Teacher-directed scientific change: The case of the English Scientific Revolution*

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Abstract

While economic factors in directed technical and scientific change have been widely studied, the role of teacher-directed scientific change has received little attention. This paper studies teacher-directed scientific change for one of the largest changes in the direction of research, the Scientific Revolution. Specifically, the paper considers the case of the English Scientific Revolution at the universities of Oxford and Cambridge during 1600–1720. It argues that exposure to different teachers shaped students' direction of research and can partly account for the successful trajectory of English science. For this, the paper introduces a novel dataset on the universe of 111,242 students at the universities of Oxford and Cambridge and their publications. Using natural language processing, the paper derives a measure of researchers' direction of research. To derive causal estimates of teacher-student effects, the paper uses an instrumental variable design that predicts students' choice of college based on their home regions, a stacked differences-in-differences approach based on teachers leaving their college, and a natural experiment based on the expulsion of teachers following the English Civil War. The results illustrate how teacher-directed change can contribute to paradigm change.

Keywords: Directed Technical Change, Economic History, Knowledge Diffusion, Innovation, Human Capital, Natural Language Processing
JEL Classification: N33, I23, O33, O31, O43, O14

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1 Introduction

"whenever I am thinking of a character, in public life it may be, or in literature, I always ask 'What was happening in the world when he was twenty?' (. . .) To the twenties I go for the shaping of ideas not fully disclosed: to the forties for the handling of things already established"

(George Malcolm Young 1949, p. 49 as cited in Hunter, 1995)

"If I have seen further it is by standing on ye sholders of Giants"

(Isaac Newton, 1675)

Can teachers influence the direction of scientific change? Until recently, the literature on directed technical and scientific change has focused on economic factors such as factor prices or market size (Acemoglu, 2002; Allen, 2009). Recently, Acemoglu and Johnson (2023) have argued that the direction of technical and scientific change also depends on institutional and ideological factors (see also Acemoglu, 2023). Acemoglu and Johnson (2023) further argue that institutions of higher learning play an important role in shaping the direction of technology and science that their graduates will pursue. While the curriculum at universities is known to be an important factor in shaping the beliefs of graduates (Cantoni et al., 2017; Acemoglu, He and Le Maire, 2022), the influence of teachers beyond the formal curriculum is significantly understudied. This paper argues that students' exposure to teachers' research interests can determine teacher-directed scientific change. Teacher-directed scientific change might be especially important for the adoption of new ideas and new paradigms that are not part of the official curriculum yet.

As an ideal test case for the role of individual teachers in students' adoption of new ideas and new paradigms, the paper studies one of the largest shifts in the direction of research, the Scientific Revolution. Specifically, the paper studies how university teachers at the English universities of Oxford and Cambridge who adopted ideas from the Scientific Revolution influenced the direction of their students' research. Between 1600 and the early 1700s, these universities educated hundreds of important innovators in science, such as e.g. Isaac Newton, Robert Hooke, John Flamsteed, or Edmond Haley. They crucially changed our understanding of natural science by innovating on topics such as laws of motion, universal gravitation, optics, and the application of early microscopes. By doing this, they broke with traditional ideas about how to approach nature, how to generate knowledge, and how to perceive the world. Altogether, the new ideas from the Scientific Revolution laid the foundation for science driven-growth and industrialization (Mokyr, 2002, 2016; Jacob, 1997, 2014; Hanlon, 2022).

Yet, the role of the English universities in the Scientific Revolution is heavily debated in the historical literature. A defining feature of this period is that the universities did not adapt their curriculum to the new ideas of the Scientific Revolution. Therefore, some historians have argued that the universities were places where one would learn everything but the ideas of the Scientific Revolution (Hill, 1965, 1968; Manuel, 1968; Westfall, 1983). Richard Westfall even described seventeenth century Cambridge as "fast approaching the status of an intellectual wasteland" (Westfall, 1983, p. 190). However, other historians have argued that the curriculum itself was less important than teachers' academic interests and real-life interaction with their students in the colleges (Curtis, 1959; Shapiro, 1969; Jacob and Jacob, 1980; Gascoigne, 1985, 1990; Jacob, 1997; Feingold, 1997). This paper adds quantitative evidence to this debate, estimating teacher-student effects based on teacher-student interaction at the colleges. These estimates of teacher-student effects allow us to re-evaluate whether early modern universities served as catalysts of intellectual change. Thereby, the paper contributes to our understanding of which institutions mattered for the emergence of a modern knowledge economy (Jacob, 1999; Mokyr, 2002, 2016, 2024; Dittmar, 2019; Curtis and De la Croix, 2023).

To quantify teachers' and students' direction of research, the paper matches novel data on the universe of all students at the English universities of Oxford and Cambridge to the universe of all publication titles in Britain.[1] By applying an automatic text-processing routine to the registers of the university of Oxford and Cambridge compiled by Foster (1891) and Venn and Litt (1952), the paper has created a new dataset on the names, degrees, places of origin, and life outcomes of all the 111,242 students and teachers at the universities of Oxford and Cambridge between 1600 and 1800. The students are then matched to the universe of all ∼470,000 English publication titles from the English Short Title Catalogue (ESTC). The paper then classifies the ESTC titles into different research fields using machine learning and state-of-the-art natural language processing techniques that rely on recent advances in large language models (LLMs) (Vaswani et al., 2017; Bommasani et al., 2021). Next, the paper matches students to their teachers based on the college a fellow was teaching at. In seventeenth and eighteenth century Oxford and Cambridge, university teaching was mainly organized at the college level, where college-employed fellows taught, dined, and lived with their students. Hence, teacher treatment occurred at the college-level, not at the university-level.[2]

To estimate the strength of teacher-directed scientific change, the paper defines a teacher's and student's direction of research, v, as a vector of the researcher's strength of research, b, across the dimensions of n research fields, $v = (b_1/n, b_2/n, \dots b_m/n)$. The paper assumes that the Scientific Revolution took place in the subset of the research fields of *astronomy, almanacs, applied physics,*

[1] During the seventeenth and eighteenth century, the universities of Oxford and Cambridge were the only universities in England. There was some competition from dissenting academies that offered a higher education for dissenting students. Dissenting academies were first founded after the Act of Uniformity of 1662 that banned dissenters from attending the universities. Yet, the demand for a higher education of dissenters only really picked up, after the Toleration Act of 1689 that opened a path for dissenters to enter priesthood (Smith, 1954). Still even then, the numbers of students educated at dissenting academies remained small in comparison to the universities (see Queen Mary Centre for Religion and Literature in English, 2023). Furthermore, competition from the Scottish universities before their reforms in the early 1700s appears insignificant (see Gascoigne, 1990, p. 249).

[2] Since all students went through the same arts degree, teacher assignment also did not depend on students' choice of degrees or courses.

mathematics, chemistry, biology, geography, medicine, and scientific instruments.[3] Then, for all fields of the Scientific Revolution, it estimates the effect of teachers' strength of research on students' strength of research in the same field. The average teacher-coefficient across all fields then captures the strength of teacher-directed scientific change. This setup allows for the inclusion of college-, time-, topic-, and student-fixed effects. Student-fixed effects absorb all non-topic-specific student heterogeneity, making this setup ideal for estimating the strength of teacher-directed scientific change.

Yet, estimating causal teacher student effects faces the major challenge of dealing with students' self-selection into different colleges. While a student's choice of college was usually based on non-teacher related factors, such as regional-ties between a student's place of origin and a college, their father's choice of college, a college's religious leaning, or the number of scholarships offered by a college, we still cannot rule out that some students self-selected into colleges based on their teacher's research interests. This would create a spurious association between teacher and student interests due to sorting. The paper uses three different identification approaches to infer causal teacher student effects: 1) an instrumental variable design that exploits the strong-ties between individual colleges and English regions to predict a student's choice of college based on their place of origin, 2) a stacked difference-in-differences approach based on the events of scientific teachers leaving their college, and 3) a quasi-natural experiment based on the politically forced expulsion of teachers and the forced appointment of teachers by Parliament following the English Civil War.

The first identification strategy is based on the historically strong ties between English colleges and English regions. These ties originated from links between grammar schools and colleges as well as preferences for cultural uniformity. Based on this pattern, the paper uses an instrumental variable strategy where a student's home region is used to predict the college he would attend and, consequently, the teachers he would face at the college.[4] The resulting variation is orthogonal to students' individual choices as it is only determined by students' home regions which students would not have been able to influence themselves.

The second identification strategy addresses the possibility that teachers might also have selected into colleges with similarly interested students or into colleges with a similar culture. Therefore, the paper exploits variation from teachers leaving their college, a process that did not involve into-college selection. The paper uses a stacked difference-in-differences approach (Cengiz et al., 2019) around teacher leaving events.

The third identification strategy exploits quasi-random variation from the forced appointment of new fellows at the University of Oxford following the end of the English Civil War. During the First English Civil War (1642-1646), the University of Oxford had sided with the king. Then, after the king's defeat in 1646, victorious Parliament set out to clear the teaching body of the university from any Royal influence by expelling half of all fellows. Thereafter, Parliament needed to appoint

[3] Appendix table 20 lists all other research fields within the text data used by this paper. The paper conducts a wide range of robustness tests to show that the empirical results are robust to using other plausible definitions of the fields of the Scientific Revolution.

[4] Throughout the seventeenth and eighteenth century women were excluded from attending university.

new fellows that were not part of the old Royal university tradition. They were either selected from outside the university (mainly the University of Cambridge) or from students at the University of Oxford that were then conferred to fellowships at different colleges. While it was not random who the visitors appointed, the paper argues that it was quasi-random which colleges the new fellows were sent to. The paper then uses the share of scientific publications of the newly appointed fellows as a treatment shock in a difference-in-difference design. The paper carefully discusses the selection process of new fellows and shows that the distribution of the newly appointed and scientifically interested fellows was unrelated to the prior distribution of scientifically interested fellows at the colleges.

Overall, the paper finds significant evidence of teacher-directed scientific change. Increasing teachers' publication shares in the topics of the Scientific Revolution by 100% led to a 4% increase in student publication shares in the topics of the Scientific Revolution at the University of Oxford and a 2% increase at the University of Cambridge.[5] The paper further introduces multiplier effects from a model of intergenerational transmission of knowledge. Multiplier effects are found to range between 1.064 and 1.031 and would have amplified teacher-student effects in the long run. Altogether, the findings suggest that universities had a modest impact on students' direction of research. Thus, the findings fit into the general history of the Scientific Revolution as a slow and gradual process that developed over a full century while also contradicting the traditional view in history that science did not matter at the English universities.

Moreover, in interpreting this effect of teacher-directed change, it is important to consider that teachers publishing on the Scientific Revolution were still a small minority at seventeenth century Oxford and Cambridge. The chance for an average student to have a teacher in a given field of the Scientific Revolution ranged between 0.5% and 1%. Average teacher publication shares per topic amounted to 0.6% at Oxford and 0.57% at Cambridge. Therefore, a 100% increase in teacher publication shares would have only exposed a small part of students to research on the Scientific Revolution.

Therefore, the paper also considers a counterfactual policy, where universities would have increased teacher publication shares in the Scientific Revolution by one standard deviation leading to an increase in students' publication shares in the Scientific Revolution by 13% at Oxford and 6% at Cambridge.[6] Given that 31% of all publications in seventeenth century England were written by graduates from the universities of Oxford and Cambridge, this would also have translated into a national increase in the share of scientific publications by 3.25%.[7] The counterfactual illustrates

[5] These coefficients are based on results from the stacked difference-in-differences approach.

[6] A one standard deviation increase would have amounted to a 4.42 percentage points in teacher publication shares in the topics of the Scientific Revolution. This would still have been a modest increase that left the fields of the Scientific Revolution in a minority position and would still be significantly below the share of science in nineteenth or twentieth century research universities.

[7] The figure is based on the results of matching students and ESTC authors. It refers to all publications by real people — excluding institutional publications such as e.g. acts of Parliament. For the calculation of the average national shares see section 6.

the potential impact universities could have had on the English Scientific Revolution had there been an institutionally stronger focus on the appointment of scientifically interested teachers.

Overall, the paper contributes to the literature on teacher-directed scientific change, the role of universities in early modern science, and the literature on teacher-student effects in educational economics.

First, the paper provides new insights for the literature on directed scientific change. Up to now we lack quantitative evidence on teacher-directed scientific or technical change. This is surprising since teacher-effects on students' quality of research have been widely recognized. One major contribution to this literature is Waldinger (2010) who uses the dismissal of Jewish scientists from Nazi Germany as an exogenous shock for department quality. He shows that PhD supervisors have a causal effect on the quality of their PhD students' publications. Borowiecki (2022) documents that within classical music teachers had a strong impact on the style of their students across multiple generations. Furthermore, the role of the curriculum on students' ideological beliefs has also been studied intensively, using textbook reforms (Cantoni et al., 2017; Arold, 2022) and the specific law-and-economic programs for judges.

Acemoglu and Johnson (2023) further present evidence of the effect of curriculum changes on students' direction of technical change. They show that the theory of shareholder value taught at business schools in the USA and Denmark changed manager's attitudes towards rent-sharing and generally depressed labor's share of income in the USA and Denmark. This paper provides new evidence of teacher-directed scientific change that can be important even in the absence of changes in the curriculum. It provides causal estimates of university teacher-effects during one of the largest shifts in the direction of scientific research, the Scientific Revolution. Therefore, the results of this paper highlight the potential importance of university teachers in catalyzing ideological shifts and paradigm change that can shape a society's direction of research in the long-run.

The paper further integrates questions raised in educational economics. There, the effect of teacher quality in post-secondary education has been of considerable interest. Borjas (2000), Ehrenberg and Zhang (2005), Bettinger and Long (2004, 2005), Hoffmann and Oreopoulos (2009), and Feld, Salamanca and Zölitz (2018, 2019) find mixed effects of the value-added effects for different university teacher quality. However, these studies only examine student performance within a fixed set of academic standards. Instead, this paper argues that one of the main virtues of university education is igniting students' interest in topics beyond the current curriculum and possibly outside the prevailing mainstream topics. So far, this outcome has received little interest in educational studies.

Additionally, the paper speaks to a growing literature on the general development of university-based science. This literature illustrates how shocks to the institutional settings of university research can have a large impact on scientific and technical productivity. De la Croix et al. (2024) demonstrate that academic labour markets between 1000-1800 were efficient in allocating human capital across universities. Dittmar and Meisenzahl (2021) present evidence that the institutional establishment of the modern research university in the German lands increased inventive activity.

Additionally, Chiopris (2024) finds that changes in scholarly mobility through railroad expansions affected the direction of innovation in nineteenth century Germany. Abramitzky et al. (2024) show that fathers' occupations shaped researchers' direction of research. Lastly, Azoulay, Fons-Rosen and Zivin (2019) study the role of senior researchers in inhibiting the reception of new researcher's ideas in their field. This paper contributes to this literature by investigating how teachers affected the direction of their students' research in the long-run. It suggests that accounting for teachers' direction of research during university hiring processes can be important for shaping the direction of research of the next generation of researchers.

Lastly, the paper contributes to the debate on the role of institutions for early modern knowledge production (Dittmar, 2019; Mokyr, 2024; Grajzl and Murrell, 2024). Early modern knowledge production in scientific topics started to increase significantly in the seventeenth century (Koschnick, 2023). Yet, what were the institutions that supported this expansion of the knowledge base, especially in overcoming forces of tradition (Nunn, 2021; Giuliano and Nunn, 2021)? Scholars have argued that the printing press (Dittmar, 2011, 2019) and networks of correspondence (Lux and Cook, 1998) played a crucial role. The paper argues that teacher-student effects at university, while not sufficient on their own, were an additional institutional factor for transmitting the ideas of the Scientific Revolution across generations. Ultimately, scientific ideas would enter an ever-increasing base of useful knowledge which, according to Mokyr (2002, 2016), formed the basis for the Industrial Revolution and self-sustained economic growth.

In what follows, section 2 provides an overview over the historical debate on the universities and introduces the historical background to the natural experiment of the Parliamentary visitations used in section 2. Section 3 introduces the data and methods from natural language processing to calculate students' direction of research, distance to the research frontier, and innovativeness. Section 4 presents the empirical framework and baseline results. Section 5 introduces three identification designs, a) an in instrumental variable approach based on historical ties between regions and colleges, b) a stacked difference-in-differences approach based on the events of teachers leaving their college, and c) a difference-in-differences approach based on the Parliamentary eviction and appointment of new teachers. Finally, section 6 provides an interpretative framework of multi-generational teacher-student effects and discusses the counterfactual of higher teacher-shares in publication on the Scientific Revolution. Section 7 concludes.

2 Historical Background

This section provides an overview over the historical debate on the impact of English universities on the English Scientific Revolution. It further discusses the historical background of the quasi-natural experiment that exploits the forced appointment of new fellows by Parliament following the English Civil War. For a detailed discussion of student life at the universities of Oxford and Cambridge during the seventeenth century, please refer to appendix section A.

2.1 The Scientific Revolution and the Universities

The Scientific Revolution was one of the largest shifts in the direction of research in history. It is usually dated between the fifteenth century and the beginning of the eighteenth century and is often associated with the names of scientific innovators such as Copernicus, Kepler, Gallilei, Boyle, or Newton. Following the Scientific Revolution's early rise on the continent, especially in Italy, it entered English discourse with the beginning of the seventeenth century (Wootton, 2015).

There are several hypotheses on the origin of the Scientific Revolution. One strain of the literature stresses the role of European discoveries and increasing commercialization that fuelled the demand for technical and scientific innovations (Hessen, 1931) and connected the spheres of the skilled craftsmen with the learned savants of the age (Zilsel and Zilsel, 2003). Another strain of the literature stresses the role of Protestantism and Puritanism (Merton, 1938; Hill, 1964). Eisenstein (1980) argues that the printing press increased the rate of the exchange of ideas. In the same spirit, Dittmar (2019) quantitatively shows that the introduction of the printing press shocked the market of ideas and led to an increase in the study of scientific subjects. Furthermore, historians argued that universities were important for intergenerational transmission of innovative ideas (Gascoigne, 1990; Feingold, 1997).

This paper restricts itself to the English Scientific Revolution. There are several factors making England an ideal case study. First, the extent of records on students, teachers, and publications is to the best of the author's knowledge unmatched.[8] Second, England was a late-comer to the intellectual debates of the Scientific Revolution with hardly any progress before 1600, but became one its intellectual centres and home to the Newtonian synthesis of physics within less than a century.[9] Lastly, throughout the early modern period, England only had two universities, Oxford and Cambridge, that were institutionally highly similar, thereby making it possible to estimate the effect of teachers within an homogeneous institutional framework.

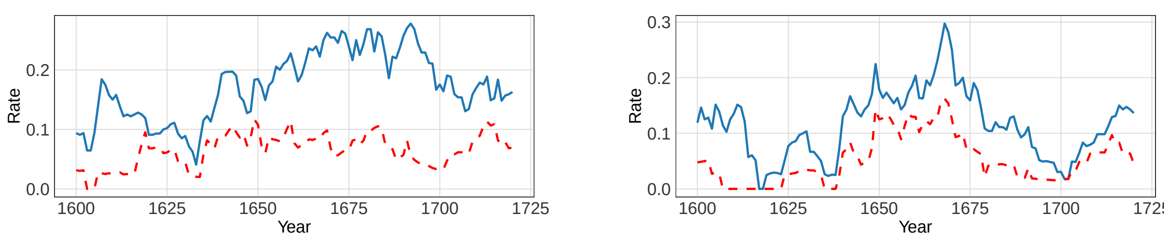
Moreover, England and the English universities have stood at the centre of a historical debate on the importance of the universities for the Scientific Revolution. While it is clear that the English universities were not a sufficient cause for the Scientific Revolution — after all they had already existed for about 400 years before the Scientific Revolution — some authors still argue that they were at least a necessary cause for the English Scientific Revolution (Curtis, 1959; Shapiro, 1971; Frank Jr, 1973; Gascoigne, 1990; Feingold, 1984, 1997). On the other hand, historians such as Manuel (1968), Hill (1965, 1968) or Westfall (1983) have doubted that the English universities were a good place to learn about the new ideas of the Scientific Revolution. They start with the

[8] In contrast, of the University of Paris's matriculation records there have only survived the entries for the faculty of arts from 1520–1680, as well as further records for the faculties of law from 1660–1790 and for the faculties of medicine for 1670–1786 (Brockliss, 1978, p. 508). For the Netherlands, records survive for the University of Leyden (Smith and Comrie, 1932; Underwood, 1969). Yet, the use of latinized names in the matriculation list at Leyden makes the list poorly suited for matching it with authorship records. Furthermore, extant material for the German universities of the seventeenth century appears scarce.

[9] Using text from English publications and natural language processing, Grajzl and Murrell (2023) date the beginning of English innovations in science back to 1615 or 1628. Using quantitiative data from Wikipedia, de Courson, Thouzeau and Baumard (2023) show that by 1700, England had become the European leader in scientific productivity.

observation that the official scholastic curriculum remained effectively unchanged since medieval times and argue that universities were passing on traditional perspectives on the natural world that were opposed to the world view of Scientific Revolution. Thus, Manuel calls restoration Cambridge an “intellectual desert” (Manuel, 1968, p. 133), Hill describes the universities as “backwaters so far as science was concerned” (Hill, 1968, p. 144), and Westfall sees Cambridge as “fast approaching the status of an intellectual wasteland” (Westfall, 1983, p. 190). Westfall even goes on to argue that “I am unable to perceive any scientific community in Cambridge. I am not even sure there was an intellectual community” (Westfall, 1980, p. 147).

In contrast, Gascoigne (1990) and Feingold (1984, 1997) start their argument by focussing on the interests of teachers at the universities. They concede that the curriculum at the universities was deeply traditional, but argue that this did not stop teachers from passing on new ideas, both inside and outside the classroom. With this, they make the case that universities were crucial for the transmission of research interests to the next generation. Feingold (1984) provides a broad range of case-studies of teachers who taught scientifically advanced material at university. Gascoigne (1990) further presents broad evidence that throughout Europe, most eminent scientists had been educated at university. He finds that 87% of all European scientists listed in the Dictionary of Scientific Biography born between 1551 and 1650 had received a university education.[10]



(a) University of Oxford

(b) University of Cambridge

FIGURE 1: Percentage share of teachers at university who published at least once in the fields of the Scientific Revolution

Notes: The blue line includes the following fields: astronomy, almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments. The red line includes the following fields: astronomy, applied physics, mathematics.

These stylized facts from Feingold (1984) and Gascoigne (1990) hold up when compared to the new dataset produced by this paper. Figure 1 presents the percentage of teachers at the universities of Oxford and Cambridge who had published at least once within fields of the Scientific Revolution.[11] We see that an average of 10–15% of all teachers had at least some interest in the fields of the Scientific Revolution. The number even reached 20% during the late restoration period of

[10]This pattern remained stable over time. For the eighteenth century, Gascoigne (1995) finds that 71% out of 614 scientists were university educated.

[11]The paper defines the fields of the Scientific Revolution as: *astronomy, almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments.*

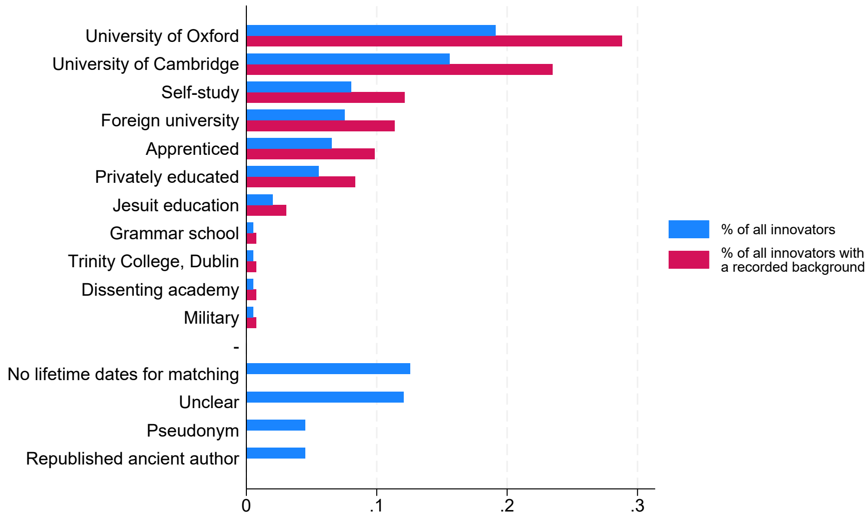


FIGURE 2: Educational background of the authors of the top 200 most innovative papers in astronomy, applied physics, and mathematics, 1620–1780

Notes: The figure presents the educational background of the 200 most innovative titles in astronomy, applied physics, and mathematics. Innovativeness is captued through an innovativeness index based on natural language processing that is introduced in this paper (see data section 3). The educational background refers to the highest level of education received. E.g. an entry for "grammar school" means that the highest formal education received was at a grammar school.

the 1670s. Note however, that this number would have significantly differed by individual colleges. Still, the aggregate statistics show that although fellows interested in the Scientific Revolution remained in the minority, their number was high enough to expose a significant number of students to the ideas of the Scientific Revolution. Appendix figure 16 reports the same graph for students at their time of matriculation.

Additionally, the paper presents evidence on the educational background of the 200 most innovative works published in England in the fields of *astronomy, applied phyics, and mathematics*, often seen as the core fields of the Scientific Revolution. The measure relies on the innovation index introduced by this paper (see section 3.5) and on a manual background search of the educational background of all authors who were not found to be matching to the university records. Figure 2 shows the results. Overall, we see that out of all authors with a known educational background, 49% had attended either the university of Oxford or Cambridge. This number is reasonably close to the percentage of 71% found by Gascoigne (1990) for the whole of Europe and using a different methodology. Together, these numbers show that the population of university graduates accounted for at least half of all publishing activity in the Scientific Revolution. Hence, the potential impact of universities on the Scientific Revolution appears large.

Lastly, the paper finds that titles by university students on the Scientific Revolution were 4% more innovative and 19% closer to the research frontier, see appendix table 24. The comparison is based on all titles in the English Short Title Catalogue within the fields of *almanacs, applied* *physics, mathematics, chemistry, biology, geography, medicine, and scientific instrument* within the time period of 1600–1720. Innovativeness and distance to the research frontier are based on natural language processing measures introduced in section 3.5. The numbers are probably an understatement since the control group of non-Oxford and Cambridge students likely includes students who studied abroad, e.g. at Leyden or Padua. Given that university students also accounted for 31% of all publications in Britain, the body of university graduates was highly relevant for British discourse and the Scientific Revolution.[12]

Yet, these numbers do not show whether these findings are due to university students' exposure to new ideas at university (as claimed by Gascoigne and Feingold) or if a university education did little more than to permit entry into the higher ranks of the scholarly community (as claimed by Hill and Westfall). Therefore, the paper will contribute to the historical debate by estimating causal teacher-effects in the Scientific Revolution based on micro-data and exploiting variation at the college-time level.

2.2 The Oxford visitations: A natural experiment

The history of the University of Oxford offers a unique shock where half of its fellows were expelled and new fellows appointed by force from outside. The paper uses this shock as the basis for a natural experiment. This section gives a short overview over the history of the Oxford visitations.

During the English Civil War, the University of Oxford had backed the cause of Charles II. In 1644, 1645, and 1646 the city of Oxford was besieged by parliamentary troops. Then, in 1648 victorious Parliament chose to reform the royalist institution and sent a board of visitors to the University of Oxford. The visitors expelled all fellows who would not submit to them and swear an oath to Parliament. Overall, about half of all Oxford fellows were expelled. The visitors then intruded new fellows that were deemed to be free of Royalist sympathies. Because the visitors wanted to break the existing Royalist and Anglican tradition at colleges, new fellows were largely intruded from outside. Hence, the paper argues that the distribution of newly appointed and scientifically interested fellows across colleges can be seen as an exogenous shock. This logic is based on the assumption that the visitors did not match the newly intruded fellows to colleges based on their research interest. This assumption appears plausible as the visitors, mostly political men who had never attended the university, would have been in a poor position to judge pre-existing college traditions. Furthermore, it was in their interest not to perpetuate college traditions, but to break with the old college traditions altogether.

