press.
- Mokyr, Joel.** 2016. *A Culture of Growth: The Origins of the Modern Economy. The Graz Schumpeter lectures* 1 edition. United States: Princeton University Press.
- Mokyr, Joel, and Hans-Joachim Voth.** 2010. “Understanding Growth in Europe, 1700-1870: Theory and Evidence.” In *The Cambridge Economic History of Modern Europe. Volume 1. 1700-1870*, edited by Stephen Broadberry and Kevin H. O’Rourke, 7–42. Cambridge University Press.
- Mokyr, Joel, Assaf Sarid, and Karine van der Beek.** 2022. “The Wheels of Change: Technology Adoption, Millwrights, and the Persistence in Britain’s Industrialization.” *The Economic Journal* ueab102.

- Moser, Petra.** 2005. "How do patent laws influence innovation? Evidence from nineteenth-century world's fairs." *American economic review* 95 (4): 1214–1236.
- Moser, Petra.** 2016. "Patents and innovation in economic history." *Annual Review of Economics* 8 (1): 241–258.
- Musson, A. E.** 1969. *Science and technology in the Industrial Revolution*. Manchester: U.P.
- Nicholas, Stephen J., and Jacqueline M. Nicholas.** 1992. "Male Literacy, "Deskilling," and the Industrial Revolution." *The Journal of Interdisciplinary History* 23 (1): 1–18. Publisher: [The MIT Press, Massachusetts Institute of Technology and the editors of The Journal of Interdisciplinary History].
- Nuvolari, Alessandro, and Valentina Tartari.** 2011. "Bennet Woodcroft and the value of English patents, 1617–1841." *Explorations in Economic History* 48 (1): 97–115.
- Nuvolari, Alessandro, Valentina Tartari, and Matteo Tranchero.** 2021. "Patterns of innovation during the Industrial Revolution: A reappraisal using a composite indicator of patent quality." *Explorations in Economic History* 82: 101419.
- O'Day, Rosemary.** 1982. *Education and society 1500-1800 : the social foundations of education in early modern Britain*. London: Longman.
- Paglayan, Agustina S.** 2024. *Raised to obey: the rise and spread of mass education. The Princeton economic history of the western world*. Princeton, New Jersey: Princeton University Press.
- Payne, Dianne.** 2006. "London's Charity School Children: The 'Scum of the Parish'?" *Journal for Eighteenth-Century Studies* 29 (3): 383–397. eprint: <https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1754-0208.2006.tb00655.x>.
- Prak, Maarten, and Patrick Wallis.** 2019. *Apprenticeship in Early Modern Europe*. Cambridge: Cambridge University Press.

- Reis, Jaime.** 2005. “Economic Growth, Human Capital Formation and Consumption in Western Europe Before 1800.” In *Living Standards in the Past: New Perspectives on Well-Being in Asia and Europe*, edited by Robert C. Allen, Tommy Bengtsson and Martin Dribe, 195–217. Oxford: Oxford University Press.
- Robson, Derek.** 1966. *Some aspects of education in Cheshire in the eighteenth century*. Manchester: Chetham Society.
- Rogers, C. D.** 1971. “Education in Lancashire and Cheshire, 1640-1660.” *Transactions of the Historic Society of Lancashire and Cheshire* 123 (3): 39–56.
- Rose, Craig.** 1991. “Evangelical Philanthropy and Anglican Revival: The Charity Schools of Augustan London, 1698–1740.” *The London Journal* 16 (1): 35–65. Publisher: Routledge  
eprint: <https://doi.org/10.1179/ldn.1991.16.1.35>.
- Rosenberger, Lukas, W. Walker Hanlon, and Carl Hallmann.** 2024. “Innovation Networks in the Industrial Revolution.” National Bureau of Economic Research Working Paper 32875.
- Sanderson, Michael.** 1972. “Literacy and Social Mobility in the Industrial Revolution in England.” *Past & Present* , (56): 75–104. Publisher: [Oxford University Press, The Past and Present Society].
- Schofield, Robert E.** 1957. “The industrial orientation of science in the Lunar Society of Birmingham.” *Isis* 48 (4): 408–415.
- Schofield, Robert E.** 1963. *The Lunar Society of Birmingham: a social history of provincial science and industry in eighteenth-century England*. Oxford: Clarendon Press.
- Schofield, R. S.** 1973. “Dimensions of illiteracy, 1750–1850.” *Explorations in Economic History* 10 (4): 437–454.

- Schools Inquiry Commission.** 1868. “Royal Commission to inquire into Education in Schools in England and Wales: Report.”
- Select Committee on Education of Poor.** 1819. *A digest of parochial returns made to the select committee appointed to inquire into the education of the poor: session 1818. Vol. I.* Vol. 224 of *House of Commons Papers*. H.M.S.O.
- Shaw-Taylor, Leigh, and Peter Kitson.** 2006. “Male Occupational Data from English Parish Registers (processed summary data), c. 1700-1820.”
- Simon, Joan.** 1994. “The state and schooling at the Reformation and after: from pious causes to charitable uses.” *HISTORY OF EDUCATION*. Publisher: Taylor & Francis Group.
- Slack, Paul.** 1999. *From Reformation to Improvement: Public Welfare in Early Modern England*. Oxford: Clarendon Press.
- Spufford, Margaret.** 1981. *Small books and pleasant histories: popular fiction and its readership in seventeenth-century England*. London: Methuen.
- Squicciarini, Mara P.** 2020. “Devotion and Development: Religiosity, Education, and Economic Progress in Nineteenth-Century France.” *The American Economic Review* 110 (11): 3454–3491. Publisher: American Economic Association.
- Squicciarini, Mara P., and Nico Voigtländer.** 2015. “Human Capital and Industrialization: Evidence from the Age of Enlightenment \*.” *The Quarterly Journal of Economics* 130 (4): 1825–1883.
- Stone, Lawrence.** 1964. “The Educational Revolution in England, 1560-1640.” *Past & Present*, (28): 41–80. Publisher: [Oxford University Press, The Past and Present Society].
- Talbert, Richard J. A., and Roger S. Bagnall.** 2000. *Barrington Atlas of the Greek and Roman World*. Princeton: Princeton University Press. Open Library ID: OL7757218M.

- Tomkins, Alannah.** 1997. “Charity Schools and the Parish Poor in Oxford, 1740-1770.” *Midland History* 22 (1): 51–70. Publisher: Routledge .eprint: <https://doi.org/10.1179/mdh.1997.22.1.51>.
- Tompson, Richard S.** 1971. *Classics or charity?: the dilemma of the 18th century grammar school*. Manchester.
- United Kingdom. House of Commons.** 1816. *Abstract of the returns of charitable donations for the benefit of poor persons, made by the ministers and churchwardens of the several parishes and townships in England and Wales, 1786–88 (Parts I and II)*. Vol. 511 of *House of Commons Papers*. London.
- Wallis, Patrick.** 2025. *The Market for Skill: Apprenticeship and Economic Growth in Early Modern England*. Princeton: Princeton University Press.
- Wallis, Patrick, Cliff Webb, and Chris Minns.** 2010. “Leaving home and entering service: the age of apprenticeship in early modern London.” *Continuity and Change* 25 (03): 377–404.
- Webster, Charles.** 1975. *The great instauration: science, medicine and reform, 1626-1660*. London: Duckworth.
- West, Martin R., and Ludger Woessmann.** 2010. “‘Every Catholic Child in a Catholic School’: Historical Resistance to State Schooling, Contemporary Private Competition and Student Achievement across Countries.” *The Economic Journal* 120 (546): F229–F255.
- Williamson, Jeffrey G.** 1982. “The Structure of Pay in Britain, 1710–1911.” *Research in Economic History* 7: 1–54.
- Wrigley, E. A.** 2011. *The Early English Censuses. British Academy Records of Social and Economic History, New Series 46*. Oxford University Press.

**Zeev, Nadav Ben, Joel Mokyr, and Karine van der Beek.** 2017. “Flexible Supply of Apprenticeship in the British Industrial Revolution.” *The Journal of Economic History* 77 (1): 208–250.

## (Online) Appendices

### A The association between vocational training and industrialization

The relationship between vocational training and economic development is well-established in the literature. The central argument is that the ‘upper-tail’ of the labor force, those with the highest levels of schooling and skills, was crucial for the technological breakthroughs that initiated the First Industrial Revolution (Mokyr, 2009; Mokyr and Voth, 2010; Meisenzahl and Mokyr, 2011). The development of useful knowledge was especially evident in the training of highly skilled apprentices, a cornerstone of vocational training and skill acquisition in early modern European cities (Prak and Wallis, 2019). However, direct evidence linking the supply of skills through apprenticeship training to broader patterns of industrialization remains limited, with existing findings largely confined to the textile sector (see Kelly, Mokyr and Ó Gráda (2023)).

In this Appendix we therefore document the general relationship between centres of training in the 18th century and the extent of industrialization in the early 19th century. Our measure of industrialization is based on the occupational structure, i.e. the number of men working in (i) agriculture, (ii) industry, and (iii) services in 1813–1820. Occupational data is based on the statistics compiled by the Cambridge Group for the History of Population and Social Structure (Shaw-Taylor and Kitson, 2006), covering 2.6 million males across 10,528 parishes in England and Wales. Ca. 39,000 unique occupational titles were classified into one of the three main sectors of the economy. Figure 12 shows the share of the workforce employed in industry in the early 19th century, highlighting concentrations in industrial centres such as the West Riding of Yorkshire, the Midlands, Lancashire, and Cheshire.