Yet, it is important to consider who might have been able to influence the visitors' decisions. One might imagine that the colleges themselves might have tried to use their political capital to influence the appointment of new fellows. Yet, the political system had been turned upside down. The colleges still had hopes of a change of fortunes and until the very last petitioned to the king. If anything, this only helped to antagonize Parliament further. Overall, it appears that

[12] This number refers to the period 1600–1720 and excludes publications by non-real persons, e.g. Parliament or newspapers.

communication between the existing heads of colleges and the visitors had broken down completely (Reinhart, 1984; Roy and Reinhart, 1997). The visitors often had to use military force to gain access to the colleges. Finally, the heads of the colleges together with half of all fellows were replaced. Appendix section A.2 provides a detailed discussion of the political background of the Oxford visitation and outlines the process which led to the appointment of new fellows.

We also need to consider the selection process employed by the visitors. The visitors themselves being outsiders to academia appointed a committee for the examination of candidates for fellowships and scholarships. While they could not overrule the visitors, they could have leveraged significant influence on the appointment of new candidates for specific colleges. Appendix table 6 lists the names of these members of the committee, including their college affiliation during their studies, their former role at Oxford, and their position at Oxford after the visitations. The list provides strong evidence that the individuals chosen for the committee presented a clean break to existing college traditions.

3 Data

3.1 Students at the English Universities

This paper presents a novel dataset on the students of the English universities of Oxford and Cambridge for the seventeenth and eighteenth century. The universities of Oxford and Cambridge were the only two universities in England during this timeframe. Overall, the dataset includes information on 144,748 students from the earliest times to the beginning of the nineteenth century. For the timeframe of 1600–1800 that is used for this paper, the empirical analysis can draw on 47,043 students at the University of Oxford, and 51,079 students at the University of Cambridge. The data is based on two detailed compilations of the matriculation and college registers of the the University of Oxford and Cambridge, the *Alumni Oxonienses* (Foster, 1891) and *Alumni Cantabrigienses* (Venn and Litt, 1952).

The individual micro-level information from the *Alumni Oxonienses* and *Alumni Cantabrigienses* is extracted using an automatic routine based on regular expression. To avoid OCR errors in the underlying data, the paper completely relies on manual transcripts. For the *Alumni Oxonienses 1500–1714*, the paper uses a double re-keyed transcript that was sponsered by *American Friends of the IHR* and made available through *British History Online*. For the *Alumni Oxonienses 1715–1886*, the paper uses a transcript from Wikidata (2022). Yet, by summer 2021 ca. 5% of the entries had not been fully transcribed. The author then transcribed these entries from the original. For the *Alumni Cantabrigienses*, the paper uses a full transcript made by *Ancestry.com* and published online by the *ACAD Cambridge Alumni Database* (see appendix section B.1). Tables 8 and 11 provide a list of all variables automatically extracted from the text.[13]

[13] As the *Alumni Oxonienses* lack a list of the abbreviations used for status and degrees, a list of the complete and translated status titles has been produced as a side-product of this work (see appendix tables 14 and 15).

Overall, Foster's *Alumni Oxonienses* and Venn and Litt's *Alumni Cantabrigienses* list a student's name, place of origin, status, time of matriculation and/or admission to college, all degrees, and the respective college a student was at for each degree,[14] as well as future careers within the Church, the Inn's of Court or the Royal College of Physicians. The *Alumni Oxonienses* and *Alumni Cantabrigienses* were compiled almost 50 years apart using slightly different methods. The individual publishing history, the individual methods used in compiling the original college registers, as well as the accuracy of these records are discussed in appendix section B.3 and B.4.

In about 3/4 of all cases, the lists provided by Venn and Litt (1952) and Foster (1891) also include the address of a student's family. Omissions of a student's family address appear to have been more common in earlier periods. However, by the second quarter of the 17$^{\text{th}}$ century, recording the address of a student's family address seems to have been common practise at matriculation or admission.

Based on this data, students are matched to teachers based on the college they attended at the time of matriculation. Overall, there were 28 colleges and halls at Oxford and 16 at Cambridge. This setup captures the teaching system at the universities of Oxford and Cambridge where the main bulk of teaching was carried out by the colleges.[15] At the same time, this setup captures the close interaction between teachers and students outside the classroom while living in the same building. Additionally, all students went through the same arts degree. Hence, teacher assignment did not depend on students' choice of degrees or courses.

3.2 The visitation shock of 1648: Quantifying the parliamentary appointment of new fellows

In order to quantify the expelled and newly appointed fellows by the visitors, we cannot simply draw on the number of new fellows who arrived between 1648 and 1652. Afterall, there were also some appointments made by the colleges themselves once the visitors had left. Instead, this paper draws on a list of fellows intruded by the order of the visitors. For this, the paper draws on a detailed compilation by Reinhart (1984, pp. 519–610). Reinhart's list in turn is a revision of a list compiled by Burrows (1881) that is based on the original visitor's register Reinhart (1984, p. 519). The paper manually matches the entries in the Reinhart list with the entries in the *Alumni Oxeniensis*.

Table 1 presents an overview of the composition of all fellows appointed by the visitors. Altogether, ∼50% of all former fellows at Oxford were expelled and ca. 80% of all newly appointed fellows were selected from outside their new college. Altogether, one third of the intruded fellows were recruited from the University of Cambridge (Reinhart, 1984, p. 412). Cambridge had already been "reformed" in 1644 (Twigg, 1983), thus being a more reliable recruitment pool for fellows

[14] In the case of a student not switching college, Foster only lists the college at matriculation time.

[15] There were a few university wide professorships offering classes to all students. However, their numbers were few and the main bulk of teaching was carried out the college-level. Since, classes by university professors were open to all students, this setup does not offer sufficient variation and is hence not further investigated by this paper. However, if professors lived at individual colleges they are included as part of the treatment.

Table 1: Overview of intruded fellows

	College	New fellows 1648–1652	Appointed by visitors	Appointed by visitors + from outside their own college
1	All Souls	39	39	39
2	Balliol	9	9	6
3	Brasenose	23	18	17
4	Christ church	52	15	15
5	Corpus Christi	22	19	17
6	Exeter	14	14	9
7	Jesus	16	16	13
8	John	27	14	14
9	Lincoln	10	9	8
10	Magdalen	40	31	26
11	Merton	21	18	16
12	New College	46	37	37
13	Oriel	11	8	8
14	Pembroke	8	8	5
15	Queens	10	6	5
16	Trinity	12	8	7
17	University College	20	17	14
18	Wadham	15	15	12
	Sum	395	301	286

Notes: The table shows the number of newly appointed fellows between 1648-1652 compared to the number fellows intruded by the visitors as well as the number of intruded fellows that were not appointed to the same college where they had studied before. The list is based on the doctoral thesis by Reinhart (1984) which presents revised numbers from Burrows (1881).

supporting Parliament. A further 5% came from other universities and another third came from Oxford colleges, but were appointed at a college different than their own. Lastly, a fifth were appointed at their own college of study, usually coming from the lower ranks of the college (Reinhart, 1984, p. 411).

The visitation shock is defined as the set of all fellows that were a) appointed by Parliament and b) not appointed at their own college. Thus, the definition of the visitation shock excludes all appointments that either were made by the colleges themselves or reflected previous appointment decisions by the colleges.

3.3 Publication titles, 1600–1800, and the direction of research

To capture the content of the British stock of knowledge of the seventeenth and eighteenth century, the paper uses the universe of 469,962 printed titles in England from the English Short Title Catalogue (ESTC) that were published between 1600 and 1800. Cleaning for duplicates leaves 329,812 titles (see appendix C.2). The ESTC was kindly shared by the British Library with the author. Seventeenth and eighteenth century publication titles offer comprehensive information on the published work, usually using the full space of the book cover and usually taking the form of short abstracts, that can be exploited using natural language processing. An average ESTC title for the subset of the fields of the Scientific Revolution consists of 48 words (see also appendix figure 10). Appendix C.1 lists a few examples and presents descriptive statistics on the titles.

Students are matched to their publications based on year of death and year of birth inferred from their time of matriculation. Section C.3 describes the matching approach. Crucially, the matching results show that all graduates from the universities of Oxford and Cambridge accounted for ∼31% of all English publications.

The paper then uses the ESTC to construct a measure of teachers' and students' direction of research based on the subject fields teachers and students were publishing in. A researcher's number of publications in subject field i is denoted as b_i. A researcher's direction of research, v, is then defined as a vector of the researcher's strength of research, b/n, across the dimensions of m subject classes, $v = (b_1/n, b_2/n, \ldots b_m/n)$. For a more detailed definition, e.g. for the definition of the teachers' direction of research, see section 4.1.

Furthermore, the paper investigates two other channels for the transmission of research interests from teachers to students, teacher innovativeness and teacher's distance to the frontier. Both measures have been identified in the literature as important factors that shape students' adoption of ideas (Waldinger, 2010; Biasi and Ma, 2022). Hence, they are treated as alternative hypotheses to students' exposure to teachers' direction of research.

However, seventeenth century titles create major challenges for the construction of these measures. While studies in the peer-effects literature using modern data can rely on citations and journal classifications to capture the research fields and innovativeness of publications (Waldinger, 2012; Iaria, Schwarz and Waldinger, 2018), this kind of data is not available for seventeenth century titles: First of all, during the seventeenth century, modern citation practises did not yet exist. Second, for the British ESTC data, classifications of individual titles are only available for about a third of all titles in the dataset. Therefore, the paper adopts an approach of using natural language processing with state-of-the-art transformer models to derive classifications of research fields, measures of innovativeness, and distance to the research frontier from the *content* of the ESTC titles. It is hoped that the new classification- and innovation-measures constructed by this paper will be of general use for the study of eighteenth century Britain.

3.4 Assigning subject classes

The paper uses a natural-language processing and machine-learning approach to assign subject classes to the universe of all ESTC titles based on state-of-the-art transformer models. For the training data, the paper relies on subject classes assigned by the British Library. They cover ∼30% of the full ESTC dataset. These classes were assigned by the various curators of the dataset (right now, the British Library) and should be seen as high-quality assignments. The paper uses the information stored in these assignments to train a state-of-the-art large language model (LLM) to predict assignments for the rest of the dataset. Using large language models, the paper is able is use context-sensitive information and vector-space representations of the meaning of text as an input for the machine learning procedure. This way, obvious problems with seventeenth and eighteenth century text such as bias from changes in language or bias arising from the usage of different words for the same concepts are avoided. Furthermore, the approach allows for capturing similarities in the content of complex expositions and arguments.

Appendix section C.6 describes the actual pre-processing of the data, training process, and model evaluation in detail. The following is a short summary of the process:

1. Titles from other languages were translated into English to standardize the dataset. For this, the paper relied on the Google Translate API

2. The granular classification system of the British library was aggregated to 47 higher-order subject classes (see table 20)

3. A DistilBERT transformer model was trained on the classifications of ∼30% of the ESTC dataset with pre-assigned subject classes

4. The pre-trained model is then used to predict subject classes the missing ∼ 70% of the ESTC dataset

This process leads to a full classification of the universe of British publications between 1600 and 1800 into 47 higher order subject classes. The full list of 47 higher-order classes is listed in appendix table 20. Importantly, the paper uses 9 higher-order classes that capture the fields of the Scientific Revolution: *Almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments.*[16] By calculating the share of student and teacher publications in each topic, we can construct a measure of students' and teachers' direction of research, see section 4.1.

3.5 Teacher innovativeness and proximity to the research frontier

The previous section has established a measure of students' and teachers' direction of research based on researchers' strength of research across multiple subject fields. The paper also investigates two alternative channels for the transmission of research interests from teachers to students, teacher innovativeness and teacher's proximity to the research frontier. Both measures have been identified in the literature as important factors that shape students' adoption of ideas (Waldinger, 2010; Biasi and Ma, 2022) and serve as alternative mechanisms for the transmission of ideas from teachers to students.

Both measures are based on mapping the text of the ESTC titles into text embeddings using a large language model (LLM). Then, the cosine distances between different vector representations of titles can be calculated to capture the distance between different titles. With this, the paper creates two measures of teachers' research quality, first teachers' distance to the frontier and second, teachers' innovativeness (described in more detail in appendix section C.7):

[16] The paper conducts a wide range of robustness tests to show that the empirical results are robust to using other plausible definitions of the fields of the Scientific Revolution.

Teachers' distance to the frontier: First, the paper defines the research frontier as all titles in the *Philosophical Transactions*, the journal of the Royal Society. During the seventeenth and early eighteenth century, the Royal Society was Britain's only scientific society, and would collect short papers on new findings at the frontier of contemporary science. Second, the paper calculates an ESTC title's average cosine similarity to the next forty years of the *Philosophical Transactions* as a measure of the research frontier. The calculation is carried out on a subject field by subject field basis.

Teachers' innovativeness: The paper uses the logic from Kelly et al. (2021) to calculate a measure of innovativeness based on the text of the titles. However, in contrast to Kelly et al. (2021), the paper uses text-embeddings from a large language model as an input for the calculation of title distances. This approach makes it possible to extract information on documents using complex and non-technical language as an input. Furthermore, in contrast to Kelly et al. (2021), this paper calculates the innovativeness index on a field-by-field basis. Intuitively, the paper defines an innovative publication as being a) novel and b) impactful. Being novel entails using new ideas and should therefore imply that a title has a high distance to the past of its field. Being impactful entails changing one's field and should therefore imply that a title has a high similarity to the future of its field. Following this logic, the paper calculates measures of 20 year *backward similarity*, 20 year *forward similarity*, and an index of *innovativeness* based on dividing *forward similarity* by *backward similarity.*

Appendix section C.8 validates this innovativeness index, by estimating the association between innovativeness and author-quality, captured through an entry in the *Dictionary of National Biography* or a fellowship in the Royal Society. We find a significant and relevant association between the innovativeness index and author-quality, proving that the approach captures (some dimensions) of innovativeness.

4 Empirical results

4.1 Framework — direction of research

The empirical analysis proceeds in three steps. First, this section sets out a framework to estimate the effect of teachers' direction of research on the lifetime direction of their students' research. Then, the next section presents baseline results for the teacher-effect. Finally, the paper presents three identification strategies to account for students' self-selection into colleges; first, an instrumental variable approach predicting a students' choice of college based on their place of birth, second a stacked difference-in-differences approach based on teachers leaving their college, and third, a natural experiment based on the parliamentary expulsion and forced appointment of teachers at the University of Oxford.

First, we start by defining the measurement of the direction of research with respect to the Scientific Revolution: Assume that a single author publishes n books across publishing fields $\Phi =$

$\{f_1, f_2, \ldots, f_m\}$. We further define the number of publications in a given field j as b_j. Then the author's direction of research across all fields is given by the vector $v = (b_1/n, b_2/n, \ldots b_m/n)$. We can further define the average direction of research of a given number of multiple authors, μ as $p = 1/\mu \cdot (v_1 + v_2 + \cdots + v_m)$. With this we can define:

1. v: A student's direction of research

2. p: For all teachers at a college, their average research direction

To simplify the notation, we define the elements of these two vectors as:

1. v_j: A student's relative share of research in field j (b_1/n):

2. p_j: For all teachers at a college, their relative share of research in field j $((b_{1,1}/n+b_{1,2}/n + \cdots + b_{1,m})/\mu)$

By estimating the effect of p_j on v_j, we can estimate the effect of teacher's research interest in field j on student's research interest in field j. Analogously, by estimating the average effect of p_j on v_j for all $j \in v$, we can estimate the average effect of teachers' direction of research on student's direction of research across all fields of v. Using variation across all fields further means that we can estimate the model with student-fixed effects, thereby absorbing all unobserved student heterogeneity that is not field specific.

The paper estimates the following model that uses variation across fields j and students i:

$$v_{jict} = \beta_1 p_{jict} + \boldsymbol{X'_{ct}} \beta_2 + \delta_i + \gamma_c + \zeta_j + \alpha_t + \varepsilon_{jict} \tag{1}$$

where the dependent variable, v_{jict}, captures student i's share of research in topic $v_j \in v$ at college c and matriculation cohort t. The treatment variable of interest, p_{jict} is the average teachers' share of research in topic v_j at college c at matriculation time t. The treatment happens at the college level, c, in time, t, where students are exposed to their college's teaching body. $\boldsymbol{X'_{ct}}$ is a vector of control variables for teacher characteristics. This includes the number of teachers at a college and the number of total teacher publications. The model further includes student-, topic-, college-, and time-fixed effects, δ_i, γ_c, ζ_j, and α_t. The model further allows to estimate the impact of all individual fields of the Scientific Revolution in determining teacher-directed change by interacting the teacher share, p_{jict}, by each field.

All publication-share vectors are transformed using a natural logarithmic transformation. Following Chen and Roth (2024), the logarithmic function over zero is defined as:

$$f(y) = \begin{cases} m(y) = log(y) & \text{if } y > 0, \\ m(0) = -1 & \text{if } y = 0. \end{cases} \tag{2}$$

which has the convenient interpretation that an increase from 0 to 1 is the same as a 100% increase in publication shares (Chen and Roth, 2024).[17] The log-transformation captures the intuition that increasing teachers' publication shares in a given topic should have marginally declining returns in teachers' influence on students. E.g. we assume that a teacher who publishes $1/11^{\text{th}}$ of his publications on science is not 11 times less influential than one who publishes all of his publications on science. Since this places a large emphasis on the extensive margin, the paper also reports robustness checks for smaller values of $m(o)$ as well as other commonly used transformations capturing decreasing returns.

The model is based on the assumption of conditional exogeneity of teachers' direction of research at college c at time t, $\mathrm{E}(\varepsilon_{jict}|\beta_1 p_{jict}, \boldsymbol{X'_{it}}, \delta_i, \gamma_c, \zeta_j, \alpha_t) = 0$. This assumption is unlikely to hold as students interested in field j might have self-selected into a college where many teachers were working on field j. This issue is mitigated by exposure to teachers at the time of a student's matriculation, thereby excluding variation from students that switched their colleges after some time at university. Thus, the analysis excludes all selection into colleges that was based on students' first-hands knowledge on the learning culture at other colleges. However, it is still possible that some students might have learned about teachers at different colleges even before coming to university and would have chosen their college accordingly. The paper addresses this concern using an instrumental variable strategy approach based on the observation that students' mainly chose colleges based on their place of origin.

It is also possible that teachers might have selected into colleges either based on students' interest or the general research culture at a college. To account for teacher-selection, the model adopts two strategies. First, section 5.2 introduces a stacked-difference-in-differences approach of teachers leaving their college. While joining a college allows for selection into specific colleges, leaving a college is uniform across colleges and therefore free of selection-bias. Additionally, section 5.3 introduces a difference-in-difference approach that is based on the dismissal and new appointment of fellows following the English Civil War at the University of Oxford. There, the University of Oxford had sided with losing Royalist side. Therefore, Parliament evicted half of all fellows and appointed new fellows from outside the colleges. The paper argues that this shock constitutes a quasi-random distribution of fellows across colleges.

The following section starts by presenting baseline results for model 1 for the full sample. Section 5.1 then introduces the instrumental variable approach, section 5.2 introduces the stacked difference-in-differences approach based on fellows leaving their college, section 5.3 introduces the eviction and new appointment of fellows shocks. Lastly, section 6 interprets the results in a multi-generational framework and discusses the impact of counterfactual policy choices.

[17]Following Chen and Roth (2024), it is important to recognize that the log scale (and related functions such as arcsinh) are scale dependent. Following Chen and Roth (2024), we can express the choice of scale as an implicit choice between the importance of the extensive and intensive margin. The ATE for this transformation can be interpreted as an approximate percentage (log point) effect, where an increase from 0 to 1 is valued at 100 log points (Chen and Roth, 2024). Additionally, Chen and Roth (2024) we approximate values $< 1\%$ as 1% to retain the original interpretation of the coefficient (in this case, this only occurs for authors with more than 100 publications who only publish one publication in a given topic — so this is a rare occurrence).

4.2 Basic patterns: Teachers' and students' direction of research

This section presents a first set of associations between teachers' and students' direction of research at the English universities between 1620–1720. The section starts by providing basic associations between teachers' direction of research on students' direction of research in the Scientific Revolution for the full sample of teachers and students. Then, it offers a simple decomposition of the teacher-effect by different research fields and compares the magnitude of the effect to other topics important to seventeenth century academia.

First, table 2 shows the main results of estimating equation 1, regressing teachers' direction of research for the fields of the Scientific Revolution on students' direction of research for the fields of the Scientific Revolution. The fields of the Scientific Revolution are defined as *astronomy, almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments*. The model estimates the average of field-specific teacher-effects on students' direction of research across all fields of the Scientific Revolution. It is based on the sample of all students that ever published.[18] Panel A shows the estimated coefficients for the University of Oxford and panel B shows the estimated coefficients for the University of Cambridge. Column (1) estimates the model from equation 1 with controls for student- and teacher-characteristics as well as college- and cohort-fixed effects. Column (2) adds topic-fixed effects. Column (3), further adds student-fixed effects. Overall, the size of coefficients decreases with a higher number of fixed effects, suggesting that the model successfully captures positive sorting of teachers and students based on teacher-quality and student skills. Since student-fixed effects absorb all unobserved student heterogeneity, including students' general skills and previous education levels, column (3) is used as the preferred specification (yet sorting might also occur based on field-specific interests — see the next section for the IV approach and a quasi-natural experiment).

For the University of Oxford, in column (3), increasing the share of teacher's research in a field of the Scientific Revolution by 1% is associated with a 0.019% increase of the publication share in that field for the average student and a 0.013% increase at Cambridge.[19] Hence, a 100% increase in teacher publication shares is associated with a 1.4% increase in student publication shares at the University of Oxford and a 0.9% increase at the University of Cambridge. In interpreting this effect, we have to remember that the share of teachers interested in the topics of the Scientific Revolution was still small in the seventeenth century. Although 25–35% of students would have had a chance to be exposed to a teacher publishing on any subject of the Scientific Revolution, the chance of being exposed to a teacher publishing on one specific topic of the Scientific Revolution was only 0.5% to 1%. Average teacher publication shares per topic amounted to only 0.6% at Oxford and 0.57% at Cambridge. Therefore, even a 100% increase in teacher publication shares would

[18] Since the paper's measure of the direction of research is not defined for students with zero publications, the model can only be estimated on publishing students. The number of students with at least one publication is $N = 1,276$ for the University of Oxford and $N = 1,359$ for the University of Cambridge.

[19] Given our weighting of the extensive margin (Chen and Roth, 2024), moving from a college with a zero teachers' share in the fields of the Scientific Revolution to a college with a 1% teachers' share in the fields of the Scientific Revolution leads to same effect as a 100% increase.

Table 2: Effect of teachers' research fields on students' research fields

Panel A: Oxford	Log share of each topic in student publications		
	(1)	(2)	(3)
	Mean top.	Mean top.	Mean top.
Log share of each topic in teacher publications	0.0483***	0.0211**	0.0194**
	(0.0135)	(0.00851)	(0.00907)
Log share of teacher publications in all topics of the Scient Rev.	-0.00839	-0.0000311	
	(0.00572)	(0.00550)	
Teacher and college level controls	Yes	Yes	—
Student publication controls	Yes	Yes	—
Year fixed effects	Yes	Yes	—
College fixed effects	Yes	Yes	—
Topic fixed effects	No	Yes	Yes
Student fixed effects	No	No	Yes
Observations	14184	14184	14184
R-squared	0.02	0.04	0.16

Panel B: Cambridge	Log share of each topic in student publications		
	(1)	(2)	(3)
	Mean top.	Mean top.	Mean top.
Log share of each topic in teacher publications	0.0417***	0.0133*	0.0134*
	(0.0107)	(0.00699)	(0.00710)
Log share of teacher publications in all topics of the Scient Rev.	-0.00710	0.00338	
	(0.00685)	(0.00579)	
Teacher and college level controls	Yes	Yes	—
Student publication controls	Yes	Yes	—
Year fixed effects	Yes	Yes	—
College fixed effects	Yes	Yes	—
Topic fixed effects	No	Yes	Yes
Student fixed effects	No	No	Yes
Observations	15408	15408	15408
R-squared	0.02	0.04	0.17

Notes: The table shows results from estimating equation 1. It regresses the share of student publication on the share of teacher publications for the fields of the Scientific Revolution. The fields of the Scientific Revolution are defined as astronomy, almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments. The strength of teachers' research fields within each of these fields is calculated as the share of all teachers' publications within field τ of all publications within all fields at college c at time t. The strength of students' research fields is calculated as the share of student i's publications in field τ out of all publications from student i. Additionally, the second coefficient reports the teachers' average share across all these topics. Column 1 estimates results for a baseline specification including teacher and student publication controls with college and college cohort effects. Column 2 adds topic fixed effects. Column 3 adds student fixed effects. Teacher and student shares are transformed using the natural logarithm from equation 2. Teacher controls include the log-transformed number of teacher publications, the log-transformed number of fellows at a college at a student's time of matriculation, and the log-transformed cohort size at a student's time of matriculation. Student controls include a student's log-transformed number of publications, and indicator variables taking the value of one if a student graduated with a B.A. or M.A, as well as a variable capturing the mean of all student publications that were predicted using machine learning. Standard errors are clustered at the college-topic level and included in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

have been a relatively limited increase — amounting to an increase in teacher publication shares in the Scientific Revolution from 0.6% to 1.2%. Therefore, the estimated association is economically highly relevant, with a 0.06 percentage point increase in teacher publication shares leading to a 0.9-1.4% increase in students' publication shares.

Also note that the model is estimated on the average student at a college. This number likely includes a high number of never-switchers (imagine e.g. a student who already decided to study theology before going to university or a student with a natural aversion to all mathematical subjects). Estimating the same model on the sub-sample of students who had at least one publication in the Scientific Revolution returns a significantly larger effect: Increasing teachers' publication shares by 1% is associated with a 0.1% increase in students' publication shares at Oxford and a 0.16% increase in students' publication share at Cambridge (see appendix table 25).[20] Therefore, a 100% increase in teachers' publication shares is associated with a 7.2% increase in students' publication shares at Oxford and 11.2% at Cambridge. Yet, referring to the coefficients for the average student (table 2) has the convenient interpretation of capturing the total change in the direction of research of all graduates and, by extension, the total change in the direction of research in all of England. Given that graduates from Oxford and Cambridge accounted for ca. 31% of all publications in England, changes in the direction of research of graduates from the universities were highly relevant for the nation's direction of research. Section 6 discusses the short-run and long-run interpretation of the estimated coefficients in more detail and discusses several counterfactual policy choices in teacher hiring.

Next, it is notable that the teacher coefficient for Oxford is ∼30% larger than the one for Cambridge. There are two possible explanations for this difference. First, the results could suggest that there was a university culture at Cambridge that was less conducive to the transmission of the ideas of the Scientific Revolution than at Oxford.[21] At the same time, the difference in the strength of the teacher-effect might also be due to a different composition of scientific fields taught at each university. Appendix figure 17 shows results from interacting the coefficient from equation 1 with individual fields. The results show that teacher-effects at the University of Oxford were mainly driven by the field of *medicine*, while for Cambridge we find large coefficient for the fields of *applied physics, biology, mathematics, and medicine*. Because, *medicine* was the largest field out of these 9, the fact that it has a larger coefficient of ca. 0.04 for Oxford and ca. 0.02 for Cambridge also points to a purely compositional effect from different field-specializations.

[20]Hence, a 100% in teacher publication shares would have been associated with a 7.1% increase in publication shares in the topics of the Scientific Revolution at Oxford and an 11.7% increase at Cambridge (see section 6 for an interpretive framework).