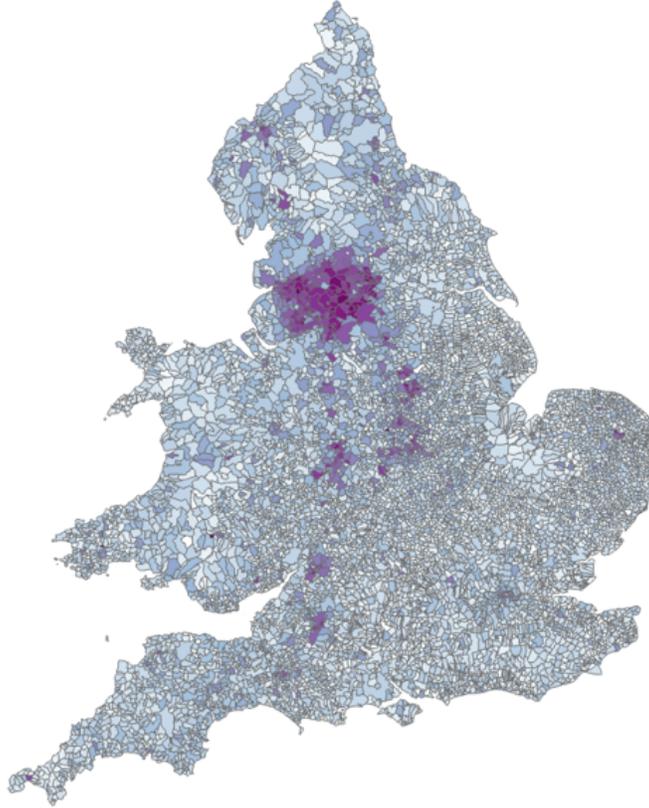


Figure 12: The share of the workforce employed in industry, ca. 1813–20

*Notes:* The share in industry is based on the 1813–20 statistics provided by the Cambridge Group for the History of Population and Social Structure, which contain the occupational titles of 2.6 million males in England and Wales. *Source:* [Shaw-Taylor and Kitson \(2006\)](#)

To analyze the association between vocational training and the occupational structure, we estimate the following equation:

$$Y_{i,1813-20} = \alpha + \beta_1 Apps_{i,1710-1805} + X'_i \mu + \Omega_c + \varepsilon_i, \quad (3)$$

where  $Y_{i,1813-20}$  denotes the number of men employed in agriculture, industry, or services in parish  $i$  between 1813 and 1820.  $Apps_{i,1710-1805}$  is the number of apprentices training in parish  $i$  between 1710 and 1805. We distinguish between all apprentices and those classified as *ingenious*.  $\Omega_c$  represents county fixed effects, while  $\varepsilon_i$  is the error term for parish  $i$ . Additionally,  $X'_i$  is a vector of geographical and pre-industrial characteristics of parish  $i$ . Our geographical controls include the quality of agricultural land, proximity to a river, latitude,

longitude, average rainfall, terrain ruggedness, parish size, and average temperature. We also account for whether the parish bordered Scotland or Wales, had access to the sea, or contained carboniferous rock strata (as a proxy for coal deposits). To capture pre-industrial characteristics, we control for access to a port or a Roman road, the presence of a cathedral, and distances to the nearest monastery in 1535 and the nearest town in 1680. A detailed description of our control variables and their sources can be found in Appendix B, and summary statistics can be found in Appendix C. Given the skewed distribution of many variables and the presence of zeros, our baseline regressions apply an inverse hyperbolic sine transformation. As a proxy for population, we control for the total number of baptism records. A particular challenge in reconstructing the occupational structure concerns the category of labourers. This was a commonly used occupational label, applied to about 30% of men in the 1813–1820 quasi-census. However, it is often unclear which sector these individuals belonged to (see Keibek (2017)). To address this potential source of bias, we include the number of unallocated labourers as a control variable in our regressions.

Table A.1: The association between local training and the occupational structure, ca. 1813–1820

	Agriculture	Industry	Services
	(1)	(2)	(3)
Apprentices	-0.0402*** (0.00773)	0.111*** (0.00760)	0.0822*** (0.00897)
Pre-development	Yes	Yes	Yes
Geography	Yes	Yes	Yes
Labourers	Yes	Yes	Yes
Baptism records	Yes	Yes	Yes
Observations	8719	8719	8719
R-squared	0.75	0.87	0.76

*Notes:* All variables are transformed by the inverse hyperbolic sine function, except for dummy variables. Standard errors are robust to control for heteroscedasticity. \* Significant at 10%; \*\* significant at 5%; \*\*\* significant at 1% level.

Table A.1 shows that apprenticeship is negatively associated with agricultural employment (Columns (1)) and positively associated with employment in industry and services (Columns

(2) and (3)). In the introduction of our paper (see Section [1](#)) we report on the results from Column (2).

## B Control Variables

This Appendix gives a definition of the control variables used in our cross-sections and lists the sources used to construct them.

- *Land quality*: To compute land quality, we follow [Andersen et al. \(2017\)](#) and use the Agricultural Land Classification Grades from Natural England, which gives land quality based on seven classes, with one corresponding to the highest quality, five to the lowest, six for non-agricultural land, and seven for urban sites. The rating is based on climatic (temperature, rainfall, aspect, exposure, frost risk), topographic (gradient, micro-relief, flood risk), and pedologic (depth, structure, texture, chemicals, stoniness) criteria. Our land quality variable gives the share of land within each parish classified in the two highest classes.
- *River*: Similar to [Andersen et al. \(2017\)](#), we use data on rivers from [Geofabrik](#) (collected as part of the OpenStreetMap project). We construct an indicator variable that takes the value 1 if a river is located within 500 meters of the parish centroid, and 0 otherwise.
- *Longitude*: Longitude of the centroid of the parish.
- *Latitude*: Latitude of the centroid of the parish.
- *Ruggedness*: Our ruggedness variable gives the average value of the Terrain Ruggedness Index (TRI), based on [SRTM DEM](#).
- *Wales*: Indicator variable that takes the value 1 if the parish borders Wales.
- *Scotland*: Indicator variable that takes the value 1 if the parish borders Scotland.
- *Land locked*: Indicator variable that takes the value 1 if the parish is landlocked.
- *Temperature*: Average annual temperature (in celsius). Data from [WorldClim Bioclimatic Data](#).
- *Rainfall*: Average annual precipitation (in millimeters). Data from [WorldClim Bioclimatic Data](#).
- *Area*: This variable measures the area (in square kilometers) of each parish.

- *Carbon share*: We follow [Fernihough and O'Rourke \(2021\)](#) and use [Asch \(2006\)](#) to measure the share of rock strata in each parish as an indicator of potential coal deposits.
- *Church*: The location of Medieval cathedrals is derived from [Buringh et al. \(2020\)](#). We created an indicator variable taking the value 1 if there was a church within 10 kilometers of the parish centroid, and 0 otherwise.
- *Population 1800*: The number of persons in each parish in 1801 is provided by [Shaw-Taylor and Kitson \(2006\)](#).
- *Port*: The location of historic ports is taken from [Alvarez-Palau and Dunn \(2019\)](#). The ports included are: Bristol, Dover, Hull, Liverpool, London, Milford, Penzance, Plymouth, Shoreham, Southampton, Swansea, Weymouth, and Great Yarmouth. We constructed an indicator variable taking the value 1 if there was a port within 10 kilometers of the parish centroid.
- *Roman road*: This indicator variable captures whether a Roman road passes through a parish. It is based on a digitized version of the Roman road network derived from the *Barrington Atlas of the Greek and Roman World* ([Talbert and Bagnall, 2000](#)). The digitized dataset was created by ([McCormick et al., 2013](#)) and published through the [DARMC Scholarly Data Series](#).
- *Distance to nearest town in 1680*: We use data on the location of 1,005 towns in the late 17th century from [Langton \(2000\)](#). Our variable measures the distance (in kilometers) from each parish centroid to the nearest town around 1680.
- *Distance to nearest monastery in 1530*: We use data on the location of ca. 770 monasteries from [Knowles and Hadcock \(1971\)](#). The dataset is manually geo-referenced by the authors. Our variable measures the distance (in kilometers) from each parish centroid to the nearest monastery in 1530.

## C Summary statistics for the association between vocational training and industrialization

Table C.1: Summary Statistics for Table A.1

Variable	Obs	Mean	Std. Dev.	Min	Max
Number of men in agriculture	8,719	39.81	98.63	0	3,351
Number of men in industry	8,719	103.25	511.23	0	18,352
Number of men in services	8,719	39.87	233.20	0	7,332
Number of apprentices	8,719	30.64	149.33	0	6,012
Land quality	8,719	19.09	26.40	0	100
River	8,719	0.50	0.50	0	1
Longitude	8,719	52.24	1.08	49.98	55.78
Latitude	8,719	-1.12	1.49	-5.69	1.75
Rainfall	8,719	745.79	184.72	504	1,869.77
Ruggedness	8,719	4.43	2.18	1.27	27.12
Size of parish (km <sup>2</sup> )	8,719	14.81	20.13	0.01	426.46
Temperature	8,719	9.58	0.58	6.35	11.12
Wales	8,719	0.01	0.08	0	1
Scotland	8,719	0.00	0.04	0	1
Landlocked	8,719	0.87	0.34	0	1
Carbon share	8,719	10.51	28.92	0	100
Port	8,719	0.03	0.18	0	1
Church	8,719	0.17	0.37	0	1
Roman road	8,719	0.26	0.44	0	1
Distance to nearest town, 1680	8,719	5.48	2.89	0.02	20.17
Distance to nearest monastery, 1535	8,719	7.19	4.60	0	40.93

*Notes:* The table presents summary statistics for the main variables used in the analyses conducted in Appendix A. It includes the number of observations (N), mean, standard deviation (Std. Dev.), minimum (Min), and maximum (Max) values for each variable.

## D Exploiting information on the relative size of the schools

As a supplementary exercise, we examine whether the association between schooling and apprenticeship varies with proxies for school size, measured by (i) income from the endowment in the 1860s, and (ii) school age. Table D.1 reports the results. Older and better endowed schools are more strongly associated with the local number of highly skilled apprentices.

Table D.1: Relative size of the schools

	Apprentices		Reading and writing		Mathematics		Reading, writing, mathematics	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Non-class school age	0.0408*** (0.00739)		0.0364*** (0.00671)		0.0299*** (0.00611)		0.0306*** (0.00580)	
Non-classical school, date unknown	0.120 (0.0968)		0.0789 (0.0947)		0.0573 (0.0964)		0.0258 (0.0945)	
Non-class school income		0.0595*** (0.0108)		0.0557*** (0.00971)		0.0493*** (0.00905)		0.0510*** (0.00869)
Non-class income unknown		-0.197 (0.212)		-0.0832 (0.194)		-0.152 (0.168)		-0.150 (0.175)
Pre-development	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geography	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8863	8863	8863	8863	8863	8863	8863	8863
R-squared	0.48	0.48	0.42	0.42	0.35	0.36	0.34	0.34

*Notes:* All variables are transformed by the inverse hyperbolic sine function, except for dummy variables. Standard errors are robust to control for heteroscedasticity. \* Significant at 10%; \*\* significant at 5%; \*\*\* significant at 1% level.

## E Construction of the charity dataset

Our charity dataset is based on a Parliamentary survey of charitable funds for the poor carried out in 1786 at the prompting of the poor relief reformer and MP Thomas Gilbert. The detailed findings of the survey, known as the *Gilbert Returns*, were published in 1816 and record over 46,000 charitable gifts from nearly all parishes in England; only 13 parishes reportedly failed to file a return ([United Kingdom. House of Commons, 1816](#)) .

The *Returns* list all known gifts for the poor, giving the name of the donor, the year made, the intended purpose of the gift, and the sums given. Charitable gifts for the education of the poor were one of the main categories reported by parishes. The more than 4,500 gifts for education listed in the *Gilbert Returns* include the initial endowments of most of the classical and non-classical schools that survived into the SIC report. They also include many later gifts that allowed schools to expand. For example, Harwich corporation school is listed in the SIC as founded in 1725. The *Gilbert Returns* record the founding donation of land for the school made in 1724 by Sir Humprhey Parsons. They also identify an earlier legacy of £50 from John Rolfe in 1717 ‘For teaching 2 poor children’, another legacy of £60 from Daniel Smith in 1727 ‘For teaching 3 poor children’ and £25 from William Godfrey in 1730 for teaching another child, all of which were used to fund the school. The sequential gifts of Rolfe, Smith and Godfrey make clear that giving was cumulative, and that these gifts increased educational opportunities incrementally over time.

Figure 5 shows the spatial distribution of the number of charitable funds in each parish in 1786. The *Gilbert Returns* document nearly all of English parishes. The rate of linkage between the reported parishes and the parish GIS is lower in parts of the north west of England where large parishes are often subdivided into townships and chapelries, making identification problematic.

The Gilbert Returns document a very large number of charitable gifts across English parishes. The quality and completeness of the evidence they contain was questioned in the

nineteenth century during the debates that led to the foundation of the Charity Commission. Historians of charity have found little evidence to support those criticisms.

The following gives a definition of treatment measures derived from the charity data. Treatment variables are restricted to endowments that we know for certain to derive from wills. We know that 63% of all charity endowments derive from wills, while 15% derive from deeds. The origin of 22% of all charity endowments are uncertain. To ensure that the treatment variation is driven by the death of benefactors, we restrict the charity data to the 63% of charity endowments that we know to derive from wills.

**Variable description:**

- *Educational charities*: Defined as all charities funded from wills with an educational purpose. Often the notes in the *Gilbert Returns* stipulate that the money to be spent on ‘teaching poor children’, which would usually involve the employment of a schoolmaster who might teach in his own quarters or in a school building. Some wills specify that the money was to be spent on ‘endowing a charity school’. We also find references to varying purposes, such as to buy books, the residence of a master or the construction of a school house.
- *Charities for the poor*: Defined as all charities from wills with the purpose of supporting the poor. Often the *Gilbert Returns* summarise the purpose as money to be spent on ‘the poor’. On other times, we find more concrete stipulations, such as ‘for a coat to a poor man’, ‘for bread to the poor’, or ‘for clothing’.
- *Monetary value*: This variable records the contemporary present-day value of educational charity. In the *Gilbert Returns*, the monetary value of endowments are either recorded as (i) lump sums, (ii) yearly income, or (iii) yearly rental income. To transform these sums into contemporary present-day value, we follow the ‘years of purchase’ rule that was common in the seventeenth and eighteenth century. For our sample period of 1710–1786 estimates of the years of purchase varied between 21 and 30 (Clay,

1974) and 18 and 32.5 years of purchase (Allen, 1988). We take the average years of returns to purchase of 26 during this 1704–1794 from (Allen, 1988) to transform rental income into monetary value. We further assume that the return to rental and non-rental investments was equivalent. Figure 13 reports the distribution of charities below £1000 and £200.

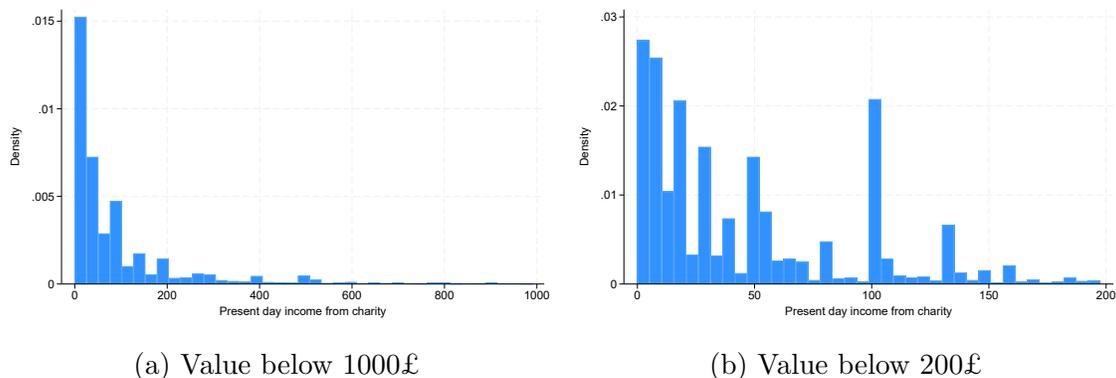


Figure 13: The number of charitable funds in 1786

*Notes:* The figure reports the distribution of the present-day value of charitable endowments from Gilbert for endowments under 1000 pounds. *Source:* Gilbert 1816.

## F Construction of the apprenticeship dataset

Our data on apprentices comes from the records of the Stamp Duty on indentures. The surviving registers run from 1710 to 1804 and contain the records of over 500,000 apprentices (Wallis, 2025). However, for some years the registers are now entirely or partially lost, and our empirical analysis is restricted to periods with complete coverage. Gaps particularly affect 1721–22, 1726–40, and 1746–52. The resulting database includes around 350,000 apprenticeship contracts, whose spatial distribution is shown in Figure 14.

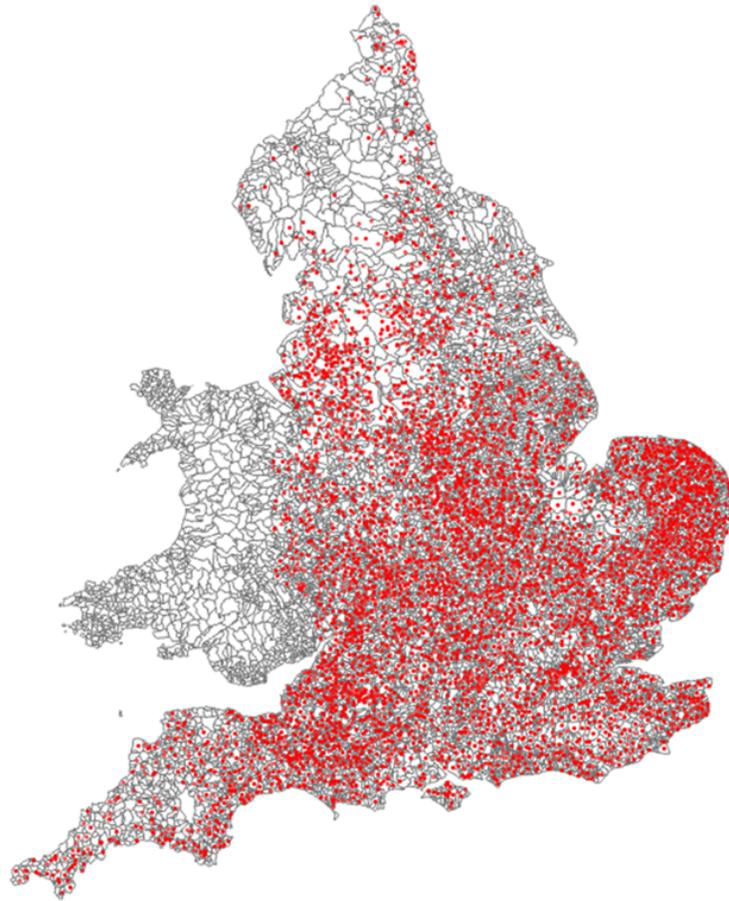


Figure 14: The spatial distribution of training, 1711–1805

*Notes:* The map shows all training locations between 1711 and 1805. *Source:* See text.

Apprentices are recorded by masters. For each observation, we have data on the appren-

tice's name, their master's name and occupation, the date the contract was made, and the location of the master, usually their parish and county. We have geolocated apprenticeships by the master's parish and categorized the master's occupation using [Campbell \(1747\)](#).

## G Coding occupations from Stamp Tax registers

To classify the skill content of all apprentices in our database, we rely on a contemporary source of information about occupations. This helps alleviate any concerns that the researchers' preconceptions might be affecting their results. To achieve this, the source of the occupational information ideally predates the Industrial Revolution. Van der Beek and co-authors have demonstrated the value of [Campbell \(1747\)](#), a guide for parents considering what job might suit their children, as a source of information on occupations in this period. Campbell described a large number of occupations, and included information on apprenticeship premiums, wages, and the abilities and skills that each required. [Justman and van der Beek \(2015\)](#) tested the internal and external validity of Campbell's evidence. [Feldman and Van der Beek \(2016\)](#) then used Campbell's descriptions of the personal characteristics that youths needed to possess if they were to succeed in a trade in order to explore skill-biased technological change in the Industrial Revolution.

We build on this approach here, using Campbell's comments about whether an occupation required apprentices to possess skills associated with schooling. In particular, we rely on Campbell's statements on whether an occupation required skills in reading and writing or demanded skills in mathematics. Campbell also specified whether occupations required strength, drawing skills, or a 'liberal education', but our analysis focuses on reading and writing and mathematics.

Our use of Campbell differs in several minor ways from [Feldman and Van der Beek \(2016\)](#). First, we do not aggregate occupations into larger groups, instead restricting ourselves to analyzing trades that are explicitly discussed by Campbell, and trades that are synonymous with Campbell's occupations. In effect, this is a string match between the master's (cleaned) occupation as reported in the apprentice dataset and an occupation described by Campbell. Synonyms are matched to occupations where multiple terms were used in the period for the same trade (e.g.: cordwainer and shoemaker; loriner and bitmaker) or where Campbell

discusses a single trade that appears with specialties or variants in the apprentice dataset (e.g.: pearl button maker and metal button maker, which are matched to ‘button maker’; knife grinder and razor grinder, which are matched to ‘grinder of knives’; or diamond cutter and diamond polisher, which are matched to ‘diamond cutter’).