[21]For example, one could speculate that Parliament's radical reform of the University of Oxford might have contributed to a more open-minded teaching tradition. Furthermore, the the Cambridge Platonists, although an important group for the development of the new sciences, might have laid out a research program that was too theoretical to effectively inspire their students to pick up the new sciences. In contrast, the pragmatic and mechanical science of Boyle, Hooke, and Wilkins at the University of Oxford might have been more conducive to inspiring their students.

4.3 Basic patterns: Topics beyond the Scientific Revolution

To further understand the estimated coefficients from table 2 in a broader context, appendix table 26 estimates equation 1 for other topics of British seventeenth century intellectual life, *art, religion, the public sphere, and classical education.* The group of art is composed of the topics of *poetry, music, and drama*. Religion is composed of *theology, dissenting theology, Catholic theology, Jewish theology, sermons, church administration, prophecies, and supernatural occurrences.* The public sphere is composed of *administration, the law, reports of current events, and moral tales.* Finally, classical learning is composed of *philosophy, political philosophy, classical education (Greek and Roman), rhetoric, foreign languages, and pedagogical education.* Appendix table 26 reports the results. It shows that, apart from the fields of the Scientific Revolution, we only find a significant teacher-effect for the topics within religion. This strong teacher-effect in religion corresponds well to the overbearing role of religion on British society throughout the seventeenth century.

Hence, the fields of religion afford themselves as a good comparison group to interpret the strength of the teacher-effect in the Scientific Revolution. It is clear that religion was important for students and that teachers could have strongly influenced a student's engagement with religion and theology. For the University of Oxford, we find that increasing the teachers' publication share in a field in religion by 1% was associated with an increase in students' publication share in that field by 0.016%, although we should note that the coefficient is insignificant. For Cambridge, we find a significant association of 0.041%. These are coefficient sizes that are comparable to the ones found for the fields of the Scientific Revolution, 0.019% and 0.013%. Hence, the results confirm that the estimated coefficients for the Scientific Revolution are comparable to the estimated coefficients for religion, the most dominant topic of the seventeenth century.

We can also reflect on the fact that teacher-directed change only seems to have been present for fields that were discussed divisively at the time. The Scientific Revolution broke with many core-beliefs of the scholastic Aristotelianism that was taught at universities and challenged many beliefs about nature and humankind's place in nature. Likewise, the seventeenth century was the century of religious conflict and religious debates. In contrast, the fields of classical education would have been part of the old scholastic curriculum and would have been widely accepted in their current form. Likewise, the material taught at universities that related to the arts and the public sphere (thinking e.g. about rhetoric, or the study of historical dramata) was not contested, even though topics in art or the public sphere surely were the subject of politically divisive views. Hence, it appears that teacher-directed change might have been stronger for areas that were divisive and strongly contested.[22]

4.4 Alternative mechanisms and robustness

The paper further conducts a range of exploratory analyses to further investigate the mechanism between teacher-directed scientific change:

[22] In Kuhnian (1962) terms, we could say that teacher-directed change was more important for fields in its revolutionary phase and less important for normal science.

1. **Teacher exposure and publication inclination/success.** The paper tests whether exposure to teachers publishing on the topics of the Scientific Revolution was associated with students' publication outcomes across the dimensions of a) ever publishing, b) students' total number of publications, and c) students' general innovativeness across all fields. Appendix table 27 presents the results. We do not find evidence that exposure to teachers' publication shares in the Scientific Revolution changed students' overall publication success across all topics.

2. **Alternative mechanisms of teacher influence.** Appendix section D.2 investigates alternative channels that might have determined students' direction of research. The paper considers teacher innovativeness and teachers' proximity to the research frontier. Both measures are described in appendix section D.2 and formally defined in appendix section C.7. We find evidence of a positive association between students' direction of research and teacher innovativeness and proximity to the research frontier. Yet the association is weaker than for teachers' direction of research. We take this as evidence that knowledge transmission might have happened across multiple dimensions of knowledge production, with teachers' direction of research being a major but not singular factor.

3. **Career choice as a transmission mechanism.** Exposure to teachers publishing on the topics of the Scientific Revolution could also have influenced students' career choices that then would have influenced students' direction of publishing. E.g. careers in the Church might have led to higher occupation-related publications of theology or sermons. Careers in medicine might likewise have increased the number of medical publications. Therefore, occupational choice might form a part of the mechanism of teacher-influence. Appendix table 28 shows results for regressing teacher publication shares in the Scientific Revolution on students' degrees and career choices in later life. The set of outcomes include *medicine* and *law*, careers as *rectors, vicars, prebendaries, physicians, and lawyers*, as well as entries in the *Dictionary of National Biography* as a proxy for notability (Laouenan et al., 2022). We do not find evidence of an association between exposure to teacher publication shares and degree or career outcomes.

The paper further conducts the following robustness checks:

1. **Development over time.** Appendix table 29 shows how associations between teacher- and student publication shares in the Scientific Revolution changed over time. We find that the association was strongest for the classical period of the English Scientific Revolution, 1640–1720. After that the coefficient strongly declined. This change was likely driven by the introduction of scientific subjects into the curriculum of the Scottish universities who became centres of the new science in the eighteenth century. It is also likely to reflect the rising opportunities to be exposed to the new science outside the universities, e.g. at public lectures, provincial scientific societies, or through enlightenment discourse (see Schofield, 1963;

Stewart, 1986*a*, 1992; Mokyr, 2016; Cinnirella, Hornung and Koschnick, 2022; Curtis and De la Croix, 2023). Lastly, the finding goes hand in hand with the overall decline of the universities of Oxford and Cambridge in student numbers (see appendix figure 8) and general reputation (Brockliss, 2016) in the eighteenth century.

2. **Functional form specifications.** Appendix table 30 reports results for using different values of $m(0)$ in the Chen and Roth (2024) definition of the logarithm from equation 2. Results are similar across specifications. We can note that the coefficient size for the University of Oxford increases slightly when using smaller values of $m(0)$. Appendix tables 31–32 present results for using $log(x + 0.01)$ or the inverse hyperbolic sine function ($arcsinh$) instead. Coefficient sizes are unaffected by the $log(x+0.01)$ specification. Significance levels are lightly higher in the $log(x + 0.01)$ specification. Table 33 further present results for a level-level specification.

3. **Bias from data quality.** Matching between students and authors can introduce type I and type II errors. The paper adopts a conservative matching strategy on type I errors. Yet, the matching approach also leads to type II errors in the form of omitted duplicate matches 11% (Oxford) and 8% (Cambridge). Appendix section C.4 provides Monte Carlo results for a similar data structure and suggests that downward bias from matching is unlikely to be higher than 20%. Furthermore, for some teachers, the end of their tenure had to be imputed (see appendix section B.4). Appendix table 34 shows robustness of the results to alternative imputation values.

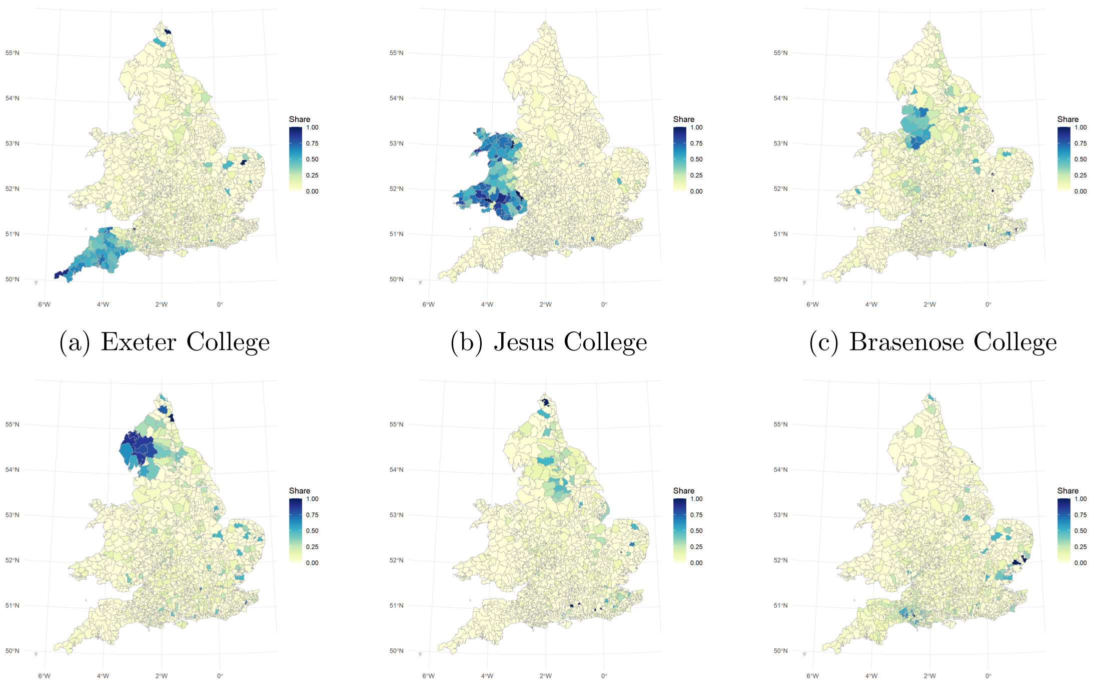
5 Identification

5.1 Instrumental variable approach: Predicting students' choice of college based on their place of origin

This section introduces an instrumental variable approach that exploits the strong ties between colleges at the University of Oxford and English regions, see figure 3.[23] It uses college-enrollment shares per hundred (an old administrative unit) to predict a student's choice of college only based on the location of a student's family. The instrumental variable then assigns each student the expected teacher publications given their place of origin. Thus, predicted exposure to teacher publications should be orthogonal to any student characteristics determined after their birth, especially a student's interest in specific topics. Furthermore, since the prediction is based on region specific college affiliations, it should also be orthogonal to any interests passed on within a family that are not universal to a region.

To construct the instrument, the paper creates a measure of expected teacher publications given a student's place of origin based on regional college shares:

[23] In contrast, ties between colleges and regions were less pronounced at Cambridge.



(a) Exeter College (b) Jesus College (c) Brasenose College

(d) Queen's College (e) University College (f) Wadham College

FIGURE 3: Students' origin from different colleges - as shares per hundred

$$\underbrace{E(v_{ijct}|h)}_{\substack{\text{Expected teacher publi. share}\\ \text{for student i given}\\ \text{place of origin h}}} = \sum_{c} \underbrace{P(C=c|H=h)}_{\substack{\text{Prob. of student}\\ \text{attending college c}\\ \text{given place of origin h}}} \times \underbrace{p_{jct}}_{\substack{\text{Teacher publi. share}\\ \text{at college c}}} \tag{3}$$

where $E(v_{ijct}|h)$ is the expected share of student i's publications in subject j at college c at time t given student's place of origin, hundred h. We can calculate it by multiplying the probability of students attending college c given their place of origin h by teachers' publication shares at each college. The probability of the event of a student attending college c given his place of origin c, $P(C = c|H = c)$, is given by the share of students from county c that originate from hundred h. We define this as $\frac{N_{h,c}}{N_h}$, where $N_{h,c}$ denotes the number of students from hundred h that attend college c and N_h denotes the number of all students from county h. We then multiply the probabilities with teacher shares at college c at time t for topic j and sum over all colleges.

The paper further imposes a uniqueness condition where the instrument is only calculated for hundreds with more than 5 students and a minimum college-hundred share of 25%. The uniqueness condition ensures that inference is based on actual college-region ties (and not on information from a single student per hundred). Appendix table 37-40 show robustness across different values of the uniqueness condition.

Table 3 presents results of using expected teacher publication shares from equation 3 as an instrument for teacher publication shares from equation 1. First, table 3 compares the baseline

Table 3: Instrumental variable approach based on college-region ties for the University of Oxford

	Baseline	With geo info	First stage	IV
	(1)	(2)	(3)	(4)
	Mean top.	Mean top.	Mean top.	Mean top.
Log share of each topic of teacher publications	0.0194**	0.0397**		0.0746*
	(0.00907)	(0.0183)		(0.0434)
Log share of each topic of predicted teacher publications			0.0257*	
			(0.0151)	
Topic fixed effects	Yes	Yes	Yes	Yes
Student fixed effects	Yes	Yes	Yes	Yes
Observations	14184	3717	3717	3717
R-squared	0.161	0.148	0.147	
Kleibergen Paap F-statistic				38.80

Notes: The table shows results from estimating equation 1 in an instrumental variable approach. The instrument of expected teacher shares given students' place of origin is defined in equation 3. The table reports estimates of the effects of teachers' research fields on students' research fields for the fields of the Scientific Revolution. Column 1 estimates results for the baseline specification from table 2 for the sample of 1600–1720, excluding the period of the Civil War and interregnum 1642–1660, see appendix B.3 for a description of changes in recording practices of geo-information. Column 2 estimates the same specification for the sub-sample of all students with available geo-information and coming from parishes with strong college-ties. Column 3 presents first stage results for the instrument of predicted teacher publication shares based on a student's home parish. Column 4 presents the IV coefficients for the instrumental variable regression. Standard errors are clustered at the college-topic level and included in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

results from table 2 with the results for the sample of students with geo-information in column 1 and 2.[24] Notably, when estimating equation 3 for the geo-sample in column 2, we find a larger effect than in the baseline in column 1. Studying the balancedness of the geo-sample in appendix table 36, we find that the geo-sample contains a higher share of students who graduated and a lower share of higher-rank students.[25] However, it is relatively balanced regarding publications on the Scientific Revolution. Based on narrative evidence (Porter, 1997), it seems that hundreds with strong college ties are likely to have been older and richer and that students coming from these parishes are likely to have had a better prior education and better career prospects.[26]

The next columns present the results for the instrumental variable approach. Column 3 shows the reduced form results. Column 4 presents the the results from the instrumental variable approach. The IV-model predicts that a 1% change in teachers' publication shares in the fields of

[24]The geo-information sample is composed of students with information on places of origin located in hundreds that fulfill the uniqueness condition. Note that geo-information on students' place of origin is only recorded for a sub-sample of the full student register from Foster (1891). First, there were general omissions on places of origin in the matriculation registers. Second, for the whole period of 1649–1660 information on students places of origin was not recorded. See the discussion in appendix B.3.

[25]We can only speculate to the origin of this. Noble students might have had a less clearly defined home address. Or it was not deemed necessary to enter them given their prominence. Additionally, matriculation entries might have been double checked for omissions and completed in case of student was graduating.

[26]Following, the previous discussion following table 2, this means that students from richer hundreds would have had a lower share of never-takers.

the Scientific Revolution led to a 0.075% increase in students' publication shares in the fields of the Scientific Revolution. Note that the IV coefficient is relevantly larger than the OLS coefficient in column 2 (with an effect size of 0.04%). This could be evidence of students negatively selecting themselves into colleges with a large share of scientific interests - or vice versa positively selecting into colleges with a large share of fellows that were interested in topics that had better job market prospects, e.g. special branches of theology or law. This seems to fit the discussion in section A.1.1 which suggests that the new scientific topics were held in low esteem by public opinion. However, it also possible that the IV-approach is able to capture some of the determinants of never-takers. As discussed before, hundreds with strong ties to colleges appear to be richer and seem to have offered better education(see the difference between column 1 and 2), thereby plausibly reducing the share of never-takers. Therefore, the IV approach might also account for the share of never-takers that are determined by place of origin. The model has a Kleibergen Paap F-statistic of 38.80 indicating a moderately strong first stage.

The validity of the instrument is based on the exogeneity of the geographical college shares. Since regional ties of colleges dated back to the earliest times of the university, long before the emergence of the Scientific Revolution, the assumption appears plausible. Yet, we cannot rule out the possibility that local development in regions might have co-influenced students' and teachers' interest in the Scientific Revolution. Some historians have argued for a link between the Scientific Revolution and emergent capitalism embedded in highly-skilled craftsmen (Zilsel and Zilsel, 2003). Therefore, if fast developing regions were associated with faster growing teacher shares in the topics of the Scientific Revolution, it would pose a violation of the exogeneity of the instrument.

To account for this challenge to the exogeneity of the instrumental variable, the paper tests whether there was an association between a range of development indicators at the hundred level and the growth rate of the predicted teacher publication shares at the hundred level ($\sum_c P(C = c|H = h) \cdot \Delta p_{jct}$). Results for Bairoch (1988) city size, Langton (2000) city size, the number of ports, and distance to ports are shown in appendix tables 41–45. Table 46 further presents results for Unitarian congregations as a proxy for radical Protestant beliefs. Overall, these results are mainly insignificant. Where we find significant effects, the coefficients are small or negatively associated with development indicators.

5.2 Stacked difference-in-differences based on fellows leaving their college

While the previous section has addressed bias from students selecting into colleges, the next two sections address bias from teachers selecting into colleges. Bias could arise from teachers' decision to join colleges with either a) interested students or b) a specific research tradition. In contrast, the process of a teacher leaving their college does not involve a selection process. Instead, teachers join the uniform "out of college" group.

To identify the treatment effect of teachers leaving their colleges, the paper uses a stacked differences-in-differences approach (Cengiz et al., 2019; Baker, Larcker and Wang, 2022). For this, we identify stacks around fellows' leaving events, $[E_e - \tau, E, E + t]$, at each college. Treatment is defined as topics covered by the leaving fellow and controls are defined as topics not covered by the leaving fellow. We impose a clean control condition that specifies that no other fellow publishing on the topics of the Scientific Revolution joins or leaves the college within the time period of each stack, $[E_e - \tau, E, E + t]$ (see Cengiz et al., 2019). Stacks are estimated separately and then pooled together. The estimated coefficient is robust to heterogeneous treatment effects (Baker, Larcker and Wang, 2022). Concretely, we estimate:

$$v_{jict} = \sum_{\tau=-9}^{9} \sum_{s \in S} \beta_{\tau,s} \cdot p_{jct} \cdot \mathbb{1}(t - E_e = \tau) + \gamma_{sc} + \zeta_{sj} + \alpha_{st} + \varepsilon_{jict} \tag{4}$$

where the dependent variable v_{jict}, student i's publication shares in topic j at college c and time t is similarly defined to equation 1. Likewise treatment $p_j ct$ is defined as teacher publication shares in topic j at college c and time t. The stacked difference-in-differences model then defines stacks S around the event E_e of fellows with publication shares in the topics of the Scientific Revolution leaving their college.[27] Each stack $s \in S$ corresponds to a leaving event at a given college c and defined across the dimension of topic j and students' matriculation time t. The length of the pre- and post-leaving-event, t length is defined as the median length of fellows' appointments, which is 9 years for both Oxford and Cambridge. $\gamma_{sc}, \zeta_{sj}, \alpha_{st}$ denote field, j, college-, c, and time-, t fixed effects specific to each stack s. Each stack, $s \in S$ is required to fulfill the clean controls condition (Cengiz et al., 2019), i.e. no other treatments besides E_e occur within $[-t, t]$.[28] The stacked difference-in-difference estimator is then estimated by pooling stacks $s \in S$ together and estimating equation 4 with fixed effects saturated at each stack level. Following (Cengiz et al., 2019), standard errors are defined at the group $\times$ sub-experiment level, the topic-stack level.

Table 4 presents the results. Note that in this setting, the clean control condition is a restrictive condition, excluding half of all leaving events. After limiting the sample to stacks with clean controls, equation 4 is estimated on 108 stacks for Oxford and 81 stacks for Cambridge. Column 1 presents results for equation 4 with field, college, and time fixed effects saturated at each stack level. Column 2 further adds student fixed effects to the specification. Results from column 2 show that increasing teachers' publication shares before the leaving event by 1% leads to an increase in students' publication shares by 0.059% at Oxford and 0.029% at Cambridge. Therefore a 100% increase in teachers' publication shares before the leaving event leads to a 4.25% increase in students' publication shares at Oxford and a 2.1% at Cambridge. Note that similarly to the results from the instrumental variable approach in section 5.1, coefficients are larger than in the baseline results in table 2. We interpret this as further evidence of negative self-selection of students away from colleges with strong publication shares in the topics of the Scientific Revolution and towards colleges with fellows publishing on more marketable topics. Section 6 discusses the interpretation of the effect size against multiple counterfactual increases in teacher shares.

[27] As before, the topics of the Scientific Revolution are defined as *astronomy, almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments.*

[28] Other treatments would be constituted by other fellows publishing on topics of the Scientific Revolution either arriving or leaving within $[-t, t]$ at college c.

Causal inference rests on the no anticipation and common trends assumptions. The paper conducts the following set of tests to test the plausibility of these assumptions:

1. **No anticipation.** A key factor is the determination of leaving event E_e. We would assume that leaving events would have been determined by job openings at other places.[29] While it would appear difficult to predict job openings years ahead, it is not plausible to believe that both fellows and students could have predicted some job openings months or even one or two years ahead of the event itself. To exclude decisions based on this information from the estimation, appendix table 47 presents results from equation 4 while excluding an expanding interval around E_e. The results indicate that the estimated coefficients are not sensitive to the periods around event time E_e, thus mitigating concerns about violations of the no-anticipation assumption.

2. **Measurement error.** Additionally, note that since some of the fellowship times had to be imputed, see appendix section B.4, some of the leaving dates might be inexact. Omitting the time period around the leaving event further avoids bias from imputed appointment lengths.

3. **Common trends.** To further test the plausibility of the common trends assumption, table 48-49 present summary statistics across a wide range of covariates for the pre- and post-treatment period. From table 48-49, indicates some minor differences in degrees and status between the pre- and post-treatment period. However, the differences are small and present in different categories for Oxford and Cambridge. Altogether, the results from table 48-49 do not indicate that there were large or systematic differences between the pre- and post treatment period.

[29] In case of the Church of England, that made up for ca. 50% of all future career paths, job openings were dependent on lucrative parishes becoming available. This could either happen through the death of the incumbent or the incumbent's appointment to another parish. It appears unlikely that both events could have been predicted multiple years ahead of the events themselves.

Table 4: Stacked difference-in-differences results for teachers leaving their college

Panel A: Oxford	Log share of each topic in student publications	
	(1)	(2)
	Mean top.	Mean top.
Log share of each topic in teacher publications	0.0594**	0.0594**
	(0.0271)	(0.0276)
Stack fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Topic fixed effects	Yes	Yes
Year x stack fixed effects	Yes	Yes
Topic x stack fixed effects	Yes	Yes
Student fixed effects	No	Yes
Observations	1098	1098
R-squared	0.18	0.25

Panel B: Cambridge	Log share of each topic in student publications	
	(1)	(2)
	Mean top.	Mean top.
Log share of each topic in teacher publications	0.0314**	0.0294**
	(0.0136)	(0.0138)
Stack fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Topic fixed effects	Yes	Yes
Year x stack fixed effects	Yes	Yes
Topic x stack fixed effects	Yes	Yes
Student fixed effects	No	Yes
Observations	1394	1394
R-squared	0.14	0.20

Notes: The table shows results from estimating equation 4. The dependent variable is student publication shares in the topics of the Scientific Revolution. Treatment is defined as teacher publication shares of before the event of a teacher leaving the college. Standard errors are clustered at the topic-stack level and included in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

5.3 Quasi-natural Experiment: Forced appointment of Oxford fellows during the Parliamentary visitations of Oxford

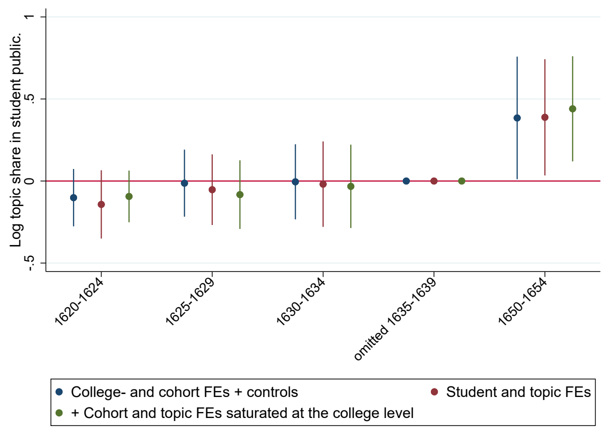


FIGURE 4: Difference in differences results for the Parliamentary visitation shock

Notes: The figure presents results from estimating equation 5. The dependent variable is defined as student publication shares in the topics of the Scientific Revolution. The treatment is defined as teacher shares in the topics of the Scientific Revolution based on the set of fellows appointed by Parliament who were appointed outside their own college. See section 3.2 for a full definition of treatment. The fields of the Scientific Revolution are defined as astronomy, almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments. Results are shown for three specification. A baseline model with college- and cohort-fixed effects as well as teacher- and student-control, a second specification with additional student-, and topic-fixed effects, and a third specification with cohort-, topic-, and student-fixed effects fully saturated at the college level — similar to equation 4 in section 5.2. The treatment period is 1650–1654. We exclude the periods overlapping with the Civil War, 1640–1644 and 1645–1650, when the university was physically besieged. $N = 2,227$. Standard errors are clustered at the college $\times$ topic level. Confidence intervals are shown at the 90% level.

This section introduces an identification approach that is based on the sudden and unexpected dismissal of teachers at the University of Oxford and the sudden and unexpected appointment of new teachers. This shock is based on the expulsion and forced appointment of fellows at the University of Oxford by the parliamentary visitors after the end of the English Civil war. The logic of the approach is outlined in section 2.2. The paper takes the forced appointment of fellows who published in the fields of the Scientific Revolution as an exogenous shock in a stacked difference-in-differences design

$$v_{jict} = \sum_{\tau=1620-1624}^{1650-1654} \sum_{s \in S} \beta_{\tau,s} \cdot \rho_{jct} \cdot \mathbb{1}(t - E_e = \tau) + \gamma_{sc} + \zeta_{sj} + \alpha_{st} + \delta_i + \varepsilon_{jict} \tag{5}$$

where the dependent variable v_{jict} measures the share of student i's publications in research field j in the fields of the Scientific Revolution. The treatment variable ρ_{jct} is defined as teacher publication shares in the fields of the Scientific Revolution from the set of teachers appointed by the parliamentary visitors who came from outside their own college. The treatment period is 1650–

1654, the period following the appointments by the parliamentary visitors. The definition of the shock is explained in detail in section 3.2. Since the equation is estimated across three dimensions at the college × topic × cohort level, it is important to clearly define treatment and control groups. We follow the stacked difference-in-differences approach from section 5.2 by creating stacks at the college level. Within each individual stack, topics with positive shares in the Scientific Revolution constitute the treatment and topics with zero shares constitute the control group. Fixed effects, γ_{sc}, ζ_{sj}, α_{st} are fully saturated at the college (stack) level. Similar to equation 4, the specification also includes student fixed effects δ_i.

First, appendix figure 18 presents results for regressing the publication shares of the full number of teachers in period τ on the publication shares of the new teachers appointed by the visitors. We find that a) there were no pre-trends in publication trends before the time of appointment and b) that increasing publication shares by the fellows appointed by the visitors leads to a $> 100\%$ increase in publication shares of all teachers. This is likely due to initially appointed fellows influencing the appointment process of later fellows.

Next, figure 4 presents results for equation 5. We find a significant increase in student publications following the visitation shocks. Furthermore, we find no evidence of pre-treatment trends in student publication shares. Note that equation 5 only captures the reduced form relationship between teachers appointed by the visitors and students, making direct comparisons to the section 5.1 and 5.2 difficult. The reduced form results show that increasing the publication shares of teachers initially appointed by the visitors by 100% leads to a 31% increase in students' publication shares. An intuitive way to compare this finding with previous teacher effects is to increase the publication shares of teachers initially appointed by the visitors by 0.3 percentage points, the same as a 100% increase in publication shares of all teachers at the mean for this period. This 0.3 percentage point increase leads to a 9% increase in students' publication share in the Scientific Revolution. Thus, the estimated teacher effect is 17% larger than in the IV approach and 34% larger than in the leaving-event approach from section 5.1 and 5.2.