The use of synonyms is most significant for five occupations where Campbell describes as a single trade an occupation that is generally subdivided in the apprentice data: wheelwrights, gunsmiths, watchmakers, attorneys, and weavers. For smiths, however, Campbell describes an array of specialist types, and we treat these as equivalent to the basic ‘smith’ that appears most often in apprenticeships. This strategy allows us to avoid the problem of deciding how to code mixed groups of trades with different skill requirements.

Second, we include all occupations covered by Campbell, and do not exclude shop keeping and professions, such as surgeons. This allows us to consider all kinds of apprenticeships for which we have data, reducing the risk that we influence the analysis with our own priors.

We are able to code 93% of 503,954 observations in the apprentice dataset using Campbell’s classifications. Apprentices bound to masters using 1,374 different occupations could not be coded. Most of these were masters with occupations that appeared infrequently, are incomplete or ambiguous in the source. Only 47 uncoded occupations involved one hundred or more apprentices. The largest number were with masters who were described as merchant taylor (2,413), gentlemen (2,232), husbandmen (611), caulkers (597), salters (546) and nailers (538). The merchant taylor were members of a London guild that encompassed members with many different occupations. The gentlemen were mainly attorneys. The lack of a code for husbandmen reflects the lack of agricultural occupations in Campbell, who wrote for a London market.

Our variables ‘reading and writing’ and ‘mathematics’ follow the definition of Campbell (1747) and include the following occupations:

**Reading and writing:** Advocate, Apothecary, Architect, Attorney, Attorney general, At-

torney of the B.R, Attorney of the Chancery court, Attorney of the Common pleas, Attorney of the Court of Arches, Attorney of the Court of Canterbury, Attorney of the Court of Lancaster, Attorney of the Cursitor's office, Attorney of the Exchequer, Attorney of the King's bench, Attorney of the Six Clerk's office, Auger smith, Banker, Barber, Barber surgeon, Battle painter, Blacksmith, Bolt maker, Book maker, Book seller, Boot maker, Box painter, Brass lock maker, Brass locksmith, Bright engraver, Bright smith, Brownstone potter, Cabinet lock maker, Cabinet locksmith, Calico engraver, Calico pattern drawer, Calico print drawer, Calico printer, Carpenter, Carpet maker, Carpet manufacturer, Carpet weaver, Chemist, Chief prothonotary, Child's shoe maker, China printer, Clerk of the Chancery court, Clerk of the Exchequer, Clerk of the King's bench, Clerk of the Remembrancer, Clerk of the Signet, Clerk of the Survey, Clock and watch maker, Clock case maker, Clock engraver, Clock hand maker, Clock maker, Clock worker, Clockmaker, Clog maker, Clog worker, Clogger, Cloth merchant, Coach smith, Coach tire smith, Cobbler, Colour maker, Colourman, Conveyancer, Cooper, Copper plate engraver, Copper plate maker, Copper plate printer, Copper plate worker, Copper smith, Cordwainer, Cursitor, Cursitor of the Chancery, Deputy registrar, Deputy registrar of the Chancery court, Deputy registrar of the Exchequer, Dial plate painter, Doctor, Doctor in physic, Doctor of medicine, Draper, Drawing instrument maker, Druggist, Dry cooper, Earthenware potter, Enamel dial plate painter, Enamel watch dial plate painter, Engine cutter, Engine maker, Engraver, Examining clerk, Fine drawer, Flower painter, Founder, Foundryman, Gallypot maker, Gate smith, Gold paint maker, Gold seal maker, Goldsmith, Grate maker, Green smith, Grocer, Gun barrel maker, Gun finisher, Gun maker, Gun tacker, Gunlock smith, Gunsmith, Hamburg merchant, Heel cutter, Historical engraver, History painter, Hooper, House carpenter, House lock maker, House wright, Instrument maker, Iron founder, Iron smith, Ivory bookmaker, Jack clock maker, Jack maker, Key smith, Ladies hairdresser, Lady's shoemaker, Lady's spring heel shoemaker, Landscape painter, Leather clog maker, Letter engraver, Letter press printer, Linen draper, Linen merchant, Lock filer, Lock forger, Lock maker, Locksmith,

Mans mercer, Mathematical instrument maker, Medal engraver, Mercer, Merchant, Merchant adventurer, Merchant of the Staple, Merchant traveller, Metal print maker, Mezzotint engraver, Mezzotint scraper, Miniature painter, Money scrivener, Movement maker, Music engraver, Notary, Notary public, Optical instrument maker, Optical turner, Oyster cooper, Oyster merchant, Padlock maker, Painter, Painter stainer, Pattern drawer, Pattern maker, Pawnbroker, Periwig maker, Perule maker, Pharmacist, Phlebotomist, Physician, Pistol filer, Pistol finisher, Pistol maker, Plate engraver, Plate locksmith, Pocket book lock maker, Portrait engraver, Portrait painter, Pot maker, Potter, Practitioner in physic, Procourator general of the Arches, Print drawer, Print engraver, Print seller, Printer, Proctor, Procurator, Procurator general, Procurator general of the Arches, Procurator of the Arches court, Procurator of the Chancery court, Prothonotary, Pump maker, Pump man, Registrar, Remembrancer, Repeating watch movement maker, Rim locksmith, Rolling press printer, Saw cutler, Scissors smith, Sea cooper, Seal engraver, Set cooper, Shear smith, Ship smith, Shoe binder, Shoeing smith, Shoemaker, Silver spoon maker, Silversmith, Small worker in silver, Smith, Solicitor, Solicitor at law, Spectacle frame maker, Spectacle maker, Square man, Square wright, Statuary, Steel engraver, Steel watch chain maker, Steel watch maker, Stock lock maker, Stock locksmith, Stone seal engraver, Surgeon, Sworn clerk, Timber man, Timber merchant, Tyre maker, Tyre smith, Watch balance maker, Watch cap maker, Watch case joint finisher, Watch case maker, Watch chain maker, Watch engraver, Watch finisher, Watch gilder, Watch glass cutter, Watch glass grinder, Watch glass maker, Watch hand maker, Watch jeweller, Watch key maker, Watch maker, Watch motion maker, Watch movement maker, Watch piercer, Watch pillar maker, Watch pinnion maker, Watch plate enameler, Watch spring maker, Watch timer, Watch tool maker, Watch verge maker, Watch wheel maker, Watch wire maker, Water carpenter, West India merchant, Wet cooper, White cooper, White iron smith, White smith, Whitesmith, Wholesale linen draper, Wig maker, Wine cooper, Wine hooper, Woman's shoemaker, Wood cutter, Woollen clothier, Woollen draper, Wright, Writer, Writer to the Signet, Writing engraver.

**Mathematics:** Architect, Auger smith, Bed joiner, Blacksmith, Bolt maker, Bright smith, Builder, Captain, Carpenter, Chemist, Cloth merchant, Coach smith, Coach tire smith, Commander, Copper smith, Dockyard foreman, Doctor, Doctor in physic, Doctor of medicine, Drawing instrument maker, Engine cutter, Engine maker, Foreman, Free stone mason, Freemason, Gate smith, Grate maker, Green smith, Grocer, Gun barrel maker, Gun finisher, Gun maker, Gun tacker, Gunlock smith, Gunner, Gunsmith, Hamburg merchant, House carpenter, House joiner, House wright, Hoy man, Instrument maker, Iron smith, Jack maker, Joiner, Jointer, Joner, Keel maker, Land surveyor, Linen merchant, Mans mercer, Mariner, Mason, Master mariner, Mate, Mathematical instrument maker, Mercer, Merchant, Merchant adventurer, Merchant mariner, Merchant of the Staple, Merchant traveller, Notary, Notary public, Optical instrument maker, Optical turner, Oyster merchant, Pawnbroker, Physician, Pistol filer, Pistol finisher, Pistol maker, Practitioner in physic, Quartermaster, Rough mason, Sailor, Saw cutler, Scissors smith, Shear smith, Ship builder, Ship carpenter, Ship joiner, Ship maker, Ship master, Ship smith, Ship wright, Ship's commander, Shipwright, Shoeing smith, Smith, Spectacle frame maker, Spectacle maker, Square man, Square wright, Stone mason, Timber man, Timber merchant, Tyre maker, Tyre smith, Upholsterer's joiner, Water carpenter, West India merchant, White iron smith, White smith, Whitesmith, Woollen clothier, Woollen draper, Wright.

## H Maps of Apprentices, Schools and Charity

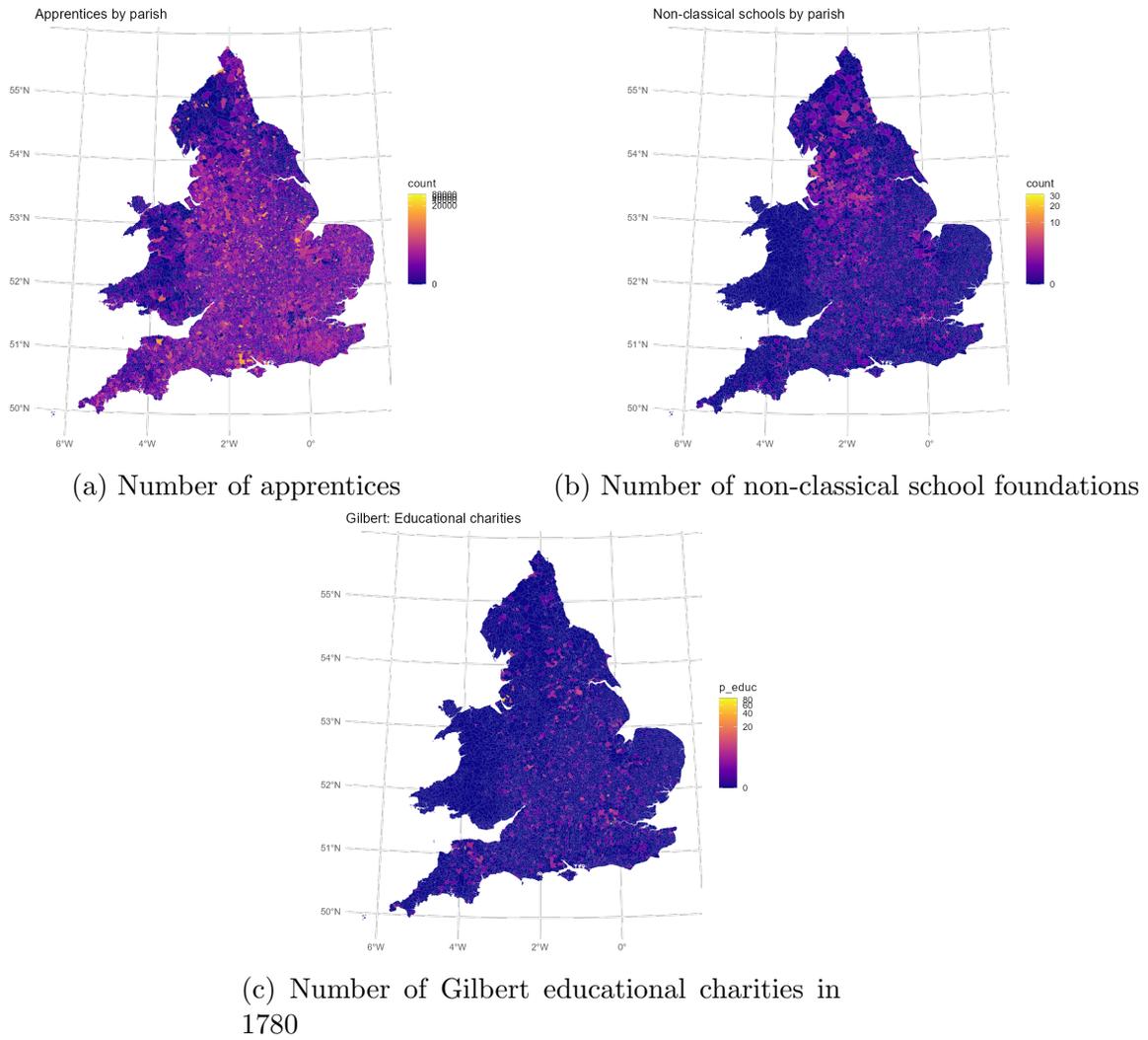
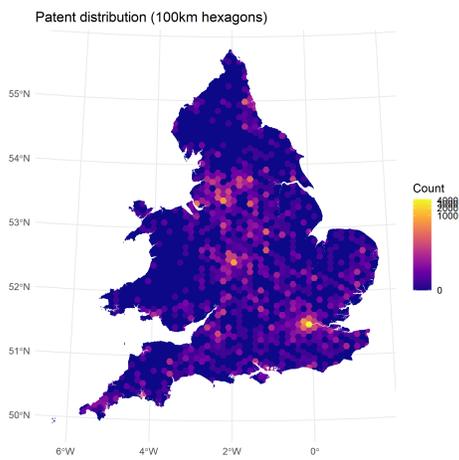
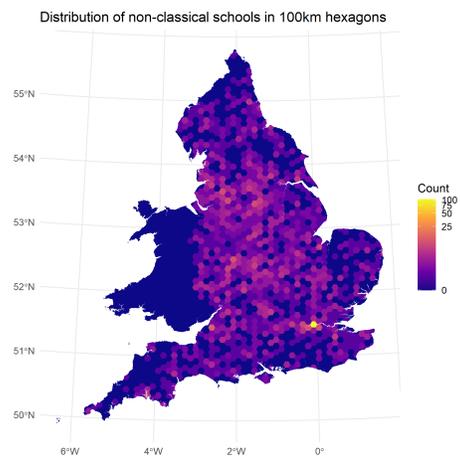


Figure 15: Parish level spatial distribution of outcomes and treatment *Notes: Patent numbers and citations from [Nuvolari and Tartari \(2011\)](#).*



(a) Number of patents



(b) Number of non-classical school foundations

Figure 16: 100km<sup>2</sup> hexagon spatial distribution of outcomes and treatment

# I The association between grammar schooling and apprenticeship, 1786–1805

Table I.1: The association between grammar schooling and apprenticeship, 1786–1805

	Apprentices			Reading and writing			Mathematics			Reading, writing, mathematics		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Grammar school, 1786	0.561*** (0.0744)		0.550*** (0.0739)	0.591*** (0.0701)	0.578*** (0.0695)	0.599*** (0.0634)	0.590*** (0.0628)	0.586*** (0.0631)	0.590*** (0.0628)	0.586*** (0.0631)	0.577*** (0.0624)	0.577*** (0.0624)
Apprenticeship charity		0.0476 (0.0432)	0.0461 (0.0433)		0.0345 (0.0408)	0.0329 (0.0407)		0.00885 (0.0386)	0.00726 (0.0383)	0.00364 (0.0379)	0.00364 (0.0379)	0.00208 (0.0375)
Educational charity		0.100*** (0.0296)	0.0898*** (0.0292)		0.0781*** (0.0279)	0.0672** (0.0274)		0.0770*** (0.0242)	0.0660*** (0.0235)	0.0657*** (0.0235)	0.0657*** (0.0235)	0.0548** (0.0229)
Poor Relief charity		-0.00177 (0.0158)	-0.00133 (0.0158)		0.0120 (0.0140)	0.0125 (0.0140)		0.00182 (0.0129)	0.00230 (0.0129)	0.00548 (0.0124)	0.00548 (0.0124)	0.00594 (0.0124)
Other charities	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Unknown	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Pre-development	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geography	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6938	6938	6938	6938	6938	6938	6938	6938	6938	6938	6938	6938
R-squared	0.54	0.53	0.54	0.48	0.47	0.48	0.41	0.40	0.41	0.40	0.38	0.40

Notes: All reported variables are transformed by the inverse hyperbolic sine function, except for indicator variables. Standard errors are robust to control for heteroscedasticity. \* Significant at 10%; \*\* significant at 5%; \*\*\* significant at 1% level.

## J Summary statistics cross section

Table J.1: Summary statistics for Table 5.1

Variable	Obs	Mean	Std. Dev.	Min	Max
Number of apprentices	6,938	9.01	39.49	0	1,223
Apprentices requiring reading and writing	6,938	4.33	18.41	0	597
Apprentices requiring mathematics	6,938	2.25	9.70	0	297
Apprentices requiring reading, writing, and mathematics	6,938	1.91	7.72	0	214
Non-classical school (1786)	6,938	0.14	0.35	0	1
Non-classical school (date unknown)	6,938	0.01	0.12	0	1
Grammar school (1786)	6,938	0.07	0.25	0	1
Parishes with charity for apprenticeship	6,938	0.18	0.66	0	12
Parishes with charity for education	6,938	0.48	2.04	0	94
Parishes with charity for hospital	6,938	0.05	0.73	0	39
Parishes with charity for church	6,938	0.10	0.47	0	13
Parishes with charity for loan	6,938	0.03	0.39	0	18
Parishes with charity for the poor	6,938	3.57	6.89	0	114
Parishes with charity for roads	6,938	0.01	0.10	0	4
Parishes with charity for fuel	6,938	0.07	0.55	0	17
Land quality	6,938	19.66	26.52	0	100
River	6,938	0.49	0.50	0	1
Longitude	6,938	52.16	1.02	49.98	55.78
Latitude	6,938	-1.05	1.50	-5.69	1.72
Rainfall	6,938	731.81	165.57	504	1,837.23
Ruggedness	6,938	4.36	2.08	1.27	23.91
Size of parish (km <sup>2</sup> )	6,938	14.48	19.78	0.01	426.46
Temperature	6,938	9.63	0.52	6.35	11.07
Wales	6,938	0.01	0.08	0	1
Scotland	6,938	0.00	0.03	0	1
Landlocked	6,938	0.87	0.33	0	1
Carbon share	6,938	8.06	25.45	0	100
Port	6,938	0.03	0.17	0	1
Church	6,938	0.16	0.37	0	1
Roman road	6,938	0.25	0.43	0	1
Distance to nearest town, 1680	6,938	5.49	2.84	0.02	20.17
Distance to nearest monastery, 1535	6,938	7.01	4.41	0	40.93

*Notes:* The table presents summary statistics for the main variables used in the analyses conducted in Section 5.1. Skill-intensive apprenticeship outcomes are defined based on whether trades required reading and writing, mathematics, or both.

# K Chen and Roth transformation

Table K.1: The association between schooling and apprenticeship, 1786–1805

	Apprentices			Reading and writing			Mathematics			Reading, writing, mathematics		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Non-classical school, 1786	0.217*** (0.0483)		0.198*** (0.0489)	0.206*** (0.0449)		0.189*** (0.0454)	0.164*** (0.0425)		0.150*** (0.0426)	0.176*** (0.0407)		0.164*** (0.0408)
Non-classical school, date unknown	-0.0190 (0.117)		-0.0320 (0.118)	-0.00110 (0.113)		-0.0154 (0.112)	-0.140 (0.113)		-0.151 (0.112)	-0.121 (0.114)		-0.132 (0.113)
Apprenticeship charity		0.0443 (0.0404)	0.0431 (0.0403)		0.0301 (0.0381)	0.0290 (0.0380)		0.00615 (0.0364)	0.00531 (0.0363)		0.00158 (0.0358)	0.000660 (0.0357)
Educational charity		0.0949*** (0.0274)	0.0811*** (0.0278)		0.0751*** (0.0262)	0.0618** (0.0265)		0.0747*** (0.0229)	0.0652*** (0.0228)		0.0637*** (0.0224)	0.0530** (0.0224)
Poor Relief charity		-0.00492 (0.0155)	-0.00365 (0.0154)		0.00919 (0.0138)	0.0104 (0.0137)		0.000161 (0.0128)	0.000920 (0.0126)		0.00375 (0.0123)	0.00464 (0.0122)
Other charities	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Unknown	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Pre-development	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geography	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6938	6938	6938	6938	6938	6938	6938	6938	6938	6938	6938	6938
R-squared	0.53	0.53	0.53	0.47	0.47	0.47	0.40	0.40	0.40	0.38	0.38	0.38

Notes: All variables are transformed according to the [Chen and Roth \(2024\)](#) transformation, except for indicator variables. Standard errors are robust to control for heteroscedasticity. \* Significant at 10%; \*\* significant at 5%; \*\*\* significant at 1% level.