Yet, we should note that the treatment of teachers appointed by the visitors might not generalize to other times or settings. Initially appointed teachers were structurally different from other teachers (especially younger, see Reinhart (1984)). They are further likely to have influenced subsequent hiring decisions, making inference from the reduced form specification difficult. Overall, the results from this section support the presence of a positive causal effect of teachers' direction on students' direction of research.

The findings also constitute first empirical evidence on the Merton thesis (Merton, 1938; Webster, 1977) which proposed a relationship between Puritan and scientific values. According to the thesis, the interregnum was a key period where, for a short while, Puritan teachers dominated university education.[30] While we cannot identify the religious beliefs of individual teachers, figure

[30] This analysis is also reflected in Hill (1968), "Oxford is not only peripheral, it is positively hostile to Baconianism except for the brief period after Oxford, the King's headquarters in the Civil War, had been conquered by Parliamentarian London" (Hill, 1968, p. 145).

18 still provides evidence that within the time period of Puritan Parliamentarism and after the Royalist cleansing of the university, teachers successfully proliferated science at the universities.

6 Transmission dynamics and counterfactual policy implications

6.1 Multigenerational transmission model

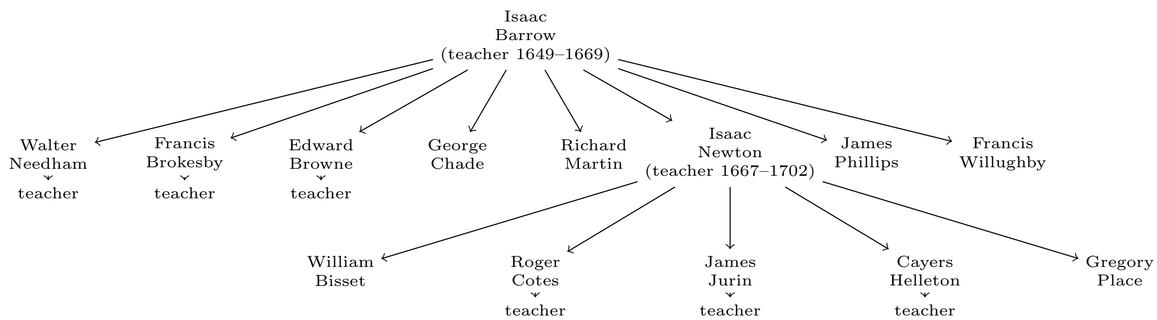


FIGURE 5: Illustration of exposure to teachers across student-teacher generations
Notes: The figure presents a snapshot of teacher-student exposures for two influential scientists, Isaac Barrow and Isaac Newton, both teachers at Trinity College, Cambridge. It connects the teachers to all the students who would a) publish on a topic of the Scientist Revolution and b) were present at Trinity College during the teaching periods of either Isaac Barrow or Isaac Newton.

Figure 5 shows teacher-student pairs across two generations. The top layer shows all of Isaac Barrow's (1630–1677) students at Christ Church who published in the Scientific Revolution. Out of these, four became teachers, including the famous Isaac Newton. The next layer then shows the students of Isaac Newton (1642–1726). Among them, three also became teachers, including, for example, the famous public lecturer James Jurin and Roger Cotes, who assisted Newton with the publication of his *Principia*.

Figure 5 illustrates how teacher-student effects would have been passed on across multiple generations, giving rise to a multiplier effect: In period t students are treated by teacher publication shares. Treated students have a higher publication share in the Scientific Revolution. In $t+1$ some proportion γ of students also become teachers. Because of the shock in t these teachers have higher publication shares and therefore have a larger impact on their students in $t+1$. The multiplier process then reiterates through all following periods.

We can formalize the multi-generational process as a geometric series:

$$log(s_{t+1}) = log(\alpha) + \beta \cdot log((1+\gamma)s_t) \tag{6}$$

where s_{t+1} is students' publication share in the Scientific Revolution in the next time period. We assume that teachers in $t+1$ are recruited from the student population in t. Students interested in the Scientific Revolution have a $1+\gamma$ chance of becoming a teacher in $t+1$. α captures influences independent of the teacher-student channel that raise students' publication shares in the

Scientific Revolution by α percentage points. β is the estimated teacher-student effect. The natural logarithm is applied to capture a) decreasing returns and b) to correspond to the empirical model from equation 1. The steady state of equation 6 is

$$s^* = e^{\frac{log(\alpha)}{1-\beta}} = \alpha^{\frac{1}{1-\beta}} \tag{7}$$

yielding the following multiplier for α[31]

$$M_\alpha = \frac{1}{1-\beta} \tag{8}$$

and the following multiplier for γ

$$M_\gamma = \frac{\beta}{1-\beta} \tag{9}$$

The multiplier M_γ captures the multiplier effect of any change in the policy of hiring teachers based on their scientific interest or any change in scientifically interested students' preferences to become a teacher. This initial effect increases students' publication shares and thereby the pool of prospective teachers. Over multiple generation this converges to $\frac{\beta}{1-\beta}$.

The multiplier M_α captures the multiplier effect of any change in students' interest in the Scientific Revolution. This would entail e.g. changes in the university wide curriculum or changes in university wide library holdings. These effects do not only have a direct effect on students' interest in the Scientific Revolution, but are amplified through the multi-generational teacher channel. In the long-run it converges to $\frac{1}{1-\beta}$. This also means that any nation wide shock that increased interest in the Scientific Revolution (take e.g. Christiaan Huygen's discovery of Saturn's rings or Otto von Guericke's vacuum experiments) would have been increased by the graduate share of all publications in Britain times M_α. Given that university graduates made up 31% of all publications in Britain, this multiplier channel would also have been relevant on a national level.[32] Therefore universities acted as nationwide multipliers of shocks to the interest in the Scientific Revolution.

6.2 Dynamics in γ

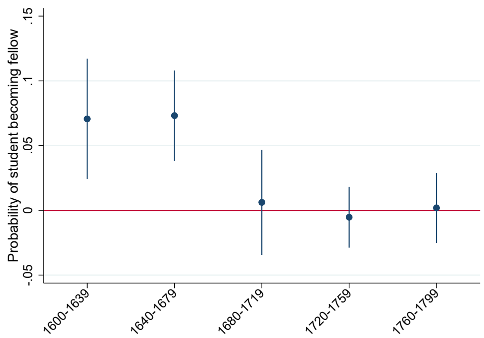
Given the previous discussion, γ is a key parameter in evaluating the institutional openness of universities with respect to the Scientific Revolution. Here, any discrimination in hiring of scientific teachers would imply $\gamma < 1$ and decrease s_t.[33] Was this the case or did seventeenth century Oxford and Cambridge have a sufficient degree of intellectual freedom to ensure $\gamma \geq 1$?

To estimate the value of γ, we regress students' publication shares in the Scientific Revolution on the event of students becoming teachers. Appendix table 50 shows that between 1600–1720 an increase in student publication shares by 100% is associated with an average 2.23% probability of

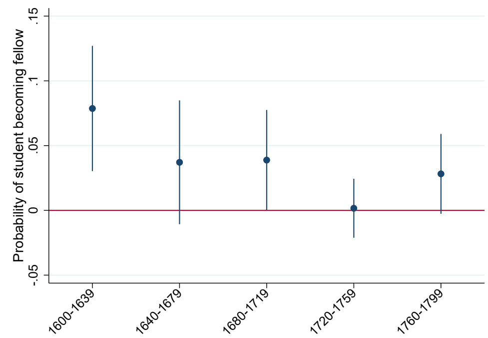
[31] Assuming $|\beta| < 1$ and $\gamma \neq 0$.

[32] The figure is based on the results of matching students and ESTC authors. It refers to all publications by real people — excluding institutional publications such as e.g. acts of Parliament. See appendix section C.3.

[33] We would usually assume that since scientific interests did not open other career opportunities (see section A.1.1), the preference of scientifically interested students to become a teacher should have been ≥ 1.



(a) University of Oxford



(b) University of Cambridge

FIGURE 6: Estimating γ over time: Students' likelihood of becoming a fellow given students' publication outcomes in the Scientific Revolution

Notes: The graph presents results from equation 1 where teachers' publication shares in the Scientific Revolution are interacted by indicator variables for individual fields. Standard errors are clustered at the college-topic level. Confidence intervals are shown at the 90% level.

becoming a teacher at Oxford and an average 2.8% probability of becoming a teacher at Cambridge. Figure 6 presents time trends. We find that γ declined over time, from 7% in the first half of the seventeenth century, to a factor close to zero during the end of the eighteenth century. Given that colleges' hiring policies did not change during this period, the decline in γ most likely reflects the growing attractiveness of opportunities outside the universities for students interested in the Scientific Revolution. This would include e.g. the foundation of the Royal Society in 1660, the success of public lecturers in science (e.g. James Jurin, see figure 1 or John Theophilus Desaguliers) or the curriculum reforms at the Scottish universities in the early eighteenth century.[34] Thus, the success of the Scientific Revolution would also have lowered the teacher share s_{t+1} at universities through a smaller γ.

6.3 Multigenerational transmission dynamics

The model in equation 6 allows us to distinguish between different types of teacher-shocks. First, there are permanent changes to teachers' interest in the Scientific Revolution, α, that are independent of the teacher channel. We can interpret this as general factors that exposed prospective teachers to the Scientific Revolution, e.g. better libraries, publications from abroad, or higher social prestige of the new sciences. These shocks are permanent and include a multiplier process over multiple periods of time. Second, there are one-time increases in teachers' publication shares, s_t, without either changing prospective teachers' interest in the Scientific Revolution, α, or the teacher-choice parameter γ. For example, we could interpret the appointments by the parliamentary visitors from section 5.3 as a one-time increase of teachers with different publication shares

[34] For the public lectures of James Jurin and Desaguliers, see Stewart (1986*b*).

that did not affect fundamental hiring preferences in the long-run.[35] These shocks are transitory and disappear after two periods. Third, there are changes to students' likelihood of becoming a teacher given students' interest in the Scientific Revolution, γ. γ might either be determined by by colleges' hiring preferences or students' comparative career opportunities. These shocks are permanent and include a multiplier process over multiple periods of time.

6.4 Counterfactual shocks

Finally, we consider the effect of a set of counterfactual shocks in the permanent appointment of scientifically interested teachers, γ, on students' publication shares. We should keep in mind that the share of teachers interested in the topics of the Scientific Revolution was very small. Although ca. 25–35% of students would have had a chance to be exposed to a teacher publishing on any subject of the Scientific Revolution, the chance of being exposed to a teacher publishing on one of the topics of the Scientific Revolution ranged between 0.5% and 1%. Average teacher publication shares in the Scientific Revolution per topic amounted to only 0.6% at Oxford and 0.57% at Cambridge. For the following calculations, we use the estimated β from the stacked difference-in-differences approach in section 5.2. Readers can easily calculate teacher effects with other βs or γs. For the sake of brevity, "teacher shares" and "student shares" refer to "publication shares in the topics of the Scientific Revolution".[36]

1. **A 100% increase in teacher shares.** Although this is a substantive increase in teaching shares, this only raises average teacher shares from 0.64% to 1.28%. At the University of Oxford, this would lead to a 4.25% increase in students' publication shares in the short run and a 4.52% increase in the long run. At the University of Cambridge, this would lead to a 2.10% increase in students' publication shares in the short run and a 2.17% increase in the long run.[37] Given that graduates accounted for ca. 31% of all publications in Britain (see appendix section C.3), this would have translated into a 1.04% increase in national publications shares in the Scientific Revolution.[38]

2. **A counterfactual world without scientific teachers.** If, e.g. a censorship system had banned teachers who were interested in the Scientific Revolution from teaching positions, teacher shares would have been close to 0%. We approximate this counterfactual with a 200% decrease in teacher shares. This counterfactual also shows the impact of the teachers that were present at universities. We see that teachers at the university of Oxford accounted

[35] One factor that ensured that Parliament's hires were only temporary was the return of the king in 1660 who then evicted Parliamentary hires. However, as we can see from appendix figure 19 that shows coefficients for regressing actual teacher publication shares on teacher publication shares from appointment by the visitors, the agenda set by the newly appointed fellows already dissipated quickly before 1660.

[36] The topics of the Scientific Revolution are *astronomy, almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments.*

[37] For Oxford, $\frac{s_{t_0}}{s_{t_1}} = 2^{0.06} \simeq 1.0425$ and $M_\gamma = \frac{0.06}{1-0.06} \simeq 0.064$, $\frac{s_{t_0}}{s_{t_1}} = 2^{0.064} \simeq 1.0452$. For Cambridge, $\frac{s_{t_0}}{s_{t_1}} = 2^{0.03} \simeq 2.1\%$ and $M_\gamma = \frac{0.03}{1-0.03} \simeq 0.031$, $\frac{s_{t_0}}{s_{t_1}} = 2^{0.031} \simeq 2.17\%$.

[38] $\frac{4.52\%+2.17\%}{2} \cdot 0.31 \simeq 1.04\%$.

for 7.28% in students' publication shares in the long-run. At the university of Cambridge, they accounted for 3.46% in the long-run.[39] Overall, they accounted for 1.67% of national publication shares.

3. **A 15% decline in γ due to outside opportunities.** This captures the decrease in students' likelihood of becoming a teacher given that students were interested in the Scientific Revolution as shown in figure 6. It appears that at the end of the seventeenth century, teacher positions became relatively less attractive given students' interest in the Scientific Revolution, most likely due to outside opportunities (e.g. the foundation of the Royal Society in 1666 as well as lucrative opportunities for public lecturers). At Oxford, this change in the opportunity costs of becoming a teacher, would have led to a secular decline in students' publication shares by 0.97% in the short-run and 1.03% in the long-run. At Cambridge it would would have led to a 0.49% decline in students' publication shares in the short-run and a 0.5% decline in the long-run.[40] Overall, it would have led to a 0.23% decrease in national publication shares.

4. **A one standard deviation increase in teacher shares.** Teaching shares at the mean are 0.64%. An additional standard deviation in teacher shares amounts to a 4.42 percentage point increase in teacher shares. Therefore, a one standard deviation increase at the mean corresponds to a 696% increase in teacher shares. While this would have amounted to a radical change in the composition of the teaching body, a 4.42 percentage point increase in publication shares would still have left the Scientific Revolution in a minority position and would have been significantly below publication shares in science of nineteenth or twentieth century universities.[41] It is a change in publication shares that could have been achieved through selective hiring, even if such a policy appears unlikely within the context of the seventeenth century. At the University of Oxford, this would have led to a 13.25% increase in students' publication shares in the short run and to a 14.20% increase in the long run. At the University of Cambridge, this would have led to a 6.42% increase in students' publication shares in the short run and a 6.64% increase in students' publication shares in the long run.[42] Overall, this would have led to a 3.25% increase in national publication shares.

Overall, the results show that, especially in the early period of the English Scientific Revolution, universities played an important role as centers of knowledge transmission and acted as multipliers for other shocks that increased interest in the Scientific Revolution. Altogether, teacher-student effects accounted for 1.67% of the national publication share in the Scientific Revolution. Yet, the

[39] For Oxford, $\frac{s_{t_0}}{s_{t_1}} = 3^0.064 \simeq 1.0728$. For Cambridge, $\frac{s_{t_0}}{s_{t_1}} = 3^{0.031} \simeq 1.0346$.

[40] For Oxford, $\frac{s_{t_0}}{s_{t_1}} = 0.85^{0.06} \simeq 0.9903$ and $\frac{s_{t_0}}{s_{t_1}} = 0.85^{0.064} \simeq 0.9897$. For Cambridge, $\frac{s_{t_0}}{s_{t_1}} = 0.85^{0.03} \simeq 0.9951$ and $\frac{s_{t_0}}{s_{t_1}} = 2^{0.031} \simeq 0.9950$.

[41] See Rüegg (2006), Dittmar and Meisenzahl (2021), and Chiopris (2024). One could argue that this counterfactual would correspond to the foundation of the nineteenth century research university (see Dittmar and Meisenzahl, 2021) or potentially the curriculum reform at the Scottish universities in the eighteenth century that incorporated scientific topics into the curriculum.

[42] $1 + \frac{696}{100} = 7.96$. For Oxford, $\frac{s_{t_0}}{s_{t_1}} = 7.96^{0.06} \simeq 1.1325$, $M_\gamma = \frac{0.06}{1-0.06} \simeq 0.064$, and $\frac{s_{t_0}}{s_{t_1}} = 7.96^{0.06} \simeq 1.1420$. For Cambridge, $\frac{s_{t_0}}{s_{t_1}} = 7.96^{0.03} \simeq 6.42\%$ and $\frac{s_{t_0}}{s_{t_1}} = 7.96^{0.031} \simeq 6.64\%$.

results also suggest that the potential for teacher-directed change in the Scientific Revolution was not fully exploited, due to the limited number of teachers interested in the Scientific Revolution. After all, an average student's likelihood to meet a teacher at their college with at least one publication in a given scientific topic still only amounted to 5%. Had there been a larger share of teachers present at the universities, teacher-student effects could have been much larger. E.g. a one standard deviation increase would have translated itself into a 3.25% increase in the national publication share in the Scientific Revolution.

These numbers show that teacher-directed scientific change had a moderate but relevant impact on all English scientific publications between 1600–1720. This is also a relevant finding since Grajzl and Murrell (2024) show that two other significant events during this period, the founding of the Royal Society and the Glorious Revolution, left no visible trace in aggregate English scientific publications. Yet, given the counterfactual policy examples, the impact of the universities and teacher-directed change could have been significantly larger.

In the end, this finding sits well with the history of the Scientific Revolution as a slow and gradual process that covered almost two centuries. Nonetheless, slow but positive growth was the unique feature that allowed European countries to create a knowledge base sufficient to support faster scientific and technological growth during the eighteenth century (Mokyr, 2002, 2016). This paper shows that teacher directed scientific change at universities was one among many factors that supported this steady growth in the Scientific Revolution.

7 Conclusion

Overall, the paper has shown concrete evidence of teacher-directed scientific change during the English Scientific Revolution. It has shown that teachers at the English universities of Oxford and Cambridge had a moderate impact on the research direction of their students for the fields of the Scientific Revolution. At the same time, in a counterfactual world of a higher share of scientifically interested teachers, they could have had a stronger impact. These results contribute to our understanding of teacher-directed scientific change in general as well as to our understanding of the English Scientific Revolution.

By matching the universe of university students and teachers between 1600–1800 with the universe of printed titles between 1600–1800 in England, the paper has provided new data on knowledge production in the early modern period. To classify printed titles, the paper has used a machine learning approach based on a transformer model and historical training data. It has further used a transformer-model based modification of the Kelly et al. (2021) approach to create a measure of the innovativeness of individual titles. By using data on a topic- and sub-student level, the paper was able to estimate the effect of teachers' direction of research on students' direction of research while applying topic- and student- fixed effects. Thus, the model absorbs all non-topic specific factors of student heterogeneity, such as talent or economic background.

In order to investigate causal effects, the paper has introduced three distinct identification approaches. First, it has used an instrumental variable approach based on the strong ties between individual colleges and English regions. Based on this pattern, the paper has predicted a student's future college based on his place of origin and then predicted the teachers a student would face at college. Second, it has used a stacked difference-in-differences approach based on teachers leaving their college. Lastly the paper has exploited a quasi-natural experiment based on the eviction and forced appointments of new teachers by victorious Parliament following the English Civil War.

Overall, the paper has shown that teachers' direction of research is a strong determinant for students' direction of research for the fields of the Scientific Revolution. The results indicate that the teacher-effect is strong and relevant and can account for 7.28% of students' share of research within the Scientific Revolution at Oxford and 3.46% at Cambridge.[43] Overall, they accounted for 1.67% of the national publication share in the Scientific Revolution. The paper has further argued that even larger effects had been possible if colleges had hired a larger share of teachers' interested in the Scientific Revolution.

The results from this paper contribute to our understanding of teacher-directed technical change. So far, evidence of teacher directed effects in history has been limited to the case of curriculum changes at business schools (Acemoglu, He and Le Maire, 2022), with other studies showing teacher-effects in quality Waldinger (2010) or style (Borowiecki, 2022). This paper contributes the literature by presenting evidence of teacher-directed scientific change during one the largest shifts in the direction of science throughout history, the Scientific Revolution. It presents evidence that the future research trajectory of students can be partly determined by their exposure to teachers at university. Hence, changing the composition of teachers at university can have a long-lasting impact on society's research trajectory.

The paper has further contributed to the historical literature on the role of the English universities for the Scientific Revolution that has been severely contested. While some scholars have argued that the universities were an "intellectual desert" (Manuel, 1968, p. 133) or an "intellectual wasteland" (Westfall, 1983, p. 190), others have argued that universities were important places for the transmission of new ideas from teachers to students (Gascoigne, 1990; Feingold, 1984, 1997). This paper provides a clear quantitative answer by showing that teachers at the English universities were able to pass on their research interests in the Scientific Revolution.

As a final open question, the paper begs the question of how much of the western take-off in science can be explained by the institution of the university. For example, China's education system was built around a centralized civil service exam that every future civil servant needed to pass. Hence, the civil service exam might have created incentives for complying with tradition and against adopting novel ideas (Needham, 1964; Lin, 1995; Ma, 2021). Huff (2003) also argues that Islamic madrasas were important centres of learning, but were exclusively centred on religion. Furthermore, early Islamic advances in science often originated in small and short-lived circles of

[43] Assuming, as in the last section, that a counterfactual world with no teachers can be approximated by a 200% decrease in teacher shares.

learning that never managed to achieve a full institutionalization (Huff, 2003) (the same can be said about early Italian academies). In contrast, the English university system always aimed at providing a broad education across many fields and fostered the exchange between fellows and students through living together in a closed college environment. This paper shows that teacher-directed change in the Scientific Revolution had a significant effect on the lifetime direction of research of the graduates of the English universities. One can speculate that the effects of teacher-directed scientific change at other important European universities of the seventeenth century, such as Leyden, Padua, or Paris would have been of a similar or larger size. Hopefully, future research can shed more quantitative evidence on the European scale of teacher-directed change in the Scientific Revolution. Similarly, it seems that future comparative research could shed further light on the global importance of European universities for the Scientific Revolution and the great divergence (Pomeranz, 2000).

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Appendices

A History of the seventeenth and eighteenth century English university

A.1 Student- and Fellow-Life at Seventeenth Century English Universities

A.1.1 Students

At the English universities of Oxford and Cambridge in the seventeenth century, most of a student's learning and social life was centred around the individual colleges. This was before the emergence of social clubs that would bring students into contact with their peers from other colleges. In contrast, the social life of students in the seventeenth century was more strictly regulated than in the centuries to come and it took place at a student's own college (Brockliss, 2016). Before, lectures had been held through chairs at the university, but this declined throughout the fifteenth and sixteenth century. Instead, since the sixteenth century, colleges themselves took up the duty of teaching their undergraduates, establishing college lectureships and college tutorial systems (Feingold, 1990, p. 8). Hence, educational experiences at the universities of Oxford and Cambridge would have differed according to the presence of different fellows at different colleges. Furthermore, fellowships were only held for an average of about 11 years, leading to constant change in the teaching body. In order to illustrate the working of this college channel, this section will give a short portrayal of students' and faculties' life at the English universities of the seventeenth century.

In the seventeenth century, a student's decision to go to university could be based on different motivations. Many boys still came to Oxford for its traditional role as a training ground for the clergy.[44] "William Trumbull instructed his son to concentrate on Greek, Latin, and the 'liberal arts' and to 'learn to make a verse, a theme and an oration'." (Porter, 1997, p. 27, citing from Berks, RO Trumbull Add. MS 46, letter 24 August 1622), a list of the humanistic skills valued by higher society in the seventeenth century. William Trumbull's list does not include mathematics, nor does it even touch the areas of the "new sciences". Such views would have been representative among student's parents. Indeed, the historical evidence illustrates that parents did not have an interest in choosing colleges with a strong reputation in mathematics or the "new sciences". To the opposite, Hill (1965, p. 55) provides examples of how some parents disapproved of their students being exposed to the mathematical "black art" (Osborne, 1689, p. 5) or the "art diabolical" (Ward and Wilkins, 1654, p. 58).[45] Even parents with less strong opinions feared that "the new sciences" would "either distract them [their sons] from more important studies or adversely affect their cultivation of good breeding" (Feingold, 1997, p. 428). Feingold (1997, ibid.) further shows how opinions of

[44] Note that during the seventeenth and eighteenth century, girls were excluded from attending university. Catholic students were excluded as well - these often attended the English college at Douai. Furthermore, non-Anglicans were excluded as well. Further note that before the English Civil War, Puritans were usually seen as reformer within the Anglican Church, not outside the Anglican Church. Hence, before the English Civil War, Puritans were not excluded, although some Puritan students might have been deterred by the Laudian administration.

[45] Seeing mathematics as a part of the dark arts had a long European history (see e.g. Taylor 1957, p. 90.)

the sciences being non-becoming for higher status were mixed with practical considerations. Thus, we can read how in 1688, Edmund Verney's father vividly warned his sons against the perils of studying chemistry:

> "I am gladd, you didd not goe through with a course of chymistry. That sort of learning I do not approve of for you; it is only usefull unto physicians and it impoverisheth often those that study it, and brings constantly a trayne of beggars along with it." (Verney, 1899, p. 405)

Instead, seventeenth century parents choosing a college for their son would have been cared about personal contacts and the regional focus of a college, as well as its religious leaning (Brockliss, 2016, p. 232).

Once a student had enrolled at a college, he would be fitted into the ranks of the student body. At Oxford, there were foundationers, whose education was sponsored through college scholarships, and non-foundationers paying for their own education (Brockliss, 2016, p. 226).[46] The foundationers themselves were split into different groups. At the top were the fellow commoners, paying the highest entrance fee and often being of noble descent. Below them came the commoners who also paid the full tuition. They were followed by battelers, not being supplied with the "commons" at dinner, but also paying lower fees. At the bottom were the pauperi, performing additional duties for the college in return for even lower fees, and often taking up the role of servitors to the upper student ranks or faculty (Brockliss, 2016, p. 227). The different status translated into different accommodation, gowns, and quality of food (ibid.).

These differences in status also translated themselves into the daily college life. Gentleman commoners dined at the fellow's table at the end of the hall, while ordinary commoners and battelers dined at separate tables. Servitors and the pauperi would wait for the upper ranks to finish, while the servitors would assist their masters. Only then would they dine on the leftovers from the upper ranks (Brockliss, 2016, p. 229).

However, the formal ritualization of social ranks does not imply that the fellows did not socially interact with the lower ranks. Fellows in their capacity as tutors shared their bedchamber with students and in case a pauperi performed servatory duties to a faculty member, we might even suspect a closer exchange between servitor and master than with other students. One example is Robert Hooke serving for the extra-collegial Robert Boyle lodging in Oxford and later becoming his laboratory assistant. Furthermore, all ranks studied together and had a strong college identity throughout the ranks (Brockliss, 2016, p. 233).

Within seventeenth century society, a student was not necessarily expected to have taken a degree at university. Nonetheless, we can see from the student data that 52% of all students took a bachelor's degree, while 33% passed on to a master's degree. Minimal residency for a B.A. were four years and further three years for an M.A. Beginning his studies, a student pursuing a B.A. would

[46] The system at Cambridge, split between sizars at the bottom, pensioners, and fellow commoners at the top was, except for naming conventions, almost identical to its sister university. Hence, for brevity's sake the following discussion will illustrate basic features of 17$^{\text{th}}$ century university life by the example of the University of Oxford.

have spent his first year studying grammar and rhetoric in order to get his Latin to an academic level (Clark, 1887, p. 225 f.; Brockliss, 2016, p. 236). After this, he would have succeeded with ancient logic and ethics, the main pillar of his bachelor's degree, and would have started to study Greek and geometry in his third year (Brockliss, 2016, p. 236). Only after having completed a bachelor's degree would students have started to study (ancient) natural philosophy, metaphysics, astronomy, and mathematics (Frank, 1973, p. 201; Brockliss, 2016, p. 236). In Oxford, the award of a bachelor's degree depended on the completion of a set of disputations, a public exercise of a scholasticly formalized debate of a given topic in Latin (see also Thompson, 1959, p. 26), and a final oral examination.[47] The completion of a master's degree depended on the requisite years of study and completion of the formal disputations (Allen, 1949; Brockliss, 2016, p. 236).[48] For the late sixteenth and early seventeenth century there survives evidence on students that were refused their degrees at examination (Clark, 1887, p. 227 f.), proving that examinations were a strict requirement and not only a formal exercise.