## L Spatial unit roots adjustments

Table L.1: Spatial unit roots adjustments

	Apprentices	Reading and writing	Mathematics	Reading, writing, mathematics
	(3)	(6)	(9)	(12)
Non-classical school, 1786	0.2356*** (0.0667) [0.0624, 0.4089]	0.2193*** (0.0473) [0.0965, 0.3421]	0.1786*** (0.0371) [0.0823, 0.2749]	0.1898*** (0.0367) [0.0946, 0.2850]
Non-classical school, date unknown	0.0139 (0.1564) [-0.4146, 0.4425]	0.0892 (0.1270) [-0.2589, 0.4372]	-0.0855 (0.1461) [-0.4859, 0.3149]	-0.0354 (0.1663) [-0.4911, 0.4202]
Apprenticeship charity	0.1592 (0.1241) [-0.1631, 0.4816]	0.1264 (0.1098) [-0.1588, 0.4116]	0.0661 (0.1129) [-0.2271, 0.3594]	0.0627 (0.1091) [-0.2205, 0.3460]
Educational charity	0.0579 (0.0491) [-0.0696, 0.1855]	0.0354 (0.0433) [-0.0770, 0.1477]	0.0434 (0.0365) [-0.0513, 0.1382]	0.0272 (0.0360) [-0.0664, 0.1207]
Poor relief charity	0.0024 (0.0377) [-0.0954, 0.1002]	0.0172 (0.0338) [-0.0704, 0.1049]	0.0125 (0.0284) [-0.0613, 0.0863]	0.0168 (0.0287) [-0.0578, 0.0914]
Other charities	Yes	Yes	Yes	Yes
Unknown	Yes	Yes	Yes	Yes
Pre-development	Yes	Yes	Yes	Yes
Geography	Yes	Yes	Yes	Yes
Observations	6938	6938	6938	6938
R-squared	0.54	0.48	0.41	0.40

*Notes:* Standard errors are reported in parentheses. 95% confidence intervals are reported in brackets. \* Significant at 10%; \*\* significant at 5%; \*\*\* significant at 1% level.

## M Patent data

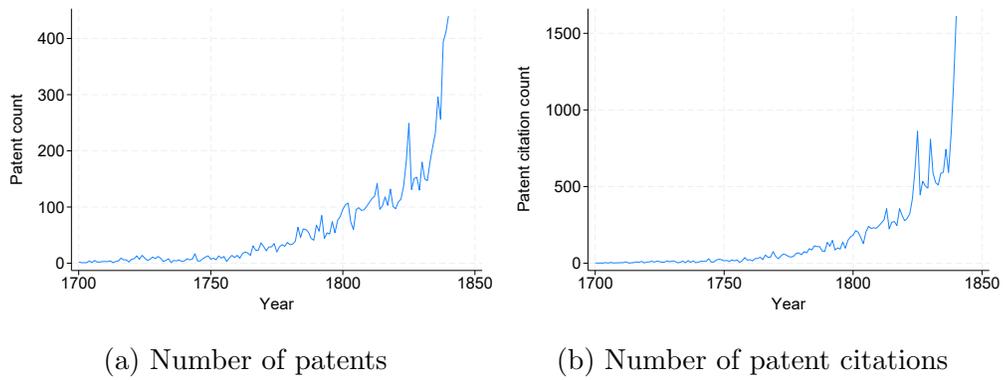


Figure 17: Long-run trend in English patenting *Notes: Patent numbers and citations from [Nuvolari and Tartari \(2011\)](#).*

## N Results for the service and retail sector

Previously, our baseline specification in Figure 6 has presented results for apprenticeships across all sectors. Results from Figure 9 have additionally shown robustness to restricting the analysis to apprenticeships within the secondary sectors.

For completeness, this Section also presents results for apprenticeships in the service and retail sector. Figure 19 presents significant treatment effects of schooling for the retail sector. Yet, for the service sector in Figure 19, we do not find significant evidence of treatment effects.

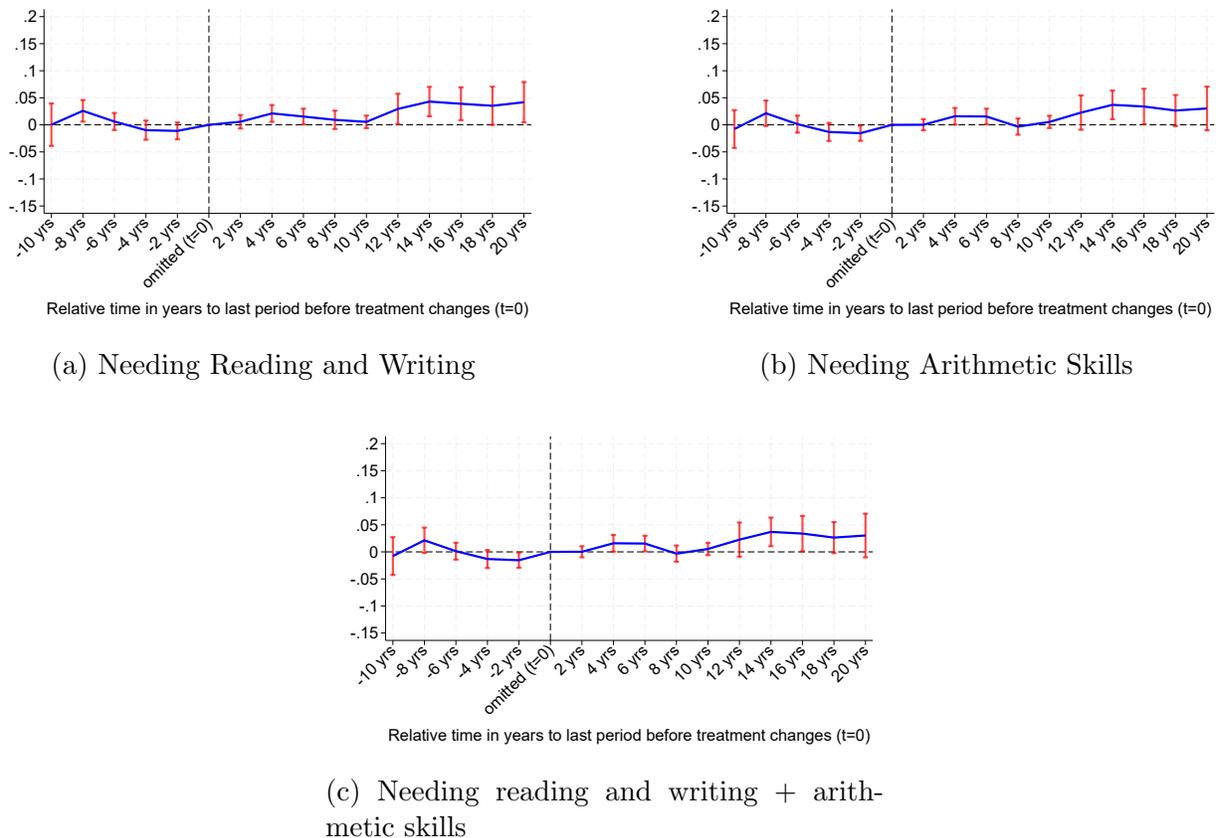
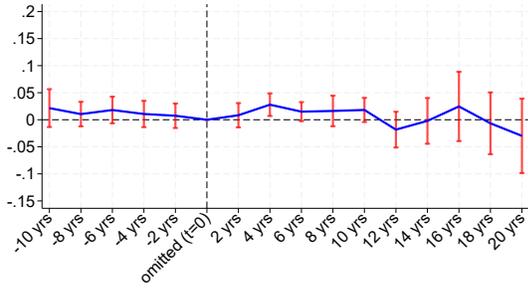


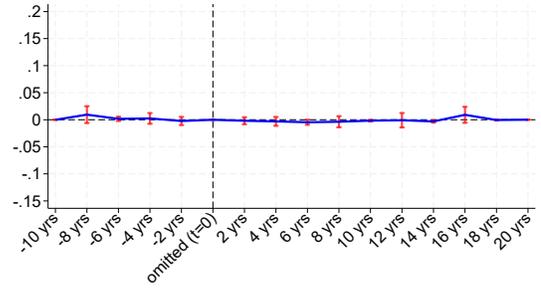
Figure 18: Results for the retail sector

*Notes:* Difference-in-differences results for the foundation events of non-classical schools and educational charities within a [10,20] pre- and post-treatment year window. The outcome captures apprentices working in the retail sector. Estimated using the estimator from [de Chaisemartin et al. \(2024\)](#). The unit of analysis is the parish  $\times$  two-year period level. Treatment is provided by the ordinal number of school foundations and educational legacies from wills. Standard errors are clustered at the parish-level.  $N = 18,003$ . 90% confidence intervals provided.



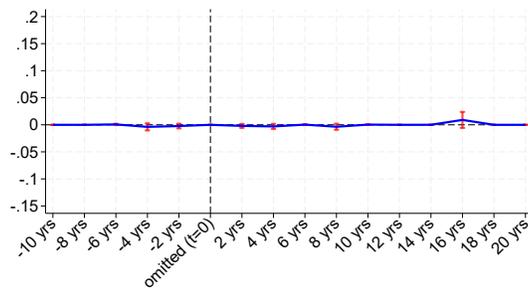
Relative time in years to last period before treatment changes (t=0)

(a) Needing Reading and Writing



Relative time in years to last period before treatment changes (t=0)

(b) Needing Arithmetic Skills



Relative time in years to last period before treatment changes (t=0)

(c) Needing reading and writing + arithmetic skills

Figure 19: Results for the service sector

*Notes:* Difference-in-differences results for the foundation events of non-classical schools and educational charities within a [10,20] pre- and post-treatment year window. The outcome captures apprentices working in the service sector. Estimated using the estimator from [de Chaisemartin et al. \(2024\)](#). The unit of analysis is the parish  $\times$  two-year period level. Treatment is provided by the ordinal number of school foundations and educational legacies from wills. Standard errors are clustered at the parish-level.  $N = 18,003$ . 90% confidence intervals provided.

## O Stacked difference-in-differences

### Empirical framework

We can further make the analysis more restrictive by performing the analysis only within small time periods in which we believe the timing of death to be plausibly random. For this, we implement a stacked difference-in-differences approach (Cengiz et al., 2019) where for each school foundation event through a will  $T_i$ , we create stacks around a narrow time frame,  $[t_i - \tau, t, t_i + \tau]$ . Clean controls units are defined as all units that a) did not experience a change in school treatment (either through a will or other forms of endowments) during  $[t_i - \tau, t, t_i + \tau]$  and also did not receive educational charity during  $[t_i - \tau, t, t_i + \tau]$ . We estimate the following model

$$\text{Apprent}_{it} = \sum_{\tau=-12}^{10} \sum_{s \in S} \beta_{\tau,s} \cdot \text{School}_{it} \cdot \mathbb{1}(t - E_e = \tau) + \gamma_{si} + \alpha_{st} + \varepsilon_{it} \quad (4)$$

where similar to equation 2, the outcome  $\text{Apprent}_{it}$  denotes the number of apprentices requiring skills in (i) reading and writing (ii) arithmetics or (iii) reading, writing, and arithmetics in parish  $i$  and two-year period  $t$ . Stacks  $S$  are then defined around each event,  $E_e$ , of a school foundation requiring estimated windows to have a maximum length of 22 years (12 pre-treatment and 10 post treatment periods).<sup>14</sup> For each stack,  $s$ , an indicator  $\text{School}_{it}$  variable captures treatment.  $\gamma_{si}$  and  $\alpha_{st}$  denote parish,  $i$ , and time-,  $t$ , fixed effects specific to each stack  $s$ . Clean controls are defined as above. The stacked difference-in-difference estimator is then estimated by pooling stacks  $s \in S$  together and estimating equation 4.

Then, as long as death events are as good as random within  $t_i \in [t_i - \tau, t_i + \tau]$  we expect conditional mean independence:

$$\mathbb{E}[\varepsilon_{it} \mid T_{it-\tau}, \gamma_{si}, \alpha_t] = \mathbb{E}[\varepsilon_{it} \mid \gamma_{si}, \alpha_t] \quad (5)$$

---

<sup>14</sup>Including one omitted period before treatment, this leads to symmetrical pre- and post-treatment periods.

Given that out of out of the sub-sample of famous people in the eighteenth century, 80% died between ca. 45 and 80 years, and 50% died between ca. 52 and 75 years (De la Croix and Licandro, 2015), we argue that a 22 year period (12 pre-treatment and 10 post-treatment periods) is sufficiently narrow to capture random variation from death and discuss results from this specification in the following subsection.

However, we additionally present results for a 10 year period (6 pre-treatment and 4 post-treatment periods) in Appendix Figure 21.

## Results

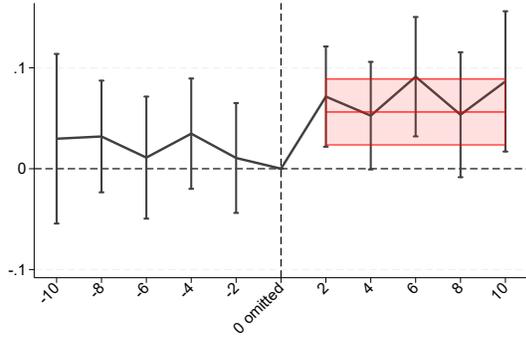
Figure 20 reports the results. We report both dynamically estimated coefficient for each two-year period pre- and post treatment (in grey) as well the estimated coefficient from a two-period stacked difference-in-differences (in red). We find significant results for apprentices requiring skills in a) reading and writing, b) arithmetics, and c) reading, writing, and arithmetics. We find that an additional school foundation led to a 6% increase in the number of apprentices requiring reading and writing skills. For arithmetics, we find evidence a 3% increase and for reading, writing, and arithmetics we find a 4% increase.

Results are comparable in size to the previous results from the staggered difference-in-differences design from section 5.2. Note that the immediate effects of school foundations in the stacked difference-in-difference approach are slightly larger as we would expect since treatment here only captures school foundation and excludes education charity. Since educational charity usually had a lower monetary value than school foundations, we expect a smaller effect.

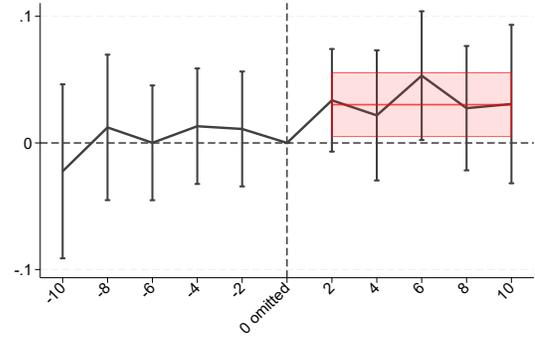
Next, Figure 21 also reports results for narrower time windows per stack. Overall, we estimate results for a 10 year period window with 6 pre-treatment and 4 post-treatment years. Within this very narrow period, we are very confident that donor deaths were as good as random. The estimated results are highly compatible with the previous 20-year period results from Figure 20. Note that results for apprentices needing arithmetic skills are not significant, however the effect size is similar to that in Figure 20. This is unsurprising since

coefficients for apprentices needing arithmetic skills in Figure 20 are also insignificant before the 6<sup>th</sup> year post treatment. Overall, we take the results from Figure 21 as confirmation that our results still hold within a very narrow frame where the exact timing of a donor's death would have been impossible to predict.

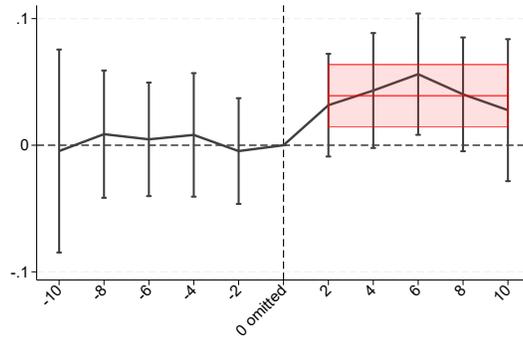
Overall, both the staggered difference-in-differences results from Figure 20 and the stacked difference-in-differences results from appendix Figure 20 show that non-classical school foundations led to an increased formation of craftsmen at the upper-tail of human capital who had the skills necessary for implementing the technological innovations of the Industrial Revolution (Mokyr, 2002, 2016).



(a) Needing reading and writing

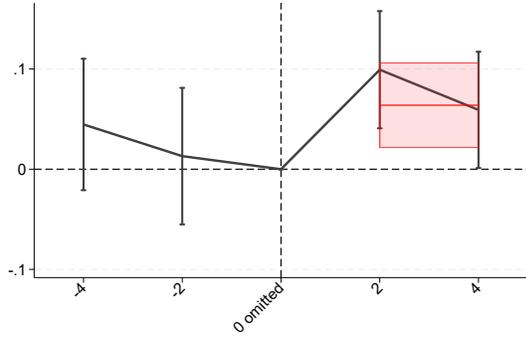


(b) Needing arithmetic skills

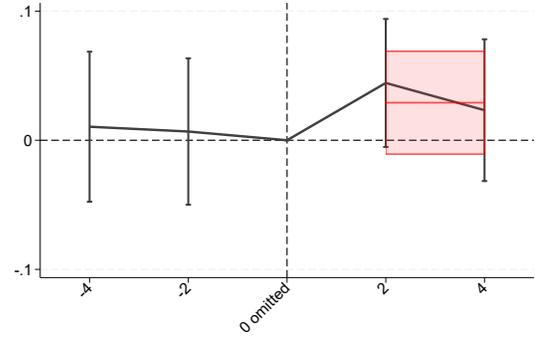


(c) Needing reading, writing and arithmetic skills

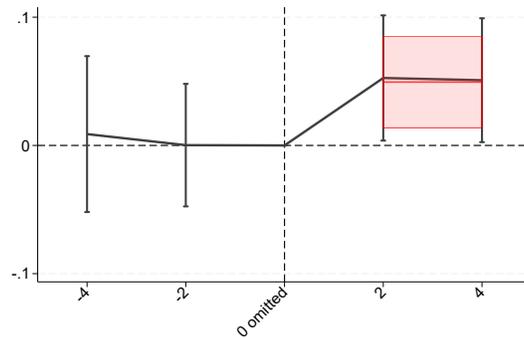
Figure 20: Stacked difference-in-differences results for non-classical schools. *Notes: Stacked difference-in-differences results (Cengiz et al., 2019) estimated from equation 4. The unit of analysis is the stack  $\times$  parish  $\times$  two-year period level. Treatment is provided by school foundations. Clean controls are constrained to units that did not receive a school foundation through wills, or other forms of endowments or any type of educational charity in stack window  $[t_i - \tau, t, t_i + \tau]$ . The outcomes are transformed using a inverse hyperbolic sine transformation ( $\text{arcsinh}$ ). Coefficients in gray reported for the dynamic stacked difference-in-differences model with two-year periods. Average treatment for the post period from a two period stacked difference-in-differences model reported in red. Estimated for the sample period 1710–1784.  $N = 244,289$ . Standard errors are clustered at the parish-level. 90% confidence intervals provided.*



(a) Needing reading and writing



(b) Needing arithmetic skills



(c) Needing reading, writing and arithmetic skills

Figure 21: Stacked difference-in-differences results for non-classical schools for a 10 year period. Notes: Stacked difference-in-differences results (Cengiz et al., 2019) estimated from equation 4. The unit of analysis is the stack  $\times$  parish  $\times$  two-year period level. Treatment is provided by school foundations. Clean controls are constrained to units that did not receive a school foundation through wills, or other forms of endowments or any type of educational charity in stack window  $[t_i - \tau, t, t_i + \tau]$ . The outcomes are transformed using an inverse hyperbolic sine transformation ( $\text{arcsinh}$ ). Coefficients in gray reported for the dynamic stacked difference-in-differences model with two-year periods. Average treatment for the post period from a two period stacked difference-in-differences model reported in red. Estimated for the sample period 1710–1784.  $N = 152,028$ . Standard errors are clustered at the parish-level. 90% confidence intervals provided.

## P Testing for linear pre-trends

Here, we adapt the model from Equation 2 to linear outcomes. This allows us to test for the presence of linear pre-trends (see [Abadie et al., 2025](#)). Results are presented in Figure 22. We do not find evidence of linear pre-trends.