This stands in clear contrast to the eighteenth century, where examination standards declined at the English universities. To some extent this decline might have already started during the seventeenth century. Indicators for this were e.g. Cambridge abandoning required residence for a bachelor's student's final Lent term in 1681 (Westfall, 1980 p. 138; Wistanley, 1935, p. 42). However, most of the changes in examination seem to have started during the "first two or three decades of the eighteenth century" (Wistanley, 1935, p. 48). Similarly, Frank (1973, p. 206) draws on additional evidence from questions discussed in the disputations and students' letters describing their experience during their disputations. This material leads him to conclude that "disputations maintained a good portion of their intellectual rigour until well into the 1720s and 1730s" (ibid.). Afterwards, the universities seem to have to have put less and less weight to an examination mode that was increasingly seen as outdated (Wistanley, 1935, p. 48–60). Around the 1800s this decline in the standard of the arts degrees led to institutional change at both, Oxford and Cambridge. Notably, in 1807 the current-day practice of awarding automatic master's degrees three years after the completion of a B.A. was established in Oxford (Brockliss, 2016, p. 237 f.), a practise that survives up to today and might be well known to many readers. Yet, this was a reform of nineteenth century Oxbridge, standing in clear contrast to the seventeenth century, where the M.A. was both a taught and examined degree that fulfilled an important role in introducing students to advanced materials of study, such as natural philosophy (ibid.).[49]

[47] These examinations usually took the form of scholastic "quaestiones", consisting of the statement of a problem, the presentation of objections, the logical treatment of each objection, and a final synthesis. For Oxford, there exist written records of the contents of these questiones for 1576 and 1622 compiled by (Clark, 1887, p. 169–217). Many of these "quaestiones' came directly from the treatises of Aristotle (ibid. p. 170) and illustrate the monopoly of scholastic teaching at the university.

[48] In Cambridge, the requirements for passing a the bachelor and master's of arts degree were similar (Wistanley, 1935, pp. 41–46).

[49] One might note that at least in Cambridge, the residency requirements were less strict for master's degrees than for bachelor's degrees (Wistanley, 1935, p. 62). However, the biographical material studied for this essays gives no indication that perpetuated absence was a common practice during the seventeenth century.

A.1.2 Faculty

On the other side of a college's body was the faculty consisting of the college's fellows and senior administrators, with the college's head or warden at the very top. A fellowship in the seventeenth and eighteenth century was situated somewhere between a modern Ph.D. and a faculty position. They were given to to advanced students, either having passed their master's degree or being senior master's students (Brockliss, 2016, p. 226 f., 281). A fellowship included an annual stipend and brought teaching obligation with it. It was usually dependent on both, a college examination and the particular conditions of the specific fellowship, sometimes linking the fellowship to a student's county or town of birth. As part of the seventeenth century world of patronage, the influence of a candidate's patron could be decisive as well (Brockliss, 2016, p. 230). After being awarded a fellowship, the award was open-ended, although the compulsory celibacy during a fellowship was often sufficient motivation to seek employment elsewhere (often becoming a parish priest). In case a fellow secured himself the position of e.g. a professorship, chaplain, or warden, etc., the fellowship still continued. For a detailed description of fellowships see Brockliss (2016, p. 281 f.).

The teaching demanded of fellows was either given through lectures at their college or through tutorial duties. The tutorial system at Oxford evolved parallel to the development of college-specific lectures. A tutor was supposed to oversee his student's academic development and to give private lessons. However, he was also a strong personal anchor in a student's life who would share his chamber with his tutor. However, during the seventeenth century tutors started to instruct multiple students at once (Feingold, 1990, p. 8), therefore leading to a decline in the strength of the tutorship channel over time. See Brockliss (2016, pp. 251–254) for a detailed discussion of the tutorial system at Oxford. All in all, seventeenth century colleges seemed to have offered students close contact to teachers and their views, either through interaction after college lectures, through a student's tutor, through conversation at dinner or through other informal meetings. Lastly, a short case study of Christopher Wren will serve to illustrate this channel. Christopher Wren enrolled at Wadham College in 1650, completed his B.A. already in 1651, his M.A. in 1653 — a speed that was unusual for this time — and was elected as a fellow of Wadham College in the same year. He was later elected as a member of the Royal Society in 1660 and would become president of the Royal Society from 1680 to 1682. Studying Christopher Wren, Downes (2012) argues that his engagement with the general arts curriculum that was based on a traditional scholastic curriculum did little to bring Wren into contact with the "new sciences". However, Downes (2012) explicitly recognizes the importance of informal acquaintance with the fellows for his learning of the "new sciences" that Wren could get at Wadham College – e.g. at dinner, where Wren, as a fellow-commoner (the upper-ranks of the student body paying highest fees), could dine at the fellows' table. Faculty members in return seem to have recognized their promising student. We do not know which form of indirect contact prevailed in the end, yet, we find that already in 1650, the year of Wren's enrolment, word from Wadham College hard reached Samuel Hartlib who noted Wren's "fine inventions and contrivances . . . Hee is but 18 years of age and highly commended by Dr. Wilkins. [and] Mr. Wallis" (Hartlib, 1650, as quoted by Frank 1973, p. 202). Both John

Wilkins, John Wallis, and Christopher Wren would be among the founding members of the Royal Society a decade later.

A.2 The political background of the Oxford visitation and the appointment of new fellows

When civil war broke out in 1642, the Laudian university sided with the king. It further started to finance the king's cause (Roy and Reinhart, 1997, pp. 695, 714). In September 1642, the city of Oxford was shortly seized by parliamentary troops after which most students left the university for their homes or joined the war parties (Roy and Reinhart, 1997, p. 698). At the end of October 1642, the city fell back in Royalist hands and soon after the town of Oxford became the king's headquarters. Finally, as the king's campaign dismantled, the city was besieged by parliamentary troops throughout May and June 1646 until it finally surrendered to Fairfax.

With the king's cause lost, Parliament was keen on extending its rule to the Royalist university. Not only did Parliament see Oxford as a dangerous stronghold of Royalist sentiment, but Oxford and Cambridge were also the training grounds for the next generation of clergymen and thus would have to be cleansed of all Laudian and suspectedly Arminian influences. In 1647 Parliament sent out an array of visitors to the university of Oxford (appendix table 5 presents a list of the original visitor including both, their former role at Oxford and their political role for Parliament). The list illustrates that the visitors were intentionally chosen as "outsiders" of the existing college tradition. Thus, the body of the visitors was dominated by parliamentary commissioners and preachers. The former Oxonians on the committee were mainly ejected heads of the halls. The only head of a former college was Nathaniel Brent, former warden at Merton, who in 1646 had resumed his role of warden at Merton college. However, it appears that Nathaniel Brent was fully excluded from the process of appointing new fellows. In February 1651 he officially sent a protest note to the visitors complaining that they had "claimed to rule Merton College as they pleased, and, without consulting the warden, they admitted fellows, masters, and bachelors of arts" (Lee, 1886, p. 263). It seems that the appointment process was indeed swift and happened without regard for pre-existing college traditions.

During 1647, the parliamentary visitors proved successful in replacing half of all college heads with senior academics from outside the university that were known to be loyal to Parliament.[50] However, until the spring of 1648, Oxford dons were generally successful in their resistance to the visitors. They based their resistance on grounds of conscience, their oaths to the king, and legal arguments that the king being was the only one with authority over the university (Reinhart, 1984, p. 322–346). This strategy played out successfully during a time of internal frictions within

[50] These new appointments reflected the circumstances of a "fluid" political situation, where Presbyterians and Independents opposed each other in Parliament (Shapiro, 1969, p. 81). Thus, appointments during this time did not follow a general strategy, nor a general Independent or Presbyterian leaning (ibid.). This uncertain climate was exacerbated by the fact that new appointments were sometimes made urgent by the death of old college heads and a subsequent election of a new college head by the existing fellows — elections that Parliament had to undo as timely as possible.

Parliament and the uncertain position of the king within the new order (Roy and Reinhart, 1997, p. 727).

During 1647, Parliament, although victorious, was still in negotiation with the king. Yet, the position of the university changed drastically with the beginning of 1648: With the Vote of No Addresses on 17 January 1648, Parliament broke off its negotiations with Charles I. Soon after, in spring 1648, Royalists rose again and ignited the Second English Civil War. At this point, loyalty to the king had become synonymous with treason (Reinhart, 1984, p. 378).

Thus, in 1648 Parliament finally enforced its rule on the University of Oxford through drawing on the military thread of its garrison at Oxford. Parliament ultimately decided to order all Oxford fellows before the visitors and asked them to swear an oath on the new commonwealth. Absence or evasive answers were taken as non-submission and non-submitting fellows were removed (Roy and Reinhart, 1997, p. 729).[51] Roy and Reinhart (1997, p. 731) show that 190 fellows out of 379 were effectively expelled, 43 were expelled but nonetheless managed to remain, and 146 submitted to the oath and remained. Thus, the personal break was not absolute, but severe.

At the same time, the parliamentary commission was overseeing the appointment of new fellows. Because the purge of old fellows had been a hasty reaction to the political events leading to the Second English Civil war, preparations for the replacement of expelled fellows were not in place. In order to maintain the functioning of the university and to leave no doubt that expelled fellows had no chance of regaining their old positions, the visitors had to act fast. The decision which new fellows to accept was taken by a committee established by the visitors in July 1648. The main aim of the visitors was to establish their authority, promote a Calvinist leaning within the fellowship, and to establish this reform in a very short time frame (Reinhart, 1984, pp. 406 f., 413). Hence, the focus was mainly political, and the speed of political events did not leave visitors enough time to choose new fellows that would be acceptable to the traditions and sentiment of individual colleges - a selection criterion that would have been unlikely either way, given their intention to disrupt these very college tradition. Hence, the paper argues that the intrusion of fellows constituted an exogenous shock to the distribution of fellows across colleges.

[51] Curiously, there remained a significant number of non-submitters who were expelled, but not effectively removed — the reasons for this are not straightforward, especially as it is difficult to categorize all the individual elaborate reasons given for non-submittance (Roy and Reinhart, 1997, p. 729).

B Data

B.1 Variable definitions and data sources

Alumni Oxonienses, 1500–1714. Catalogue of the alumni from the University of Oxford 1500–1714 as compiled by (Foster, 1891). The catalogue includes detailed information on, amongst other, the name of a student, year of matriculation and degrees, place of origin, and status. Note that reliable recording of students only started around ca. 1580. The data source is discussed in detail in section B.3. The transcript was obtained from British History Online, `https://www.british-history.ac.uk/alumni-oxon/1500-1714`, accessed 5 April, 2020. The book was digitized using double rekeying.

Alumni Oxonienses, 1715–1886. Catalogue of the alumni from the University of Oxford 1715–1886 as compiled by (Foster, 1891). The catalogue includes detailed information on, amongst other, the name of a student, year of matriculation and degrees, place of origin, and status. The data source is discussed in detail in section B.3. The transcript was obtained from Wikidata, `https://www.wikidata.org/wiki/Q19036877`, accessed 20 August, 2022. The transcript was carried out by Wikidata volunteers. Missing sections were transcribed from the original by the author.

Alumni Cantabrigienses, from the earliest times to 1900. Catalogue of the alumni from the University of Cambridge from the time of its foundation to 1900 as compiled by (Venn and Litt, 1952). The catalogue includes detailed information on, amongst other, the name of a student, year of matriculation and degrees, place of origin, and status. Note that reliable recording of students only started around ca. 1580. The data source is discussed in detail in section B.3. The transcript was obtained from ACAD - A Cambridge Alumni Database, `https://venn.lib.cam.ac.uk/` (Dawson, 2001), accessed 11 November, 2020. The paper uses the transcribed raw data from ACAD instead of the pre-classified text.

English Short Title Catalogue (ESTC). Titles of works printed in 1600–1800 in either England or in the English language. The catalogue further includes data on publication years, author names, author lifetime dates, and subject classes. The ESTC 1600–1800 was kindly shared with the author by the British Library.

Hundreds in 1831. Historical boundaries above the parish-level and below the county-level. The dataset represents boundaries of hundreds in 1831 before the Counties Act of 1844 and thus should be a close approximation of hundred boundaries in the preceding centuries. Data obtained from Satchell, Shaw-Taylor and Wrigley (2017).

Student publication shares. Student i's publication shares in a given subject j out of all of student i's publications. Subject shares across all subjects j constitute student i's direction of research. A student's number of publications in subject field i is denoted as b_i. A student's direction of research, v, is then defined as a vector of the researcher's strength of research, b/n, across the dimensions of m subject classes, $v = (b_1/n, b_2/n, \ldots b_m/n)$.

Teacher publication shares. Teacher publication shares at college c in time t. Individual teacher publication shares are analogously defined to student publication shares. Teacher shares at the college level are defined as an average across all individual teachers $(b_{1,1}/n+b_{1,2}/n+\cdots+b_{1,m})/\mu$, where μ denotes the number of teachers.

Teacher publication proximity to *Philosophical Transactions*. Average similarity of teachers' publications to the titles of the articles journal of the Royal Society, the *Philosophical Transaction*. Proximity for title i is calculated as cosine similarity to all *Philosophical Transactions* articles within the same subject class as title i. For fields without teacher publications, we assume that the similarity is zero. See section C.7 for formal definition of the measure. To interpret this measure, we argue that the *Philosophical Transactions* constituted the scientific frontier. Therefore, proximity to the *Philosophical Transactions* can be interpreted as proximity to the scientific frontier or as an inverse measure of distance to the research frontier.

Teacher publication innovativeness. Maximum innovativeness of teacher publications. Innovativeness for title i is calculated as the share of forward similarities (BS) and backward similarities BS to titles in the same field $I_i = \frac{FS_i}{BS_i}$ similar to Kelly et al. (2021). Similarities are based on cosine similarities within the embedding space and calculated for the backward period of $[t-20, t-1]$ and the forward period of $t+1, t+20]$. See section C.7 for formal definition of the measure. The breakthrough index is normally distributed around zero. For fields without teacher publications, we assume that teachers neither signal innovativeness nor backwardness and assign and therefore assign zero values to these teachers. Following Kelly et al. (2021), we can interpret this measure as the frequency of breakthrough innovations within teacher publications.

Number of teacher publications. Total number of lifetime publications of teachers in college c and matriculation cohort t.

Cohort size. Size of a matriculation cohort c in a given college and year t.

Student status. Indicator variable of the status of students as recorded during enrollment. For the historical context of student status see section A.1.1. For a list of status classes and translations from Latin, see table B.7.

B.2 Geographical proxies for development

Bairoch city size. Population of 62 English towns in 1600 and of 144 towns in 1700. The Bairoch dataset only records cities of at least 5,000 inhabitants. Population is given in 1,000s. Data obtained from Bairoch (1988).

Langton city size. Population of English 1,050 English towns at the end of the seventeenth century from Langton (2000). Population is given in 1,000s. Data obtained from Bennet (2012).

Port cities. The number of historical ports in 1680. Data obtained from Alvarez-Palau and Dunn (2019).

Distance to port cities. Distance to historical ports in 1680 from Alvarez-Palau and Dunn (2019) in 100km.

Unitarian congregations. The total number of unitarian congregations in a given hundred between 1618 (the date of the first foundation) and 1720. Data obtained from Unitarian Historical Society (2020).

B.3 Critical discussion of the Alumni Oxonienses and Alumni Cantabrigienses

The earliest published record of the students at the English early-modern universities was the *Alumni Oxonienses* (Foster, 1891). The editor of the *Alumni Oxonienses*, Joseph Foster, extended his work beyond the matriculation registers by further drawing on the university archives to compile all the degrees awarded at Oxford and tried to incorporate a wide array of biographical information on each student to get additional information about a student's life after graduating. Foster was in a good position to do so: He had already spent years on the collection of material on members of the Inns of Court, knights and members of Parliament (Foster, 1891, pp. i ff.).[52] After the completion of the *Alumni Oxonienses* by Joseph Foster, mathematician John Venn (who also gave his name to Venn diagrams) started to compile a similar list for Cambridge, the *Alumni Cantabrigienses* (Venn and Litt, 1952). Because the matriculation lists for Cambridge were less complete than the Oxford ones, Venn additionally resorted to the admission lists of each college (Venn and Litt, 1952, pp. i ff.). In general, college admission lists have the advantage that they capture the actual date of enrollment at a college as opposed to the date of the official matriculation that was sometimes postponed by one or two years after enrolment. Furthermore, admission lists had a less unified structure than the matriculation list. For example, some colleges only include a student's county of origin for his place of origin while others record the actual birth-place (Venn and Litt, 1952, pp. viii. ff.). Additionally, not all colleges started recording a student's place of origin at the same time. Furthermore, some colleges started to keep their admission lists later than others (mainly around the turn of the sixteenth century) necessitating Venn to still rely on the matriculation register for some cases.

Furthermore, Foster (1891) and Venn and Litt (1952) include information on students' outcomes including students acquiring a priesthood and an incumbents' position, being mentioned in the *Dictionary of National Biography*, joining the Inn's of Court or being a member of the Royal College of Physicians. For compiling this information, Foster consulted the *Index Ecclesiasticus*, Cotton's *Fasti Ecclesiae Hibernicae*, Foster's *Judges and Barristers*, Foster's *Inns of Court Reg.*, Foster's Gray's Inn Register, Foster's *Dictionary of M. P.'s* as well as the *Munk's Roll* from the College of Royal Physicians. It further lists membership in the Royal Society. In compiling these outcomes, Venn closely followed the methodology of Foster. However, Venn's method for compiling a list of Anglican incumbents differed significantly from Foster's. While Foster drew on the Institution

[52]Foster himself concludes that "In these absolutely unique collections, I possess the materials for illustrating and annotating the Oxford Matriculation Register to an extent and with an accuracy that no one else, not even the authorities of the University themselves, can hope to rival" (Foster, 1891, p. iii)

Books at the public Record Office, Venn relied on the more complete County Histories including compilations of the Episcopal registers of local dioceses (Venn and Litt, 1952, p. xiii). Furthermore, we should keep in mind that Venn had the privilege of working a few decades after Foster, thus being able to draw on updated and extended volumes of e.g. the *Dictionary of National Biography*.

Comparing the summary statistics between Oxford and Cambridge in appendix tables 8 and 11, shows that most variables show little difference between both universities (e.g. comparing 53% with a bachelor's degree at Oxford to 55% with a Bachelor's degree at Cambridge or 35% with a master's degree at Oxford to 38% with a bachelor's degree at Cambridge), a result that would be expected for these highly similar sister-universities. This speaks both for the accuracy of the *Alumni Oxonienses* and *Alumni Cantabrigienses* as well as the quality of this study's automatic extraction of information from the texts. The accuracy of the works of Foster (1891) and Venn and Litt (1952) have been further recognized by the historical literature. Thus, for the *Alumni Oxonienses*, Porter (1997, p. 40 f., 45) argues that the matriculation register is more consistent than the censuses of 1605, 1611, 1612, 1622, 1634, 1642, 1661, 1667, and the 1690s, while also containing more information on the student body.

However, these records are necessarily only as good as the original matriculation registers or admission registers of the universities. Recording practises did vary over time and political shocks also affected the recording practice: For Oxford, before 1622, a student's name, status, age, and county were usually recorded, then after 1622 his father's name and place of residence would also be included (Porter, 1997, p. 30). However, we lack information on student's age, father's name and place and county of residence for the interregnum years 1648-1660, as the intruded keeper of the records was not given the old recordings by his predecessor, forcing him to start anew with all categories (ibid.). Thus, the completeness of data for Cambridge where Venn and Litt could additionally rely on the admissions list seems to be superior when it comes to students' place of origin and further personal controls.

Furthermore, data before 1580, the time of the formal establishment of the matriculation registers (Stone, 1974, p. 12), seems to be unsystematic and irregularly recorded. Furthermore, matriculation dates did not always correspond to the actual date of enrolment at a college, with the matriculation being a formal act that was only irregularly enforced (Porter, 1997, p. 31 f.). Porter (ibid.) further suggests that some students not taking a degree could have avoided matriculation altogether and that there even was a number of students taking a B.A. who had not matriculated (ibid., Stone, p. 13). Some of the latter, however, are included in the *Alumni Oxonienses 1500-1714*, although without a matriculation date. Degrees and degree dates were regularly recorded, however. Again, with respect to matriculation dates, Venn and Litt's information for Cambridge that additionally gives the date of admission to a college seem to be more reliable.

There are additionally, a number of degrees not associated with a specific college or hall. While in the early times before 1620 and especially 1580, this would often have been due to irregular book-keeping, there are a couple of other reasons for later times where the quality of book-keeping had increased substantially: Some degrees were conferred by Royal Charter as a reward and were

FIGURE 7: Family's Geo-Location

(a) Geo-location of origin for Oxford students (b) Geo-location of origin for Cambridge students

not the product of actual studies at Oxford. A high number of these titles fall in the time of the civil war, when scholars were compensated for lost time in their studies when serving in the king's army. Furthermore, the university was always ready to award degrees to figures of political eminence, or respectively their family or protégé (see e.g. Roy and Reinhart, 1997, p. 727).

B.4 Discussion of data coding and data quality

The previous discussion of the source material raises a few quantitative challenges that need to be clearly addressed.

1. Especially during earlier times, matriculation was recorded infrequently, with sometimes a one or two year lag between the actual date of admission to a college.

2. Some degrees were not associated with a specific college.

3. For Oxford, information on students' places of origin has not been recorded for the period 1648–1660.

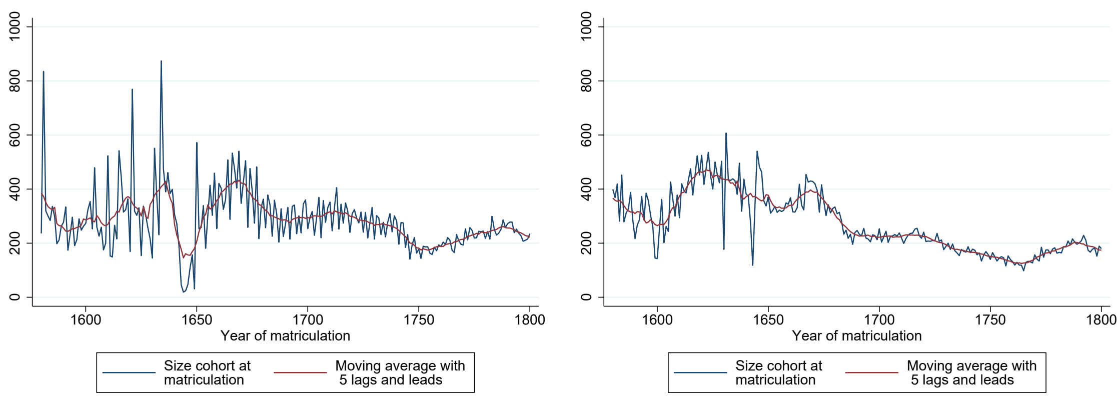
4. Teaching was mainly carried out by fellows, but faculty also involved other ranks such as heads of colleges or university wide professorships.

5. For a significant share of fellows, the records do not include the year a fellowship ended.

6. Matching between the Oxford and Cambridge student registers and the ESTC produced a number of duplicate matches that were excluded.

The rest of this section will describe these data quality issues in more detail, consider potential bias, and describe methods used to mitigate the issues. First, figure 8 plots total student numbers at Oxford and Cambridge. The lag in the recording of matriculation years can clearly be seen in the form of spikes in matriculation years before ca. 1640. After that the quality of recordings increased at both Oxford and Cambridge. In line with our previous discussion, the figure shows that overall years of matriculation are more consistently recorded in the *Alumni Cantabrigienses* than in the *Alumni Oxonienses.* In quantifying the size of the potential bias, the figure indicates 8 that lags in recording only affected a small part of the cohort and only exhibited lags of one or two years. As the previous discussion suggested that lags in recordings were unsystematic, we expect this to lead to a small downward bias from measurement error.

To further take precaution that delayed matriculation might not overlap with the same person's fellowship leading us to a regress a person on themselves, the paper adopts the strict rule that whenever the matriculation and fellowship year overlap, the fellowship is recorded as the matriculation year + 1. While this only applies to a few rare cases, this rule guarantees that we never regress a person on themselves.



(a) Size of Matriculation Cohorts at Oxford, 1580–1800

(b) Size of Matriculation/Admission Cohorts at Cambridge, 1580–1800

FIGURE 8: Development of student matriculation/admission over time

Furthermore, students without a matriculation entry, but only a degree from the university are excluded from the sample. This is a) due to the necessity to assign treatment at the college and matriculation level. Furthermore, as we suspect a large number of them to be honorary degrees. As these would not capture knowledge transmission processes, it is desirable to exclude them.

Additionally, teaching at the seventeenth century universities of Oxford and Cambridge was almost exclusively carried out by fellows at individual colleges. Yet, there was also a small number of professors who taught university wide classes — a remnant from medieval times as well as a few newly endowed chairs. Therefore, we are in need of also assigning treatment from exposure to professors. We continue to assign professors to the college they were attached to. This captures the intuition that while these professors would also have taught students outside their classes, it still appears plausible that the exposure to a professor would be strongest at their own college. In the following, we define a university teacher as either a fellow, a head of a college (warden or president), or a professor situated at a college. The main intuition behind treatment exposure in this paper is that students would adopt ideas after getting to know a teacher through repeated interaction at their own college.

Next, for about 54% of fellows at Oxford and 52% of fellows at Cambridge, the source material only records the starting date of the fellowship but not the end date. To address this, the paper imputes fellowship durations by calculating the average length of fellowships with known end dates and using this average to impute the fellowship duration of fellows with missing end dates. The approach is based on the intuition that fellows usually only served for a limited period of time. One of the main motivations to leave the college was a rule that fellows were barred from marrying (in the seventeenth century, the universities carried as much of the marks of modern universities as of old monastic institutions). For both of the universities, fellowship durations had a mean of 11 years. The imputation introduces measurement error to the treatment variable, leading to potential downward bias. However, appendix table 34 documents that results are robust to using a range of different imputational values for fellowship length. Additionally, since the leaving-fellows approach in section 5.2 is especially sensitive to the definition of fellowship lengths, appendix table 47 shows robustness when omitting years around the leaving date.

Lastly, the process of matching students and authors from the ESTC also introduces a source of measurement error. Basically, in matching procedures are based on a tradeoff between type I errors (false matching two pairs) and type II errors (not matching two pairs). The concrete matching procedure, including the rate of excluded non-unique matches, is described in section C.3.

To evaluate the size of potential bias from matching, appendix section C.4 reports Monte Carlo simulations for type I and type II errors. Results show that even in the presence of 20% type II errors (similar to the 11% omitted non-unique author-matches at Oxford and 8% at Cambridge in section C.3), the downwards bias only amounts to less than 20% at the mean. Given that the paper adopts a matching approach that minimizes type I errors at the cost of type II errors, it is unlikely that downward bias resulting from matching will be larger than 20%.