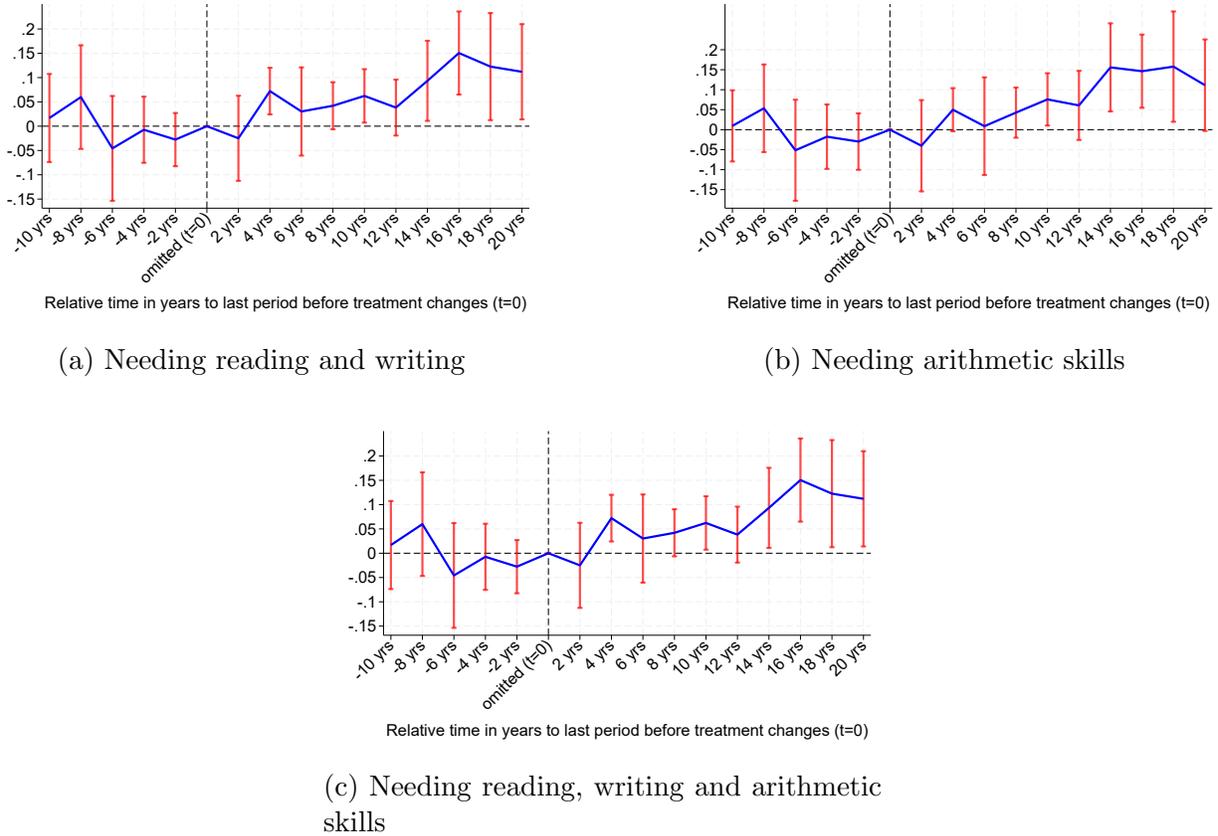


Figure 22: The effect of educational legacies on highly skilled artisans — linear outcomes  
*Notes:* Difference-in-differences results for the foundation events of non-classical schools and educational charities within a [10,20] pre- and post-treatment year window. Outcome variables are measured in levels. Estimated using the estimator from [de Chaisemartin et al. \(2024\)](#). The unit of analysis is the parish  $\times$  two-year period level. Treatment is provided by the ordinal number of school foundations. Standard errors are clustered at the parish-level.  $N = 18,003$ . 90% confidence intervals provided.

## Q Robustness: Alternative transformation for the dependent variable

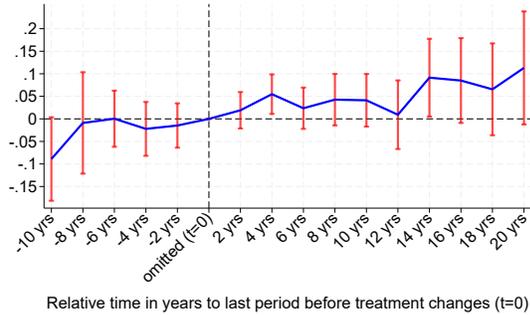
To account for the scale-dependence of transformations like  $\log(1 + x)$  or the inverse hyperbolic sine transformation, we follow [Chen and Roth \(2024\)](#) in explicitly defining the relation between the extensive and intensive margin.

We explicitly model the trade-off between the extensive and intensive margin as follows:

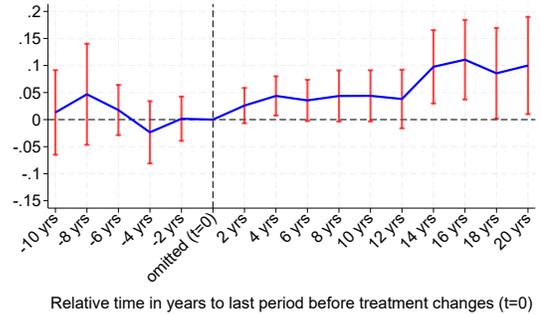
$$f(y) = \begin{cases} m(y) = \log(y) & \text{if } y > 0, \\ m(0) = -1 & \text{if } y = 0. \end{cases} \quad (6)$$

where an increase from 0 to 1 equals a 100% increase in the dependent variable.

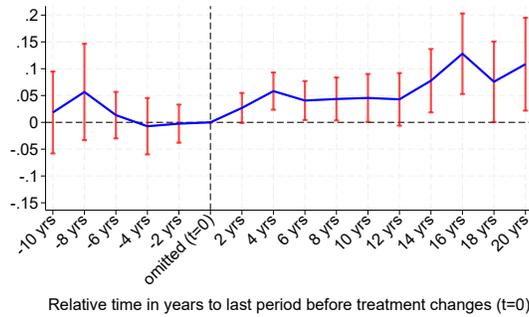
We then repeat estimating our baseline results from equation 2 and Figure 6 with outcomes that are transformed using the [Chen and Roth \(2024\)](#) specification from equation 6. Results are presented in Figure 23. We find that our results are almost identical to the use of the hyperbolic sine transformation in our baseline results.



(a) Needing reading and writing



(b) Needing arithmetic skills



(c) Needing reading, writing and arithmetic skills

Figure 23: The effect of educational legacies on highly skilled artisans — outcomes transformed using the transformation from equation 6

*Notes:* Difference-in-differences results for the foundation events of non-classical schools and educational charities within a [10,20] pre- and post-treatment year window. Outcome variables are transformed using the [Chen and Roth \(2024\)](#) transformation from equation 6. Estimated using the estimator from [de Chaisemartin et al. \(2024\)](#). The unit of analysis is the parish  $\times$  two-year period level. Treatment is provided by the ordinal number of school foundations. Standard errors are clustered at the parish-level.  $N = 18,003$ . 90% confidence intervals provided.

## R Robustness: Sample restriction 1754–1784

As discussed in data Section 4, our apprenticeship data has gaps for the years 1721–22, 1726–40, and 1746–52. Given that our differences-in-differences results are estimated across these gap, we naturally need to consider compositional bias from these gaps in the data.

To mitigate these concerns, we restrict our analysis to the period 1754–1784 for which we have a complete set of apprenticeship records for all years. Results are presented in Figure 24. Reassuringly we find that results are very similar to our baseline results for the full period in Figure 6.

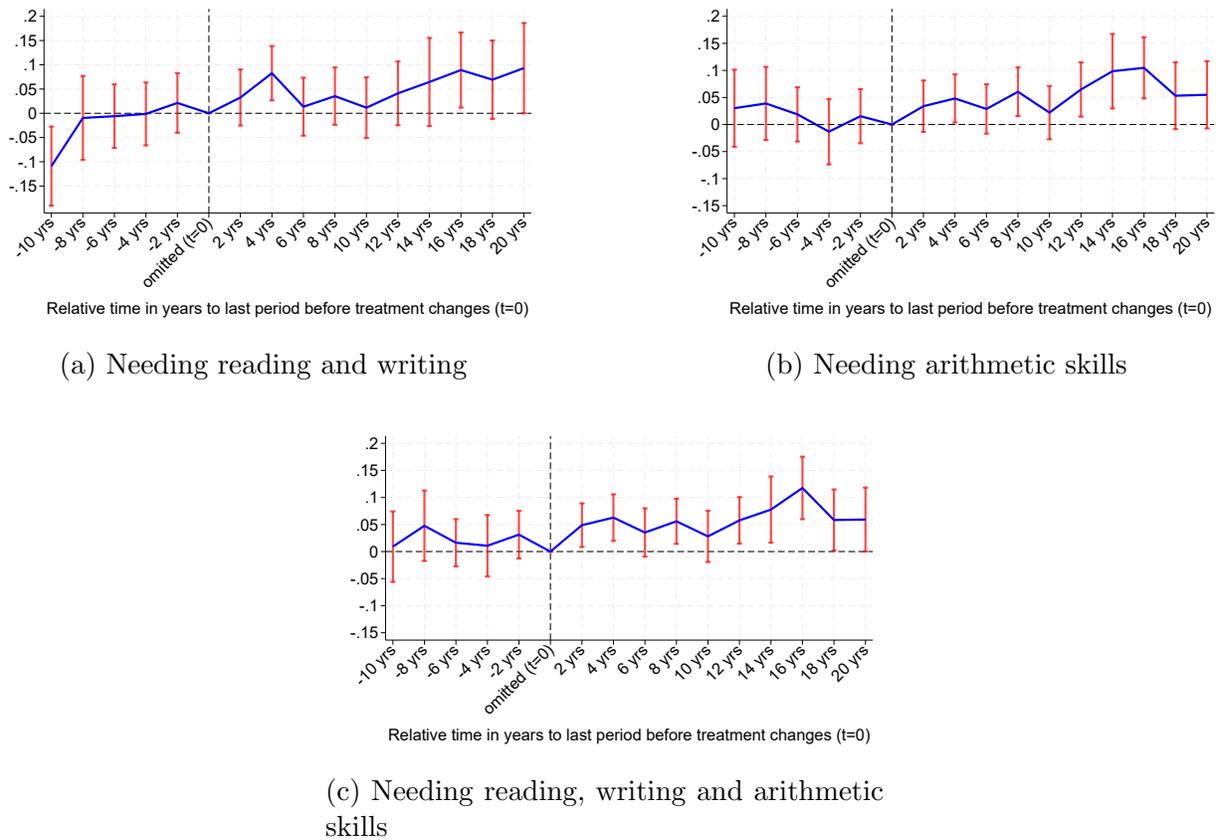


Figure 24: The effect of educational legacies on highly skilled artisans — estimated on 1754–1784 sample

*Notes:* Difference-in-differences results for the foundation events of non-classical schools and educational charities within a [10,20] pre- and post-treatment year window. Results are estimated for the restricted sample of 1754–1784. Estimated using the estimator from [de Chaisemartin et al. \(2024\)](#). The unit of analysis is the parish  $\times$  two-year period level. Treatment is provided by the ordinal number of school foundations. Standard errors are clustered at the parish-level.  $N = 18,970$ . 90% confidence intervals provided.