B.5 The Oxford visitation: Material on visitors

Table 5: Background of Parliamentary Visitors Sent to Oxford

Name	Former role at Oxford	Political Role
Original proposal of visitors		
Ministers		
Edward Corbett	Parliamentary preachers	
Long Harry Wilkinson	Parliamentary preachers	
Edward Reynolds	Parliamentary preachers	
Robert Harris	Parliamentary preachers	
Francis Cheyneel	Parliamentary preachers	
John Wilkinson Sr.	Ejected by Charles II. as Head of Magdalen Hall	
Christopher Rogers	Ejected by Charles II. as Head of New Inn Hall	
John Wilkinson Jr.	Master of Magdalen Hall	
Civilians		
Nathanial Brent	Warden of Merton and Judge Marshall for Parliament	
John Mills	Advocate of the New Model Army	
William Prynne		
Country gentlemen		
Sir William Cobbe		Parl. comm. for Buckinghamshire and Oxfordshire
William Cope		Parl. comm. for Oxfordshire
George Greenwood		Parl. comm. for Oxfordshire
John Heylin		Parl. comm. for Westminster
Thomas Kingt		Parl. comm. for Oxfordshire
John Packer		Parl. comm. for Berkshire
William Prynne		Parl. comm. for Flintshire
John Pulston		Parl. comm. for Flintshire
William Typping		Parl. comm. for Oxfordshire
Additions through lobbying of the House of Lords		
Gabriel Beck		Parl. comm. for Oxfordshire
John Cartwright		Parl. comm. for Northamptonshire and Oxfordshire
William Draper		Parl. comm. for Oxfordshire
Samuel Dunch		Parl. comm. for Berkshire

Notes: The information on the parliamentary visitors is taken from Reinhart (1984, p. 308 f.). Abbreviations: Parl. Comm.: Parliamentary commissioner

TABLE 6: Background of the Committee for the Examination of Candidates for Fellowships and Scholarships Set up 5 July 1648

Name	University education	Former role at Oxford	New role at Oxford
Intruded heads of colleges			
Joshua Hoyle	Magdalen Hall, Oxford; Trinity College, Dublin (BA 1610, MA 1618, BD 1625)	—	Master of University College since 1648 and Professor Divinity since 1648
Edmund Stanton	Matr. at Wadham (9 June 1615), transferred to Corpus Christi (adm. 4 October 1615, BA 1620, MA 1623)	—	President of Corpus Christi since 1648
Daniel Greenwood	Lincoln College (matr. 1624, BA 1626, MA 1629, BD 1640)	—	Principal of Brasenose College since 1648
John Wilkins	Matr. at New Inn Hall, transferred to Magdalen Hall (BA 1631, MA 1634)	—	Warden of Wadham College since 1648
Preachers sent by Parliament			
Mr. Langley	Matr. Magdalen College (1627), transferred to Pembroke College (BA 1632, MA 1635)	—	One of the seven Preachers of 1646; Master of Pembroke since 1647
Henry Cornish	New Inn Hall (matr. 1631, BA 1634, MA 1636-7)	—	One of the seven Preachers of 1646; Canon of Christ Church since 1648
John Palmer	Queen's College (matr. 1628, BA 1628, BM 1630)		Warden of All Souls since 1648
Proctors			
Robert Crosse	Lincoln College (matr. 1622, BA 1625, MA 1628, BD 1637)	Fellow of Lincoln College (1627–1642), but left the university in 1642, joined the assembly of divines at Westminster	Regius professor of Divinity 1648
Ralph Button	Exeter College (matr. 1631, BA 1633), transferred to Merton College (1640)	Fellow of Merton College (1633–1642), but left the university in 1642 and went to Gresham	Canon of Christ Church 1648, junior proctor since 1648
Remaining loyal fellows			
Robert Hancocke	Exeter College (matr. 1640)	Fellow of Exeter College (1648–1657)	Delegate of the visitors
Thankfull Owen	Exeter College (matr. 1636, BA 1639-40), transferred to Lincoln College in 1642 (MA 1646)	Fellow of Lincoln College (since 1642)	Delegate of the visitors
Edward Copley	Exeter College (matr. 1631, BA 1632), transferred to Merton College (MA 1639-40)	Fellow of Merton College (since 1633)	Delegate of the visitors
Anthony Clifford	Gloucester Hall (matr. 1634, BA 1637, MA 1640)	Fellow of Exeter College (1641–1662)	Delegate of the visitors since 1647

Notes: The information on the committee is taken from (Burrows, 1881, p. 141) and (Reinhart, 1984, p. 407). Full names, degrees, and biographical information have been supplemented by drawing on the *Dictionary of National Biography* and Foster's *Alumni Oxenienses*. Degrees refer to the period before 1648 and exclude any degrees awarded by the visitors themselves.

Table 7: Overview of Intruded and Reinstituted "Royal Society" Fellows, 1647–50 and 1660

Name	College before visitation	Start	End	College during interregnum	Start	End	College after restoration	Start	End
Intruded Fellows									
Morley; George (1597 - 1684)				Wadham College; Oxford	1648	1659			
Wallis; John (1616 - 1703)	Queen's College; Cambridge	1644	1645	Exeter College; Oxford	1649	1660	Exeter College; Oxford	1660	1703
Pope; Walter (c 1627 - 1714)				Wadham College; Oxford	1651	1662			
Wood; Robert (? 1621 - 1685)				Lincoln College, Oxford	1650	1659			
Petty; Sir; William (1623 - 1687)				Brasenose College; Oxford	1648	1652			
Pett; Sir; Peter (? 1630 - 1699)				All Souls; Oxford	1649	1650			
Harley; Thomas (- c 1685)				All Souls; Oxford	1648	1659			
Croke; Sir; George (- 1680)				All Souls; Oxford	1648	1659			
Submitted to Visitors									
Bathurst; Ralph (1620 - 1704)	Christ Church; Oxford	1640	-	Christ Church; Oxford	-	1660	Trinity Oxford (President)	1660	1704
Stayed at Oxford after Visitations									
Willis; Thomas (1621 - 1675)	Christ Church; Oxford		B.Med. 1646	pratised at Oxford; kept close connections to Christ Church	1648	1660	Christ Church; Oxford (Sedleyan Professor)	1660	1675
Expelled by Vistors and Reinstituted Fellows									
Morley; George (1597 - 1684)	Christ Church; Oxford	1622	1648				Christ Church; Oxford	1660	1660
Birkenhead; John (1616 - 1679)	All Souls; Oxford	1639	1648				All Souls; Oxford	1660	1661
Dolben; John (1625 - 1686)	Christ Church; Oxford	1647	1648				Christ Church; Oxford	1660	1660
Expelled by Visitors and not Reinstituted in 1660									
Clerke; Henry (c 1622 - 1687)	Magdalen; Oxford	1642	1648						
Newly Instituted in 1660									
Mayow; John (1640 - 1679)							All Souls; Oxford	1660	1678

The fellows are compiled drawing on the *Raymond and Beverly Sackler Archive Resource Project* and Reinhart (1984).
Fellowship dates are coded consistently with the dataset with starting dates are only measured after a fellow's M.A.

B.6 Summary statistics for the Alumni Oxonienses and Alumni Cantabrigienses

Table 8: Descriptive Statistics of Oxford students and faculty, 1580–1720

	Mean	Std.Dev.	Sum	Obs
Student graduates with B.A.	0.5377	0.4986	20146	37465
Student graduates with M.A.	0.3193	0.4662	11961	37465
Student graduates with doctoral degree	0.0427	0.2023	1601	37465
fellow	0.0538	0.2255	2014	37465
scholar	0.0027	0.0516	100	37465
armiger	0.1307	0.3371	4275	32710
baronet	0.0034	0.0584	112	32710
clerici	0.1020	0.3027	3338	32710
comitis	0.0003	0.0175	10	32710
doctoris	0.0079	0.0888	260	32710
episcopi	0.0001	0.0096	3	32710
eques auratus	0.0061	0.0778	199	32710
equitis	0.0125	0.1113	410	32710
gentilis	0.3039	0.4600	9942	32710
militis fil	0.0056	0.0748	184	32710
militis	0.0081	0.0895	264	32710
pauper puer	0.0494	0.2168	1617	32710
pauper	0.0160	0.1256	524	32710
plebeii	0.3297	0.4701	10783	32710
servus	0.0241	0.1534	789	32710
Cohort size	23.5826	15.6002	883521	37465
Number student publications	0.3339	3.7371	12511	37465
Number teachers	9.7927	9.0555	366885	37465
Number teacher publications	22.3969	36.3513	839100	37465
Observations	37465			

Table 9: Publication statistics for publishing Oxford students and faculty, 1620–1720

	Mean	Std.Dev.	Min	Max	Obs
Share of each topic in student publications	0.0300	0.1405	0	1	42625
No. student publications	7.9491	16.3708	1	311	42625
Share ML predicted in student publications	0.4204	0.3686	0	1	42625
Student graduates with B.A.	0.6938	0.4609	0	1	42625
Student graduates with M.A.	0.5985	0.4902	0	1	42625
Share of each topic in teacher publications	0.0236	0.0953	0	1	42625
No. teacher publications at college	26.8851	40.4879	0	218	42625
No. teachers at college	10.7949	9.1566	0	59	42625
Cohort size at college	23.0036	15.4439	1	110	42625
Observations	42625				

Table 10: Publication statistics for the fields of the Scientific Revolution for publishing Oxford students and faculty, 1620–1720

	Mean	Std.Dev.	Min	Max	Obs
Share of each topic in student publications	0.0070	0.0716	0	1	12375
No. student publications	7.9491	16.3712	1	311	12375
Share ML predicted in student publications	0.4204	0.3686	0	1	12375
Student graduates with B.A.	0.6938	0.4609	0	1	12375
Student graduates with M.A.	0.5985	0.4902	0	1	12375
Share of each topic in teacher publications	0.0068	0.0448	0	1	12375
Teacher innovation index	0.0531	0.2257	0	1	12375
No. teacher publications at college	26.8851	40.4891	0	218	12375
No. teachers at college	10.7949	9.1569	0	59	12375
Cohort size at college	23.0036	15.4443	1	110	12375
Observations	12375				

Table 11: Descriptive Statistics of Cambridge students, 1580–1740

	Mean	Std.Dev.	Sum	Obs
ba	0.5618	0.4962	22276	39653
ma	0.3628	0.4808	14386	39653
fellow	0.0989	0.2985	3921	39653
scholar	0.0000	0.0000	0	39653
fellow commoner	0.1021	0.3028	3844	37641
pensioner	0.4766	0.4995	17938	37641
sizar	0.4213	0.4938	15859	37641
Cohort size	32.2511	18.7545	1278853	39653
Number student publications	0.3121	3.3532	12377	39653
Number teachers	26.8912	18.8449	1066318	39653
Number teacher publications	37.9042	42.2314	1503016	39653
Observations	39653			

Table 12: Publication statistics for publishing Cambridge students and faculty, 1620–1720

	Mean	Std.Dev.	Min	Max	Obs
Share of each topic in student publications	0.0302	0.1438	0	1	47552
No. student publications	7.3223	15.0851	1	217	47552
Share ML predicted in student publications	0.4035	0.3810	0	1	47552
Student graduates with B.A.	0.7631	0.4252	0	1	47552
Student graduates with M.A.	0.6218	0.4849	0	1	47552
Share of each topic in teacher publications	0.0281	0.1013	0	1	47552
No. teacher publications at college	44.5606	44.6073	0	186	47552
No. teachers at college	29.6696	20.1699	0	77	47552
Cohort size at college	30.5639	18.9679	3	89	47552
Observations	47552				

Table 13: Publication statistics for the fields of the Scientific Revolution for publishing Cambridge students and faculty, 1620–1720

	Mean	Std.Dev.	Min	Max	Obs
Share of each topic in student publications	0.0057	0.0634	0	1	13374
No. student publications	7.3223	15.0855	1	217	13374
Share ML predicted in student publications	0.4035	0.3810	0	1	13374
Student graduates with B.A.	0.7631	0.4252	0	1	13374
Student graduates with M.A.	0.6218	0.4850	0	1	13374
Share of each topic in teacher publications	0.0058	0.0308	0	1	13374
Teacher innovation index	0.1091	0.3119	0	1	13374
No. teacher publications at college	44.5606	44.6085	0	186	13374
No. teachers at college	29.6696	20.1705	0	77	13374
Cohort size at college	30.5639	18.9684	3	89	13374
Observations	13374				

B.7 Status Abbreviations and Degree Titles

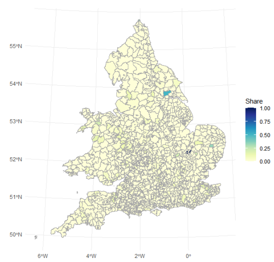
Table 14: Overview of status abbreviations — as translated by the Author

Classification in Project	Abbreviation in Original	Full Title	Translation
Commoner	pauper	Pauper	Poor
	p.p.	Pauper puer	Poor boy
	serv.	Servus	Servitor (as additional duty performed at the college)
	pleb.	Plebeii	Commoner
Academic	doctoris	Doctoris	Doctor title
Clergy	cler.	clerici	Clerical
	episcopi.	Episcopi	Bishop
Nobility	gent.	Gentilis	Gentleman (lower nobility)
	militis	Militis	Military (from *miles*)
	arm.	Armiger	Esquire (literally *arms-bearer*, but for the register strictly limited to esquire — see Hehir (1968, p.14))
	eq.	equitis	Knight (from *eques*)
	eq. aur.	Eques auratus	Knight Bachelor (literally *golden knight*)
	baronet	Baronet	Baronet
	comitis	Comitis	Earl
Further extensions	fil.	filius	Son of
	nat. min.	natu minimum	The youngest
	nat. max.	natu maximum	The oldest

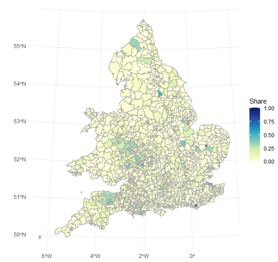
Table 15: Coding Overview for Degree Titles

General Classification in Project	Sub-classification in Project	Abbreviation in Original	Full Degree Name
Bachelor's Degree		B.A.	Bachelor of Arts
	Clerical Degree	B.D.	Bachelor of Divinity
	Medical Degree	B.M.	Bachelor of Medicine
	Medical Degree	B.Med.	Bachelor of Medicine
	Law Degree	B.C.L.	Bachelor of Civil Law
	Law Degree	LL.B	Bachelor of Law
Master's Degree		M.A.	Master of Arts
Doctoral Degree	Clerical Degree	D.D.	Doctor of Divinity
	Law Degree	D.C.L.	Doctor of Civil Law
	Law Degree	L.L.D.	Doctor of Law
	Medical Degree	M.D.	Doctor of Medicine
	Medical Degree	D.Med.	Doctor of Medicine

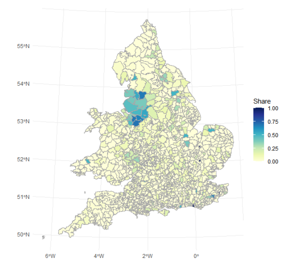
B.8 The spatial distribution of students' place of origin by college



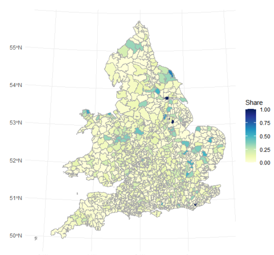
(i) All Soul's College



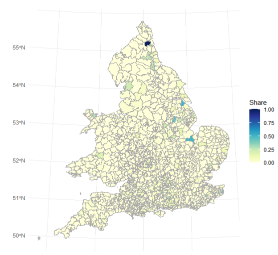
(ii) Balliol College



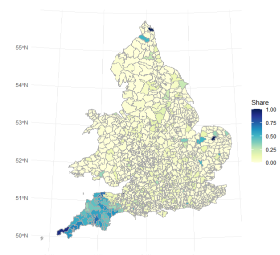
(iii) Brasenose College



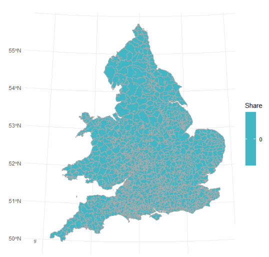
(iv) Christ Church



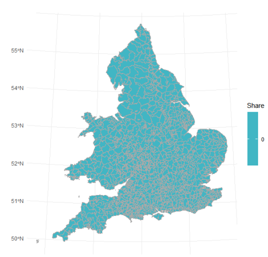
(v) Corpus Christi College



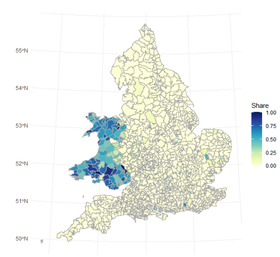
(vi) Exeter College



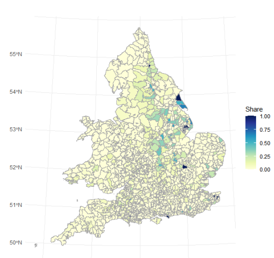
(vii) Harris Manchester College



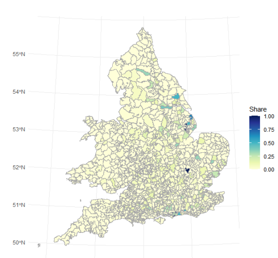
(viii) Hertford College



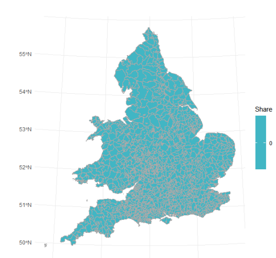
(ix) Jesus College



(x) Lincoln College

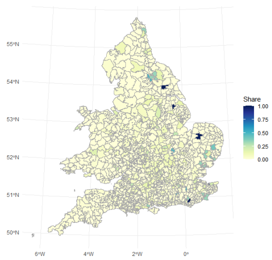


(xi) Magdalen College

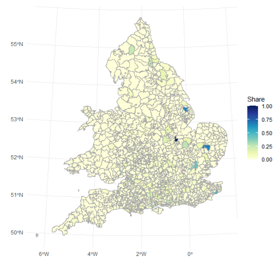


(xii) Mansfield College

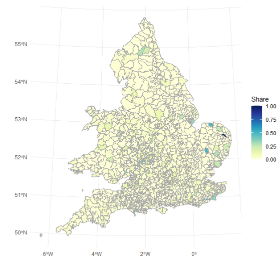
FIGURE 9: Students' origins from each college (shares per hundred).



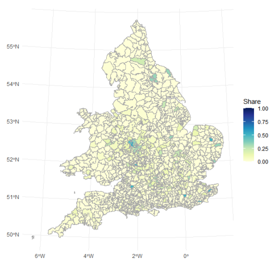
(xiii) Merton College



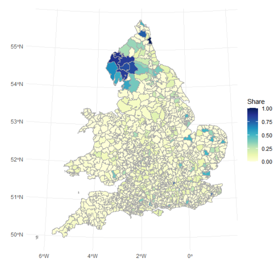
(xiv) New College



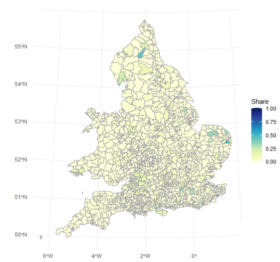
(xv) Oriel College



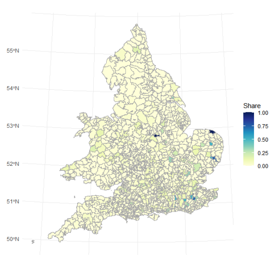
(xvi) Pembroke College



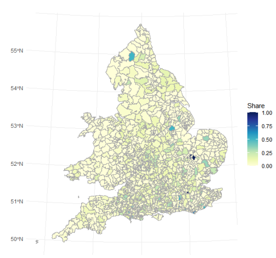
(xvii) The Queen's College



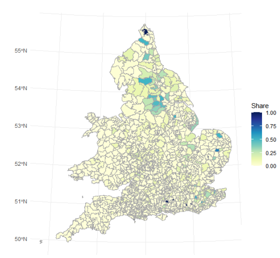
(xviii) St Edmund Hall



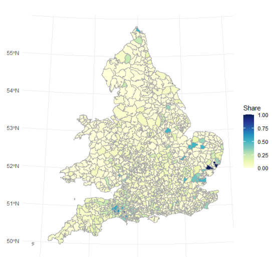
(xix) St John's College



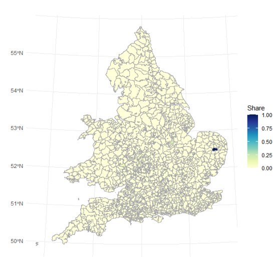
(xx) Trinity College



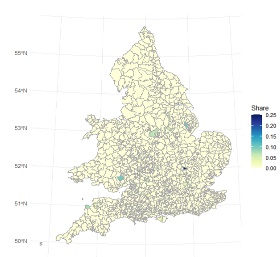
(xxi) University College



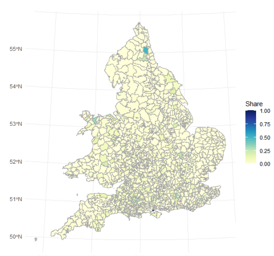
(xxii) Wadham College



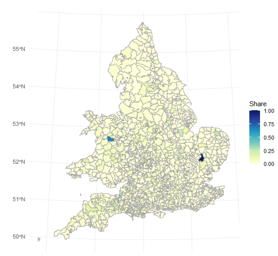
(xxiii) Worcester College



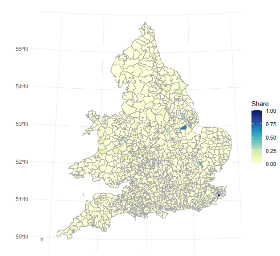
(xxiv) Broadgates Hall



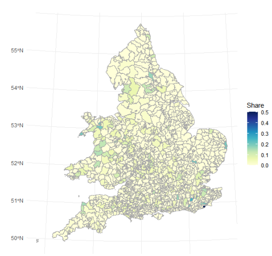
(xxv) Hart Hall



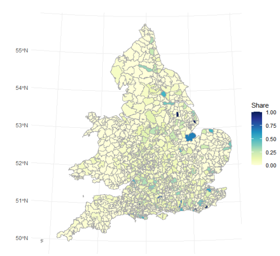
(xxvi) New Inn Hall



(xxvii) St Alban Hall



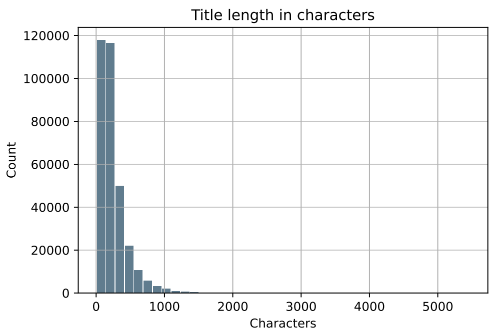
(xxviii) St Mary Hall



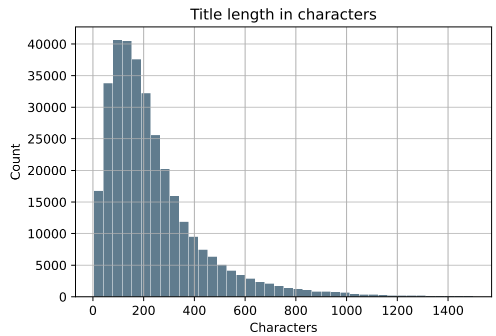
(xxix) Magdalen Hall

C Data

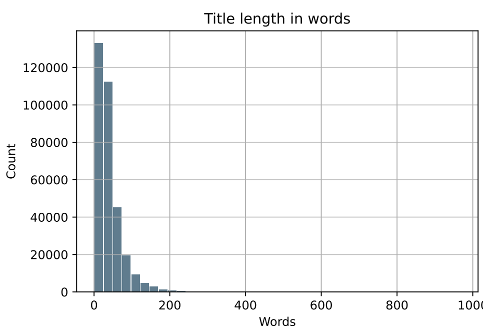
C.1 ESTC titles



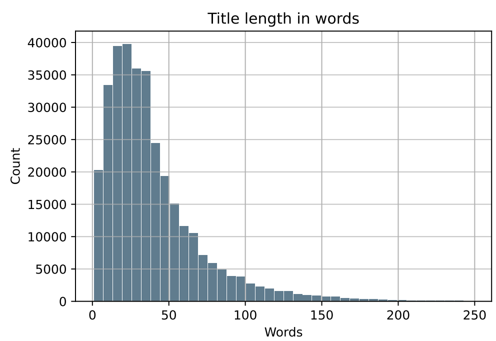
(a) Length in characters



(b) Length in characters (less than 1500)



(c) Length in words



(d) Length in words (less than 250)

FIGURE 10: Histogram for ESTC text length

The following lists a few examples illustrating the amount of information available from seventeenth and eighteenth century titles. These examples of titles are not meant to be representative in content, but to illustrate the varying degree of information found in seventeenth and eighteenth century titles, a format that is usually unknown to the modern reader. Figure 10 shows histogram plots for title length in either character or word counts.[53]

> Dioptrica nova. A treatise of dioptricks, in two parts. Wherein the various effects and appearances of spherick glasses, both convex and concave, single and combined, in telescopes and microscopes, together with their usefulness in many concerns of humane life, are explained.

or

> Moor's arithmetick. In tvvo books. The first treating of the vulgar arithmetick in all its parts, with several new inventions to ease the memory, by Nepairs rods, logarithms, decimals, &c. fitted for the use of all persons. The second of arithmetick in species

[53]The statistics apply to the translated titles that are cleaned for near duplicates

or algebra, whereby all difficult questions receive their analytical laws and resolutions, made very plain and easie for the use of scholars and the more curious. To which are added two treatises: 1. A new contemplation geometrical upon the oval figure called the ellipsis. 2. The two first books of Mydorgius his conical sections analized by that reverend divine Mr. W. Oughtred, Englished and completed with cuts. By Jonas Moore, Professor of the Mathematicks. (Jonas Moore, 1660)

or

Arithmetick made easie for the use and benefit of trades-men. Wherein the Nature and Use of Fractions, both Vulgar and Decimal, are Taught by a New and Exact Method. Also The Mensuration of Solids and Superficies. The twelfth edition, corrected and amended. By J. Ayres, late Writing-Master in St. Paul's Church-Yard, London. To which is added, A short and easy method; after which Shop-Keepers may State, Post, and Balance their Books of accompts. By Charles Snell, Writing-Master, and Accomptant, in Foster-Lane, London. (John Ayres, 1714)

or

The complete wall-tree pruner; or Principles of Pruning and Training all sorts of Wall Fruit Trees, and Espaliers, In the most Improved Degree of Perfection and Fruitfulness; Systematically Explained by a New Scientific Plan, never before attempted. Comprehending The Completest Practical Directions for performing all the different Operations of Pruning and Training all Sorts of Wall Trees and Espaliers, in the most successful Manner, according to their different Modes of Bearing, and in their several Stages of Growth, from the earliest State of Training to their utmost Maturity, and latest Duration, whereby to have them always Prosperous, Beautiful, and abundantly Fruitful. Consisting of Common Wall Trees, Half Standard Wall Trees, High Standard Wall Trees, Espalier Trees, &c. comprehensively explaining the respective Orders of Training, different Modes of Bearing, several Sorts of Bearers, various Kinds of Branches and Shoots, Fruit Buds, Fruit Spurs, and all other Parts of the Trees in their different Ways and Habits of Growth, describing accordingly the peculiar and most effectual Methods of Pruning, both for occasional and general Practice. With full Explanations of the whole Process and true Principles of First Pruning and Training, General Pruning, Summer Pruning, and Winter Pruning. The Whole being Systematically displayed, according to an eligible New Plan, is peculiarly calculated to render all the different Operations of Pruning easily comprehended, and successfully practised, that every one may prune his Wall Trees, &c. with the utmost Facility, and Certainty of having them in the highest State of Perfection, and Bearing; the Fruit large, fair, and of superior Quality. Also, A Complete Register of all the different Species and respective Varieties of the best Fruits, with their Times of ripening, &c. By John Abercrombie, (oxford Street (319.)

London.) Author of Every Man His Own Gardener, The British Fruit Gardener, and other Works no Gardening. (John Abercrombie, 1783)

or

Osteographia elephantina: or, a full and exact description of all the bones of an elephant, which died near Dundee, April the 27th. 1706. with their several dimensions. To which are premis'd, 1. An Historical Account of the Natural Endowments, and several wonderful Performances of Elephants; with the manner of Taking and Taming them. 2. A short Anatomical Account of their Parts. And added, 1. An exact Account of the Weight of all the Bones of this Elephant. 2. The Method us'd in preparing and Mounting the Skeleton. 3. Four large Copper Plates, wherein are represented the Figures of the Stuff'd Skin, and prepared Skeleton, as they now stand in the Publick Hall of Rarities at Dundee; with the separated Bones in several Views and other Parts of this Elephant.

C.2 Cleaning the ESTC titles

The raw data poses several challenges:

1. Publication titles are written in different languages (especially in Latin)
2. There is a significant number of near duplicates with varying title length
3. Sometimes, editions and publishers are included in the title itself

To deal with foreign languages, this paper adopts an approach where all titles are first translated to the same language to be comparable. It first identifies foreign languages using Facebook's *fasttext* package. It then uses the Google Translator API for translating titles. This returns high-quality translations that should be practically indistinguishable from titles of works that were already translated back in the past (see next paragraph on near duplicates).

The significant number of near duplicates seems to stem from several versions of the book that have been entered into the database. However, some entries seem to have only included parts of the title, possibly from different editions with different covers, so that the titles were not spotted as duplicates. A further challenges arises from different editions with slight changes in the title, e.g. from translations or different editions:

> "A panegyric on our late sovereign lady Mary Queen of England, Scotland, France, and Ireland, of glorious and immortal memory. Who died at Kensington, on the 28th. of December, 1694. By James Abbadie, D.D. minister of the Savoy" (Abbadie, Jacques, 1654-1727)

and

> "Panegyric of Mary Queen of England, Scotland, France, & Ireland, of glorious & immortal memory. Decedie in Kensington on December 28, 1694. By J. Abbadie D. en T. Minister of Savoy" (Abbadie, Jacques, 1654-1727)

automatically translated from:

> "Panegyrique de Marie reine d'Angleterre, d'Ecosse, de France , & d'irlande, de glorieuse & immortelle memoire. Decedie à Kensington le 28. Decembre 1694. Par J. Abbadie D. en T. Ministre de la Savoye" (Abbadie, Jacques, 1654-1727)

Here, the first title is a contemporary translation from the original French work - taking a small liberties with the original work (adding the late sovereign). Hence, translations give rise to very similar, but slightly different titles. Furthermore, the automatic translation came to a very similar, but slightly different translation.

Thus, an algorithm spotting near duplicates should be able to correctly identify duplicates where the text of both titles almost literally overlaps, however with one of the titles having an attachment of additional text. It should also be able to ignore small differences in the texts arising from translations or different editions. Furthermore, it should not capture semantically similar titles, but titles that have a high word-by-word similarity.[54] As a solution to this task, the paper uses Jaccard distances on word-vector representations of titles.[55] Jaccard distance is the complement to Jaccard similarity measuring the size of the intersection of two sets divided by the size of their unions, $J(A,B) = \frac{A \cap B}{A \cup B}$. Jaccard distances are calculated for the matrices of each author's word-vector representation of their titles. In the case that an author name does not exist, the paper uses either the corporation name or general title classifier if known. For all titles without any information on origin, titles are grouped by the first 10 letters of their titles. The Jaccard distances are calculated for pre-cleaned titles (already removing parts of the title-string that do not belong to the title, e.g. information on the publisher). All titles below a threshold distance of 0.5 are identified as near duplicates. Then for each list of similar titles, the algorithm only keeps the title that was published first. Altogether, the algorithm removes 183,978 near duplicates, reducing the number of distinct titles to 285,985.

Finally, titles are cleaned by removing information that is not related to its content using regular expressions. This includes e.g. the name of the publisher or editor, information on the number of volumes, or the number of the current edition. It also removes information on months and weekdays, as well as information on attached copper-plates.

[54] We would expect e.g. authors to publish multiple works on similar topics. These should still be listed as distinct titles.

[55] Another possible candidate for measuring near duplicates are Euclidean distances between titles. However after practical experimentation with different titles, Jaccard distances seem to outperform Euclidean distance measures with respect to minimizing false positive duplicates.

C.3 Matching students and fellows to publishing records

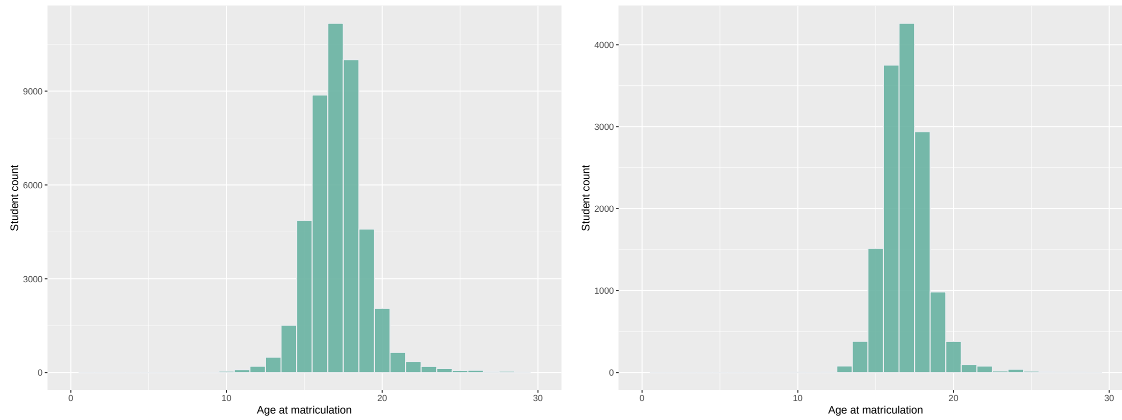
This section describes matching titles from the ESTC catalogue to the catalogue of university students. Matching between the entries of the ESTC catalogue and the student and fellow entries from the *Alumni Oxenienses* (Foster, 1891) and the *Alumni Cantabrigienses* (Venn and Litt, 1952) faces a number of challenges. First, seventeenth and early eighteenth century spelling practices were not yet standardized. Second, years of death are only given for a small subset of students within the *Alumni Oxenienses* and *Alumni Cantabrigienses*. Furthermore, contemporary information on years of deaths are often inaccurate within a small range (explained in detail below). In case a year of death was not recorded, the paper has to rely on years of wills or years of birth instead. Here, years of wills are an imperfect proxy for years of death. Additionally, years of birth are often less precisely recorded than years of death. Finally, whenever years of birth were not included in the *Alumni Oxenienses* and *Alumni Cantabrigienses*, years of birth had to be extrapolated from the year of matriculation creating a further source of inaccuracy.

To address these challenges, the paper uses a combination of phonetic matching and matching on a range of $[+1, -1]$ years of death, whenever years of death are given. Whenever years of death are not known, the paper matches on a range of $[+3, -3]$ years of wills and if wills are not recorded on a range of $[+3, -3]$ years of birth. Overall, the matching approach is similar to the Ambramitzky, Boustan, and Eriksson (ABE) Algorithm (Abramitzky, Boustan and Eriksson, 2012; Abramitzky et al., 2021). Yet, in contrast to the ABE method, the paper does not match on the closest match with the [3-3] year range, but considers these entries as duplicates. By ignoring closest matches within the [-3,3] year range, the paper minimizes type I errors at the cost of type II errors. The section continues by first addressing challenges in spelling and date accuracy in detail. It then describes the matching strategy and presents statistics for matching rates.

First, seventeenth century spellings of names were not yet standardized and it is common to find contemporary sources referring to the same person with different spellings. Sometimes, people even changed the spelling of their own name over time. For example, Edmond Halley used the spelling of “Edmond” and “Edmund” interchangeably in both his letters and publications (Hughes and Green, 2007). Hence, the paper adopts a phonetic matching procedure that reduces the spelling of names to their phonetic sounds. It uses the New York State Identification and Intelligence System (NYSIIS) phonetic code known to combine high accuracy with a low number of false positives (Snae, 2007). It also seems to successfully capture some basic Latinizations of names. For example, it matches “Silius Titus” in the ESTC catalogue with “Silas Titus” from the ESTC catalogue.[56]

Second, any matching of seventeenth and eighteenth century biographical information must take account of the inaccuracy of lifetime dates during this age. In principle, years of death are more reliable than years of birth for seventeenth and eighteenth century records. For example, Cummins (2017) shows that for the European high nobility, years of death did not show significant

[56]Manually comparing the entry for “Silius Titus” in the *Oxford Dictionary of National Biography* provides the same year of matriculation and name of College as the Oxford register. Hence, it appears that the Oxford entry “Titus, Silas, s. Silas, of Bushey, Herts, gent. Christ Church, matric. 16 March, 1637-8, aged 15” is identical to “Titus, Silius, 1623?-1704”, the author of *Killing no Murder*.



(a) University of Oxford

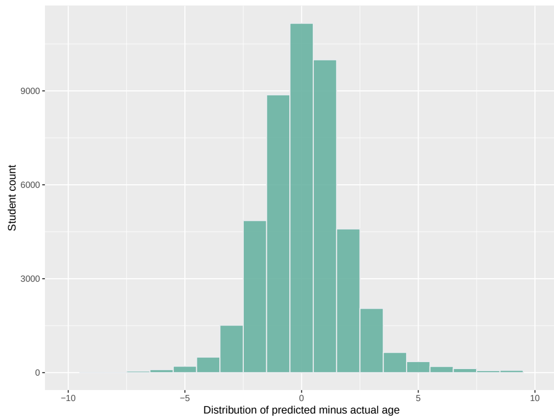
(b) University of Cambridge

FIGURE 11: Distribution of students' age at matriculation

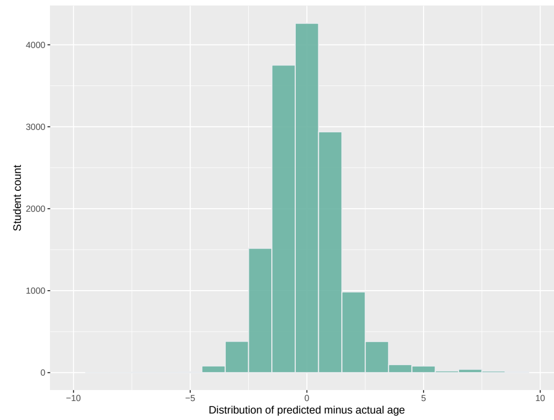
patterns of age heaping. However, 10–20% of recorded birth years showed patterns of age heaping in the seventeenth century. The number is likely to be higher for university students from common backgrounds. Yet, even the accuracy of historical death years, especially for the non-nobility, should not be taken for granted. A further issue are conversions between the Julian and Gregorian calendar that was only adopted in England in 1752. Besides the general difference between the Gregorian and Julian calender of a 10–11 days, the Julian calender started the new year on the 25th of March, thus creating a difference of about 1/4 of a year. For lifetime entries in the ESTC it is impossible to know whether lifetime dates are taken at Julian face value or converted to the Gregorian calender (even in the case of the Oxford Dictionary of National Biography this is not always clear). Hence, any successful matching of seventeenth and eighteenth century records needs to allow for a certain degree of fuzziness in the recording of dates.

Given this background on the accuracy of historical dates, years of death within a range of $[+1, -1]$ years are used for matching. However, the university registers only contain years of death for about 15% of all students making it necessary to match on birth years for the rest of the sample For ca. 40% of all students, the age of matriculation is recorded. From this we can calculate the year of birth. For the rest of students, the age at matriculation is not known. Yet, it is possible to predict the year of birth based on the year of matriculation (or award of B.A./M.A.) and students' median age at matriculation.

Figure 11 shows the age distribution of students at the time of matriculation. The median age at matriculation was 17, with the 10th and 90th percentiles between 15 and 19. Hence, based on the assumption that the non-recorded age at matriculation followed a similar distribution, a student's year of birth can be extrapolated based on a student's year of matriculation minus medium age 17. For students without information on their year of matriculation, the year of the award of either their bachelor's or master's degree is used with the additional knowledge that based on the university's statutes, a bachelor's degree took four and a master's degree two years. Figure 12 shows that calculating the differences between known years of birth and extrapolated age from



(a) University of Oxford



(b) University of Cambridge

FIGURE 12: Distribution of prediction error between predicted and actual age at matriculation for students with recorded age mat matriculation

students' year of matriculation, bachelor's degree, and master's degree is normally centred around 0. Hence, at least for students with information on their age at matriculation, extrapolating years of birth appears unbiased. Furthermore, it can be seen that the distribution of extrapolated minus actual years of death's 5 percentile lies at -3 and its 5th percentile at 3, an inaccuracy that should be accounted for when matching. Hence, if years of death are not known the paper matches on birth intervals of $[+3, -3]$.

TABLE 16: Matching statistics for authors, Oxford

	Match on	Matched authors	Unique matches	Dropped dupl. matches	% Dupl. of all matches
1	Step 1: Year of death	2713	2664	49	0.02
2	Step 2: Year of will	23	23	0	0.00
3	Step 3: Year of birth	1766	1338	428	0.24
4	Overall	4502	4025	477	0.11

TABLE 17: Matching statistics for authors, Cambridge

	Match on	Matched authors	Unique matches	Dropped dupl. matches	% Dupl. of all matches
1	Step 1: Year of death	2891	2778	113	0.04
2	Step 2: Year of will	111	111	0	0.00
3	Step 3: Year of birth	1019	807	212	0.21
4	Overall	4021	3696	325	0.08

Overall, 204,700 entries from the ESTC with information on the author's name and lifetime dates are matched against 144,748 students with information on either year of birth, death or the year of their matriculation or further degrees.[57] This yields an overall of 120,225 title matches. However, a last issue arises from duplicate matches: Being only able to match on names and

[57]It should be noted that not all names on authorship from the ESTC might be meaningful. Sometimes first names are not fully included. Furthermore, pseudynoms (e.g. "Philosophus" or "Isaac Bickerstaff", one of Jonathan Swift's pseudonyms) might further obscure authorships.

Table 18: Matching statistics for titles, Oxford

	Match on	Matched titles	Unique matches	Dropped dupl matches	% Dupl. of all matches
1	Step 1: Year of death	20069	18900	1169	0.06
2	Step 2: Year of will	62	62	0	0.00
3	Step 3: Year of birth	13634	7757	5877	0.43
4	Overall	33765	26719	7046	0.21

Table 19: Matching statistics for titles, Cambridge

	Match on	Matched titles	Unique matches	Dropped dupl. matches	% Dupl. of all matches
1	Step 1: Year of death	18121	16796	1325	0.07
2	Step 2: Year of will	473	473	0	0.00
3	Step 3: Year of birth	8445	5160	3285	0.39
4	Overall	27039	22429	4610	0.17

lifetime dates, can lead to the presence of duplicate entries for common entries. Table 16–19) show the number of total and unique matches as well duplicate matches for students from Oxford and Cambridge. As would be expected, matching on the greater range of $[+3, -3]$ for years of birth than $[+1, -1]$ for years of death creates more duplicate matches. Overall, 17.32% of all matches are duplicate matches that are dropped from the matching sample.[58] This yields an overall number of 94,378 unique title matches for 3808 students from Oxford and 3464 students from Cambridge.[59] Overall, at least 31% of all ESTC titles from 1600 to 1720 that were published under some personal name (as opposed to institutional publications, e.g. from Parliament or other institutional bodies) were written by a university graduate.

C.4 Monte Carlo Simulation of matching errors

To assess the robustness of the estimated teacher-student effects under type I and II matching errors, this section introduces a Monte Carlo simulation on a similar data structure as employed in the paper. The synthetic panel data comprises 120 matriculation years across 28 colleges. Therefore, it is comparable to the structure of the University of Oxford. For the ease of interpretation of the Monte Carlo results, the synthetic panel does not include an additional topic dimension. Each college is assigned sequential teacher presence of 11 years. Teacher publication shares in the Scientific Revolution are generated such that 75% of teachers have a size of zero and 25% are drawn from a normal distribution. The teacher distributions are simulated as:

$$p_{it} = d_i \cdot |Z_i|, Z_i \sim N(0.2, 0.05). \tag{10}$$

with

$$d_i = \begin{cases} 1, & \text{with probability } 0.25, \\ 0, & \text{with probability } 0.75, \end{cases} \tag{11}$$

[58] Given that the ESRC does not contain additional information on authorship, there is little room for exploiting additional information to decrease the rate of duplicate matches.

[59] Note that these numbers do refer to raw ESTC titles and not the ones cleaned from duplicates.

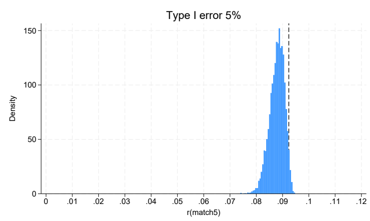
The student outcomes are assigned as:

$$y_{jt} = 0.1p_{jt} + \varepsilon_{jt},\ \varepsilon_{jt} \sim N(0, 0.025) \tag{12}$$

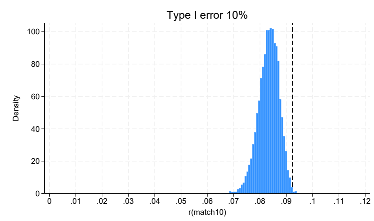
Measurement error is introduced via two mechanisms:

1. Type I errors: In each replication, 5%, 10%, or 20% of teachers are randomly re-assigned a teacher size drawn from the overall teacher distribution.

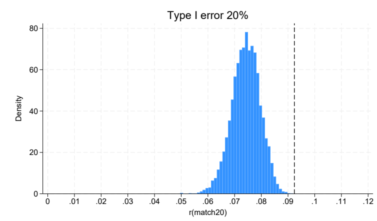
2. Type II errors: The same percentages of teachers are randomly dropped from the sample (i.e. their publication share is set to zero).



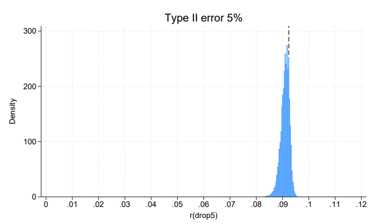
(a) Type I error 5%



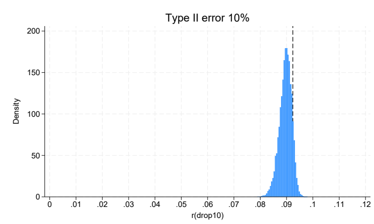
(b) Type I error 10%



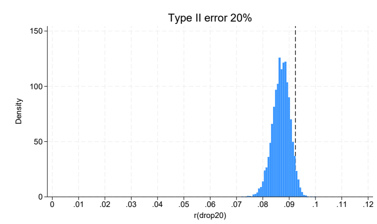
(c) Type I error 20%



(d) Type II error 5%



(e) Type II error 10%



(f) Type II error 20%

FIGURE 13: Distributions of the estimated coefficient on teacher size under (a–c) matching error and (d–f) dropping error scenarios. *Notes: The horizontal line in each subfigure indicates the baseline coefficient.*

In 10,000 Monte Carlo replications, the paper estimates the effect of teacher size on y:

$$y_{jt} = 0.1\beta p_{jt} + \zeta_j + \alpha_t + \varepsilon_{jt} \tag{13}$$

where p_{it} denotes teacher shares at college j and matriculation year t. The model further includes college and time fixed effect j and t.

Figure 13 shows the distributions of the estimated coefficients. Panels (a)–(c) present the distribution of coefficients for 5%, 10%, and 20% type I errors, respectively; panels (d)–(f) show the distributions for type II errors. The horizontal line in each figure indicates the baseline (true) coefficient.

We see that in the presence of up to 10% type II errors, the downwards bias only amounts to ca. 11% at the mean. Even in the presence of up to 20% type II errors, the downwards bias only amounts to ca. 19.7% at the mean. Matching results from section C.3, show that we have 11% of duplicate (omitted) author-matches at Oxford and 8% duplicate author-matches (omitted) at Cambridge. Given that the paper adopts a matching approach that minimizes type I errors at the cost of type II errors, it is unlikely that, on average, downward bias resulting from matching will be larger than 20%.

C.5 Classification – Machine Learning

Transformer models are foundation models (Vaswani et al., 2017; Bommasani et al., 2021) trained on very large corpora of text that cover a large part of human knowledge, e.g. including Wikipedia and Google Books. Using pre-trained foundation models offers a natural representation of the meaning embedded in words and sentences. In contrast to word-embedding models that translate the meaning of individual words into a multi-dimensional vector representation, transformer models use a self-attention mechanism to capture the meaning of words based on their context in a textual environment. As in word-embedding models, each input is assigned as an embedding that is stored in a 512×768 dimensional matrix. However, in contrast to word-embedding models, the inputs are longer periods of text that can be translated into text-specific embeddings. Transformer based models have set the standard for the current state of natural language models and, as e.g. in the case of GPT-3 and GPT-4, often approach near-human capabilities of text processing.

Before training a transformer model on the ESTC titles, the data on the titles had to be-processed in order to make them comparable. In a first step, the text data had to be made comparable across different languages. For this, the language of all titles were identified using the fasttext library (see Bojanowski et al., 2017) and non-English titles translated using the Google Translate API. Appendix figure 14 shows the composition of all titles in foreign languages. It can be seen that Latin titles prevailed, with French coming into more common use during the second half of the eighteenth century. In a second step, the vary granular subject classes assigned by the British Library (with about 50,000 different classes)[60] had to be turned into higher-order classes. For this, each of the $\sim 50,000$ classes were hand-assigned to 47 higher-order classes. The list of the 47 higher-order classes was designed to capture scientific fields such as mathematics, astronomy, applied physics, biology, or chemistry. Appendix table 20 lists all topic names and provides a short description of each topic.

Next, the higher-order classifications were used to train a transformer model that was then used to predict classes for the full dataset. The paper uses a DistilBERT transformer model that provides a good compromise between accuracy and model size. The model uses a standard set of hyperparameters with a learning rate of 0.005, 3 epochs, and an effective batch size of 32.[61] For testing the model, it is first trained on 60,000 observations of titles with higher-order classes. It is then used to predict a training dataset with 47,650 observations with known subject classes. The predicted classes are then compared to the true classes. Overall, the model has a

[60] The number refers to all titles before cleaning for duplicates.

[61] To save GPU memory, the model uses a batch size of 8 and 3 gradient accumulation steps.

Matthews correlation index of 0.66. Furthermore, table C.6 shows that the model is successful in predicting all kinds of classes, even those that are based on context-sensitive distinctions such such as *Sermons*, *Catholic*, or *Sects* as contrasted to *Religion* or *Moral tales*. Figure 15 presents the confusion matrix for the DistilBERT model. Larger spillovers mostly occur within related fields such as *Administrative* and *Legal* or *Stories* and *Supernatural*, but not between distinct fields such as *Astronomy* and *Chemistry*. Given the successful evaluation of the training dataset, the full DistilBERT model is then trained on all 75,856 titles with manually assigned higher-order subject classes.

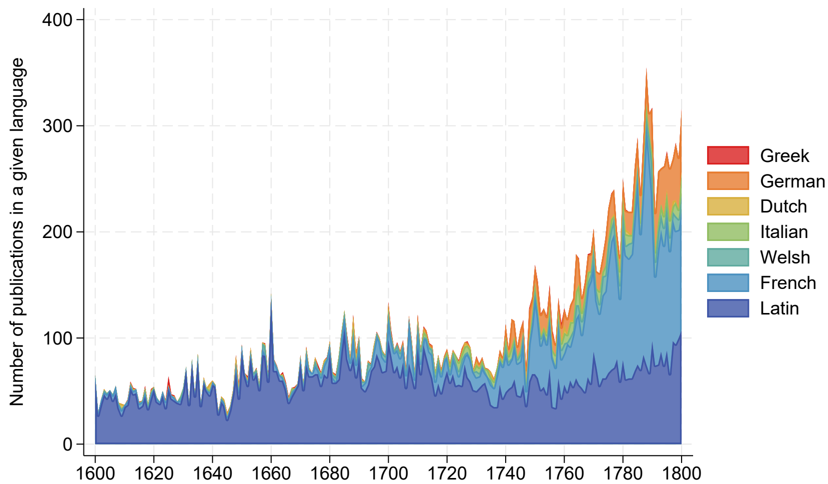


FIGURE 14: ESTC titles published in foreign languages over time

Table 20: Text classification based on ESTC subjects

Category	Description
Scientific Revolution	
Almanacs	All almanacs and calendars
Astronomy	The physics of the heavens
Applied physics	Mechanical philosophy that is not part of astronomy, e.g. optics, heat, and mechanical forces.
Biology	Natural histories including the study of plants and animals
Chemistry	Systematic study of the elements, minerals, metals, etc.
Geography	Geography, Cartography, Geology
Scientific Instruments	All scientific instruments (including nautrical instruments)
Mathematics	All mathematical treatments
Medicine	Medical studies, incl. anatomy, and surgery
Occult studies	
Alchemy	Occult studies, purification of materials
Astrology	The study of the heavens in relation to signs, omens, and prophecies
Supernatural	All descriptions of magical events, wonders, and ghosts
Prophecies	Prophecies of future events
Higher education	
Philosophy	Philosophical treatises (excludes political philosophy)
Political Philosophy	All philosophical treatises on political institutions
Political economy	Political economcy, society wide study of improving agriculture, manufactures, or trade, does not include administrative reasonings on the economy, e.g. famines or other scarcities[62]
Classical Education	Latin, Greek, ancient mythology, drama and poetry
Pedagogy	Pedagogical works on education
Logic and rhetoric	Logic and rhetoric as classical categories of education
University matters	University administration and politics
Languages	Foreign languages as well as English (excluding Latin and Greek learning, see classical education)
Business, trade, and innovation	
Useful techniques in agriculture	Technical instructions agriculture
Useful techniques in trades	Technical instructions in artisanship, trade, or manufacturing
Encyclopedias and dictionaries	Systematic collections of knowledge on a given topic, usually with lists and explanations of terms or concepts
Navigation	Publications on navigation, incl. finding latitude and longitude at sea and nautical instruments
Business	Business endeavours, communication, and advertising
Printing and book trades	Anything related to printing and publishing

[62] A note of warning: By placing a focus on the study of the economy independent of the administrative proceedings of the state, this category might be ill-suited to fully capture early mercantilist ideas as well as some early physiocratic ideas.

Architecture	Architectural works
Public sphere	
Stories and public discourse	Descriptions and tales of any kind of notable event or personal experience, pamphlets, periodicals, and discussion of politics
Moral tales	Moral advise often linked to stories with a moral core
Biographies	Biographical description of the life of noteworthy individuals
History	State history
Curiosities and wonders	Strange, phenomena, and sightings
Antiquities and archaeology	Antique collections, archaeological findings
Amusements	Games, food, and festivities
Travel descriptions	Descriptions of foreign (or national) travel
Societies	All kind material (statutes, transactions) on all societies except for economic societies
Economic societies	All kind material (statutes, transactions) on economic societies
Art	
Fine arts	Visual arts, painting
Drama	Drama, excluding classical drama (see classical education) as well as prosaic fiction
Poetry	Poetry and songs
Music	Music and music theory
Religion	
Religion	All religious topics
Religion – Sermons	Sermons (often relating other topics to religious themes)
Religion – Catholicism	All works on Catholicism
Religion – Judaism	All works on Judaism
Religion – Dissenters	All works on dissenters (Quakers, Baptists, Methodists etc.)
Church administration	Administration of the worldly body of the church
Public administration	
Administrative	Administration and politics, proceedings of the House of Commons and local administrative bodies
Legal	Legal questions
Military	Management of the military and navy, military strategy and practises
State affairs	Diplomacy, Royal privileges, Treaties, and Peace negotiations
Wars	Reports on military campaigns, battles, and wars
Colonial exploration	Overseas expeditions, including description of natives, and descriptions of the slave trade

Subject classes are constructed as classifiers for the more than 50,000 subject classes from the ESTC subject index classification.

C.6 Classification – Evaluative statistics

precision	recall	f1-score	support	Class no.	Class name
0.800000	0.800000	0.700000	12369.000000	0	Administrative
0.100000	0.100000	0.100000	32.000000	1	Alchemy
0.800000	0.800000	0.800000	647.000000	2	Almanacs
0.600000	0.600000	0.600000	538.000000	3	Amusements
0.500000	0.500000	0.500000	134.000000	4	Antiquities
0.600000	0.600000	0.600000	245.000000	5	Applied physics
0.700000	0.700000	0.700000	135.000000	6	Architecture
0.700000	0.700000	0.700000	338.000000	7	Art
0.600000	0.600000	0.600000	366.000000	8	Astrology
0.500000	0.500000	0.600000	308.000000	9	Astronomy
0.300000	0.300000	0.400000	207.000000	10	Biography
0.700000	0.700000	0.700000	387.000000	11	Biology
0.600000	0.600000	0.600000	121.000000	12	Chemistry
0.500000	0.500000	0.500000	1268.000000	13	Church administration
0.700000	0.700000	0.700000	1089.000000	14	Classical education
0.300000	0.300000	0.300000	123.000000	15	Curiosities and wonders
0.800000	0.800000	0.800000	3698.000000	16	Drama
0.000000	0.000000	0.000000	21.000000	17	Economic societies
0.400000	0.400000	0.500000	69.000000	18	Economics
0.600000	0.600000	0.600000	561.000000	19	Education
0.500000	0.500000	0.600000	327.000000	20	Encyclopedias and dictionaries
0.700000	0.700000	0.700000	782.000000	21	Exploration
0.800000	0.800000	0.800000	665.000000	22	Foreign languages
0.700000	0.700000	0.700000	240.000000	23	Geography
0.300000	0.300000	0.400000	265.000000	24	History
0.500000	0.500000	0.600000	2786.000000	25	Legal
0.800000	0.800000	0.800000	458.000000	26	Mathematics
0.900000	0.900000	0.900000	2875.000000	27	Medicine
0.400000	0.400000	0.400000	1675.000000	28	Mercantile
0.500000	0.500000	0.600000	406.000000	29	Military
0.600000	0.600000	0.600000	1030.000000	30	Military Wars
0.400000	0.400000	0.400000	1032.000000	31	Moral tales
0.600000	0.600000	0.600000	376.000000	32	Music
0.700000	0.700000	0.700000	271.000000	33	Navigation
0.500000	0.500000	0.500000	453.000000	34	Philosophy
0.800000	0.800000	0.800000	6093.000000	35	Poetry
0.400000	0.400000	0.400000	301.000000	36	Political philosophy
0.800000	0.800000	0.800000	1145.000000	37	Printing and book trades
0.600000	0.600000	0.600000	259.000000	38	Prophecies
0.800000	0.800000	0.700000	10251.000000	39	Religious
0.400000	0.400000	0.400000	399.000000	40	Religious Catholicism
0.600000	0.600000	0.600000	153.000000	41	Religious Judaism
0.500000	0.500000	0.500000	2501.000000	42	Religious Sects
0.800000	0.800000	0.800000	3915.000000	43	Religious Sermons
0.500000	0.500000	0.600000	130.000000	44	Scientific instruments

0.600000	0.600000	0.600000	206.000000	45	Societies
0.400000	0.400000	0.500000	539.000000	46	State affairs
0.600000	0.600000	0.600000	5066.000000	47	Stories
0.600000	0.600000	0.600000	206.000000	48	Supernatural
0.700000	0.700000	0.700000	381.000000	49	Technical instructions Agriculture
0.600000	0.600000	0.600000	465.000000	50	Technical instructions Trades
0.000000	0.000000	0.000000	39.000000	51	Travel descriptions
0.500000	0.500000	0.500000	255.000000	52	University learning
0.400000	0.400000	0.400000	71.000000	53	University matters

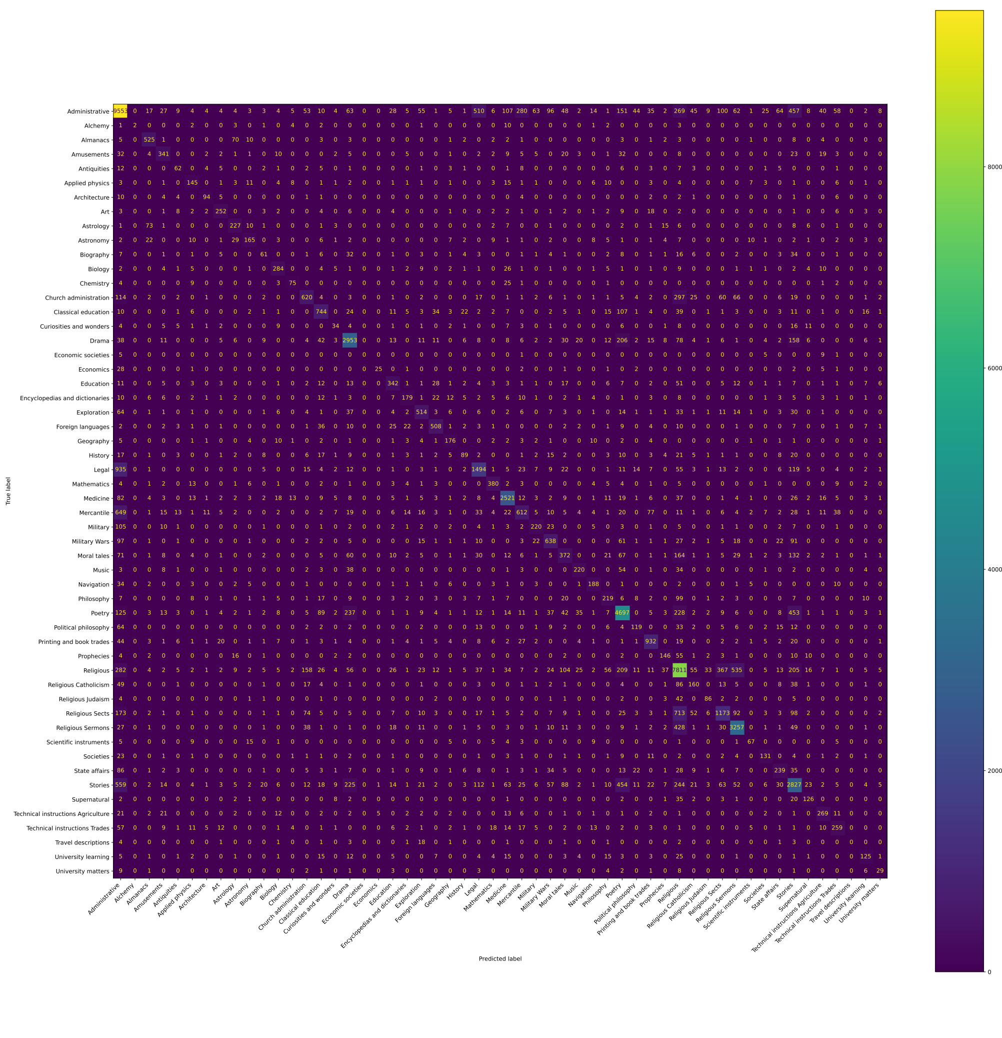
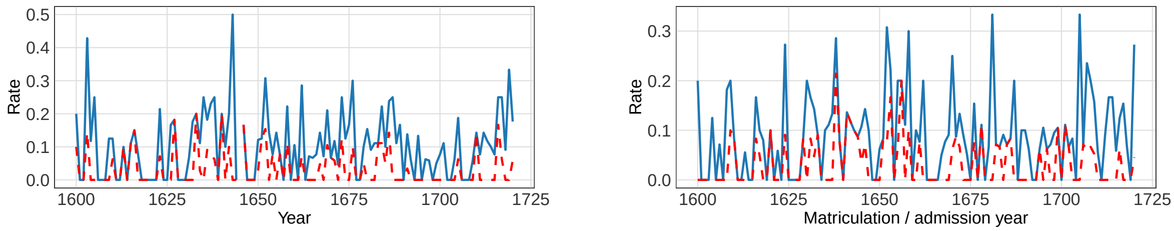


FIGURE 15: Confusion matrix – DistilBERT classification



(a) University of Oxford

(b) University of Cambridge

FIGURE 16: Percentage share of students at the time of matriculation/admission who published at least once in the fields of the Scientific Revolution

Notes: The blue line includes the following fields: astronomy, almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments. The red line includes the following fields: astronomy, applied physics, mathematics.

C.7 Calculation of teachers' direction to the research frontier and teachers' innovativeness

First, the paper introduces a new approach of calculating a researcher's innovativeness based on a forward/backward logic introduced in Kelly et al. (2021). It is based on the intuition that an innovative publication is more similar to the future of its field than to the past of its field. Hence, one can get a measure of a publication's innovativeness by dividing its forward similarity (similarity to future titles in the field) over its backward similarity (similarity to past titles in the field):

$$\text{Innovativness}_i = \frac{\text{Forward similarity}_i}{\text{Backward similarity}_i} \tag{14}$$

Hence, the measure captures the logic that an innovative publications needs both to be novel and to have an impact on the future of the field. The index captures novelty through the inverse backwards similarity and impact on the future of a field through forward similarity.

Kelly et al. (2021) implement this logic in a tf-idf bag-of-words approach. It transforms both the text of the document and all the text of the corpus into a large vectors of words. With these, it calculates the frequency of a word in a document compared to its frequency in the whole corpus. Based on this, it calculates similarities between documents based on the overlap of words that are infrequent in the whole corpus, hence words that individually characterize the individual title.

However, this approach is more suited to highly technical text with many specific technical terms, such as modern patents used by Kelly et al. (2021).[63] Yet, the scientific literature of the

[63] The literature on scientific and technical innovation usually defines innovativity as how much a publication changed its field. For example, Funk and Owen-Smith (2017); Park, Leahey and Funk (2023) and Wu, Wang and Evans (2019) measure disruptive publications using citation counts. Funk and Owen-Smith (2017) define disruptive inventions as publications that replace the corpus of citations they cite. Wu, Wang and Evans (2019) compare whether future works are more likely to cite the cited works in an article or the article itself. However, the context

seventeenth century uses a more complex language that poses a significant challenge to bag-of-word approaches. Hence, this paper pioneers a new way of applying the basic logic from Kelly et al. (2021) to more complex corpora of text: It applies a a BERT transformer model to the text to create context-sensitive text-embeddings and then calculates the textual similarity based on the text-embeddings.[64] This approach offers a powerful approach that is able to capture similarities in the meaning of documents in contrast to similarities in word-frequencies. Appendix section C.9 illustrates the advantages of transformer models over bag-of-word or word-embedding models by comparing the performance of different language models for an exemplary set of titles.[65]

Technically, the index is calculated by taking the mean of a title i's cosine similarity (cos) to all other titles in its field within a shifting time-frame. We define backward similarity as a title's mean cosine similarity to all titles within a twenty year time interval into the past, T_p.

$$BS_i = \frac{1}{N} \sum_{j \in T_p}^{N} cos(i, j) \tag{15}$$

Analogously, forward similarity is defined as a title's mean cosine similarity to all titles with a twenty year time interval into the future, T_f

$$FS_i = \frac{1}{N} \sum_{j \in T_f}^{N} cos(i, j) \tag{16}$$

Title i's innovativeness is then defined as the ratio of its forward similarity (FS) over its backward similarity (BS):

$$I_i = \frac{FS_i}{BS_i} \tag{17}$$

Following Kelly et al. (2021) we can interpret this innovation index as a language-based alternative to a citation index. To the best of the author's knowledge, it is the first paper within the innovation literature that uses transformer distances to calculate a publication's innovativeness.

In a next step, the paper creates a measure for a title's proximity to the research frontier. The paper introduces proximity to the *Philosophical Transactions*, the journal of the Royal Society, as a proxy for proximity to the research frontier of the Scientific Revolution. Since its foundation in 1665, the *Philosophical Transactions* was the only scientific journal in Britain during the seventeenth and early eighteenth century. It was founded to publish new findings at the frontier of the Scientific Revolution. Articles that were submitted to the *Philosophical Transactions* had to pass an early

of the seventeenth and eighteenth century poses the challenge that citations were not yet a common practise within seventeenth and eighteenth century academia. Therefore, the paper adopts a language-based innovation index. Instead of counting citation links, this approach calculates the similarity between the content between titles.

[64] The paper uses the ll-MiniLM-L6-v2 model that was pretrained on over 1 billion sentence pairs and optimzed as as a sentence and short paragraph encoder.

[65] Within the context of the ESTC, we should note that Bert uses word piece tokenization that breaks individual words into multiple tokens. This has the advantage that unknown words are broken down into pieces. For most unknown words a representation exists at least for some of its sub-parts reconstructing its original as close as possible. This feature is especially valuable for dealing with different spellings in the seventeenth century.

editorial review process that practically ensured that articles were scientifically relevant and of a sufficiently high quality (Andrade, 1965; Csiszar, 2016). The paper collects all 10,730 titles from the journal's articles and uses them as a proxy for the research frontier of the Scientific Revolution.

Calculating the proximity to the *Philosophical Transaction* rests on two tasks. First, classifying the Philosophical Transactions into the same subject fields as for the ESTC and second, calculating the ESTC titles' proximity to the current research frontier in a given field. The paper solves the first task of classifying the titles from the *Philosophical Transactions* by using the DistilBERT classification model that was pre-trained on the ESTC subject classes in section 3.4. The model was also trained on scientific texts from the same time period and therefore perfectly applies to the classification task for the *Philosophical Transactions*. Furthermore, this approach has the advantage of applying the same classification system to both datasets. Next, the paper calculates forward facing cosine similarities of ESTC title i to all titles in the *Philosophical Transactions* from the next 40 years in the same field, T_f :

$$\text{Dist. frontier}_i = \frac{1}{N} \sum_{j \in T_f}^{N} cos(i, j) \tag{18}$$

Using proximity to the next forty years is supposed to capture proximity to the concepts that will be important in the future, i.e. the frontier. The index mainly differs from the innovation index by a) using proximity to a select group of titles that are seen as high-quality and b) not requiring a title to be novel. In comparison, the innovation index requires a title to be (one of) the first in its field to introduce a new concepts and to have a large impact, while the proximity to the *Philosophical Transactions* index only captures a title's use of "cutting-edge" concepts from the research frontier.

C.8 Validation of innovativeness index

To validate the innovation index, we test whether there is an association between high-quality authors and high-innovativeness publications. The paper identifies high-quality authors as those that are listed in the *Dictionary of National Biography* (D.N.B.), a collection of noteworthy people in British history, and those that were fellows of the Royal Society. Concretely we estimate:

$$\text{(max)innov}_{it} = \beta_1 \text{high-quality author}_{it} + \boldsymbol{X'_{it}}\beta_2 + \alpha_t + \varepsilon_{it} \tag{19}$$

where (max)innov_{it} captures the maximum value of the innovation index from equation 17 across an author i's publications at matriculation time t. The main dependent variable, high-quality author_{it}, is an indicator variable that captures whether author i either has entry in the *Dictionary of National Biography* or was a fellow of the Royal Society. $\boldsymbol{X'_{it}}$ is a vector of author level controls, including the total number of publications, year of matriculation and year of matriculation squared. α_t captures matriculation year fixed effects. In the fixed-effects specification, matriculation year controls are omitted.

Table 22 presents the results. We find that having an entry in the *Dictionary of National Biography* is associated with a 0.015 points increase in the innovation index (column 2) at Oxford and a 0.013 points increase at Cambridge. This amounts to a 22% standard deviation increase in the innovativeness index at Oxford and a 18% standard deviation increase in the innovativeness index at Cambridge (column 4). Likewise, becoming a fellow in the Royal Society is associated with a 0.040 points increase in the innovation index (column 4) at Oxford and a 0.022 points increase at Cambridge (column 4). This amounts to a 59% standard deviation increase in the innovativeness index at Oxford and a 32% standard deviation increase in the innovativeness index at Cambridge.

Overall, we find a strong association between high-quality authors and publication quality as captured through the innovation index from equation 18. This is strong evidence that the index successfully captures (some dimensions of) historical innovativeness.

Table 22: Association between students having an entry in the Dictionary of National Biography / members of the Royal Society and the innovation index

Panel A: Oxford	(Max) students' innovation index			
	(1)	(2)	(3)	(4)
	Innov.	Innov.	Innov.	Innov.
Entry in D.N.B.	0.0147***	0.0146***		
	(0.00496)	(0.00525)		
Fellow of the Royal Society			0.0413*	0.0400*
			(0.0238)	(0.0242)
Number publications control	Yes	Yes	Yes	Yes
Matriculation year control	Yes	No	Yes	No
Matriculation year squared control	Yes	No	Yes	No
Year fixed effects	No	Yes	No	Yes
_cons	Yes	No	Yes	No
Observations	1564	1562	1564	1562
R-squared	0.14	0.20	0.14	0.20
Mean dep. var.	1.04	1.04	1.04	1.04

Panel B: Cambridge	(Max) students' innovation index			
	(1)	(2)	(3)	(4)
	Innov.	Innov.	Innov.	Innov.
Entry in D.N.B.	0.0123***	0.0125***		
	(0.00358)	(0.00373)		
Fellow of the Royal Society			0.0207***	0.0221***
			(0.00726)	(0.00749)
Number publications control	Yes	Yes	Yes	Yes
Matriculation year control	Yes	No	Yes	No
Matriculation year squared control	Yes	No	Yes	No
Year fixed effects	No	Yes	No	Yes
_cons	Yes	No	Yes	No
Observations	1696	1696	1696	1696
R-squared	0.15	0.21	0.14	0.21
Mean dep. var.	1.03	1.03	1.03	1.03

Notes: The table shows results from estimating equation 19. The model tests the association between the innovativeness index from equation 17 and the notability of authors. Notability of authors is either captured through having an entry in the *Dictionary of National Biography* (D.N.B.) (column 1–2) or being a fellow of the Royal Society (column 3–5). Controls include the number of publications, matriculation year, and matriculation year squared. Column 2 and 4 further include year fixed effects. Robust standard errors in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

C.9 Comparison of different natural language models for processing distances

In order to illustrate the differences between different ways of measuring sentence similarities, e.g. bag-of-words methods, word-embeddings, sentence embeddings, and the BERT model, we can take a look at a stylized example of titles. We compare Isaac Newton's famous work *Opticks: or, A Treatise of the Reflexions, Refractions, Inflexions and Colours of Light* to a work that is known to have been an important influence for Newton, Christian Huygen's *Treatise on Light: In Which Are Explained the Causes of That Which Occurs in Reflection* and a later work on optics that was likely inspired by Newton's work, David Gregory's *Elements of catoptrics and dioptrics.* We further compare Newton's Optics to a set of unrelated titles that mentions similar words such as "light" or "reflexions", but in an unrelated context. Table 23 shows the comparative statistics. A good measure of sentence similarity should be able to a) identify titles of similar content that are described with different words and b) distinguish related from unrelated titles using the same words, but in a different context.

Comparing Newton's *Opticks: or, A Treatise of the Reflexions, Refractions, Inflexions and Colours of Light* and Huygen's *Treatise on Light: In Which Are Explained the Causes of That Which Occurs in Reflection* is relatively straightforward. Both titles essentially describe the same set of phenomena that are explained, although described slightly differently. However, the challenge set by David Gregory's *Elements of catoptrics and dioptrics* in comparison to Newton's *Opticks* is significant as both works do not have an overlapping technical vocabulary. In order to identify the similarity between both works we need the additional information that catoptrics deals with the phenomeon of reflacted light and that dioptrics is the branch of optics studying refraction. Hence, the similarity exists between the meaning of the words, and not the technical vocabulary itself. Looking at the unrelated placebo titles, we see that titles such as *The words of the everlasting and true Light, vvho is the eternal living God, and the King of saints* or *A true and impartial account of the dark and hellish power of witchcraft* use the same technical vocabulary of light and colour, but in a different context. Thus, distinguishing Newton's *Optics* from these placebo titles not only involves comparing the meaning of words (e.g. "dark" and "colour" might be similar), but understanding the context of its use.

Table 23 compares a tf-idf bag-of-words approach, word-embeddings in spacy, sentence embeddings in Google's Universal Sentence Encoder, and a BERT transformer model.[66] It shows that the bag-of-words tf-idf method succesfully identifies a high similarity between Newton's and Huygen's works, but shows a similarity of 0 between Newton's and Gregory's works on optics. Comparing Newton's work to a group of unrelated placebo titles, it picks up on the use of "light" and "reflexions" in a completely different context, although the similarity scores are still relatively low. In general, we see that the main shortcoming of bag-of-word methods is its inability to account for

[66] Before running the similarity measures for Tf-idf and spacy, titles are broken down into only nouns, adjectives, and adverbs – terms that are most likely to capture the relevant topic of the words.This avoids an overweighting of usual stop-words such as "that" or "and" or of verbs with versatile meanings. Nouns, adjectives, and adverbs are identified using spacy. Both USE and BERT use context-information from the whole sentence and thus require the complete use of complete use of the text-structure.

the similar meaning of different words, leading to a significant loss of information in comparing scientific articles.

These shortcomings of bag-of-words methods might lead us to prefer similarity measures based on word embeddings. Column (2) presents the average of the similarity of word-vectors using spacy. This method is able to successfully capture the similarity between Newton's, Huygens's, and Gregory's work. However, the vector representation of words also recognizes a similar meaning in the unrelated controls that also use phrases of light - although in a religious, or figurative meaning. The method still gives a higher similarity score to the true works on optics. However, the difference in similarity scores is less than we might prefer. Thus, the results on word-embedings highlight the need for a method that can account for different meanings based on context. This leads to transformer models based on deep neural networks that can compute context-aware representations (Vaswani et al., 2017). Column (3) shows the results for Google's Universal Sentence Encoder (Cer et al., 2018) that uses sentence embeddings from a pre-trained transformer model and column (4) shows results for the BERT transformer model (Devlin et al., 2018). The results for the USE are disappointing. It gives a lesser similarity score to Gregory's work than to *The words of the everlasting and true Light, vvho is the eternal living God, and the King of saints.* However, the BERT model successfully identifies the true works of optics and gives a significantly lower similarity score to the unrelated placebos. Thus, it is able to distinguish between the context of physical treatments of light and colours and the context of religious and figurative use of light and colours. These results indicate that using transformer models can lead to more comprehensive and accurate similarity measures between book titles than tf-idf bag-of-word models or word-embedding models. However, it still shows the presence of false positives within a lower probability limit. Hence, this paper will combine the transformer models for measuring novelty with a prior categorization of topics. Similarity measures are then only calculated for documents within each topic.

TABLE 23: Comparing title similarities with different NLP methods

Similarity between:	Tf-idf	Spacy	USE	BERT
Newton's famous work on optics:				
"Opticks: or, A Treatise of the Reflexions, Refractions, Inflexions and Colours of Light"1)				
and				
Prior works on optics:				
"Treatise on Light: In Which Are Explained the Causes of That Which Occurs in Reflection & Refraction"2)	0.24	0.67	0.38	0.64
Later works on optics:				
"Dr. Gregory's Elements of catoptrics and dioptrics. To which is added, I. A method for finding the foci of all Specula as well as Lens's universally. As also for Magnifying or Lessening a given Object by a given Speculum or Lens in any assign'd Proportion, &c. A particular account of microscopes and telescopes, from Mr. Huygens. With an introduction shewing the Discoveries made by Catoptrics and Dioptrics."3)	0	0.55	0.21	0.41
Unrelated placebo titles:				
"The words of the everlasting and true Light, vvho is the eternal living God, and the King of saints"	0.08	0.46	0.28	0.23
"A true and impartial account of the dark and hellish power of witchcraft"	0	0.47	0.22	0.18
"A new torch to the Latine tongue: so enlightned, that besides the easie understanding of all classical authours, there is also laid open a ready way to write and speak Latine well and elegantly"	0	0.48	0.18	0.12
"Political reflections upon the finances and commerce of France; shewing the causes which formerly obstructed the advancement of her trade"	0.11	0.41	0.19	0.20

1): Isaac Newton, 1704, 2): Christiaan Huygens, 1690, 3): David Gregory, 1715.

List of natural language processing models used: Tf-idf: term frequency-inverse document frequency implemented with Python's sklearn. Spacy: Word-embeddings implemented in spacy with similarity calculated as average cosine similarity accross words. USE: Universal Sentence Encoder, a sentence embedder based on a transformer model (Cer et al., 2018). The paper uses the TF2-v5 model from Tensorflow. BERT: Bidirectional Encoder Representations from Transformers, a state-of the art transformer model (Devlin et al., 2018). The paper uses the ll-MiniLM-L6-v2 model that was pretrained on over 1 billion sentence pairs and optimzed as as a sentence and short paragraph encoder. The text of the titles is presented in the original spelling. For the presentation of this stylized example the "unrelated controls" titles have been shortened but remain otherwise unchanged.

C.10 Trends in scientific fields and innovativity

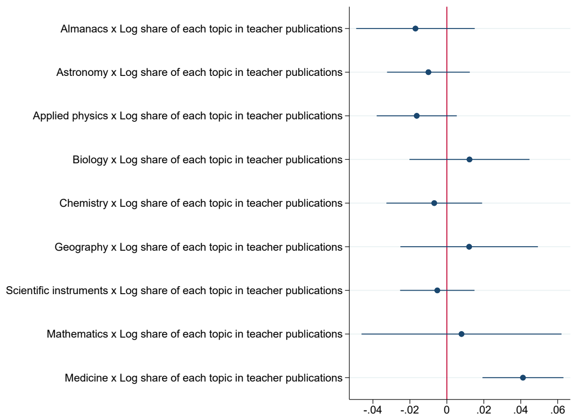
Table 24: Effect of teachers' research fields on students' research fields

	Publication innovativeness / dist. to frontier	
	(1)	(2)
	Log innov.	Log frontier
	1620–1720	1600–1720
Author went to Ox/Cam	0.00435*	0.0191**
	(0.00243)	(0.00942)
Title lengths control	Yes	Yes
Publication year fixed effects	Yes	Yes
Observations	4206	4493
R-squared	0.10	0.09

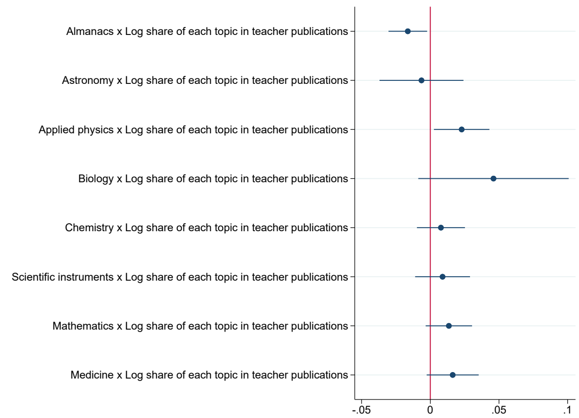
Notes: The table shows results from regressing innovativeness / distance to the frontier on the indicator variable of authors having attended the University of Oxford or Cambridge. The sample are all ESTC authors between 1600–1720 / 1620–1720 who were real persons (excl. e.g. publications by Parliament). Note that the innovativeness index compares a [t-20,t] period to a [t,t+20] period. Therefore, with the ESTC starting in 1600, column 1 is only estimated on the sample of 1620–1720. The model includes publication year fixed effects and a control variable for title length in characters. Column 1 shows the association between authors having attended university and author innovativeness, defined in section 3.5 and C.7. Column 2 shows the association between authors having attended university and distance to the frontier, defined in section 3.5. Standard errors are clustered at the publication year level and included in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

D Empirical results

D.1 Additional results from section 4



(a) University of Oxford



(b) University of Cambridge

FIGURE 17: Field-specific impact of teachers on students' research within the fields of the Scientific Revolution

Notes: The graph presents results from equation 1 where teachers' publication shares in the Scientific Revolution are interacted by indicator variables for individual fields. Standard errors are clustered at the college-topic level. Confidence intervals are shown at the 90% level.

TABLE 25: Teacher-effect for the fields of the Scientific Revolution estimated on the sub-sample of only students that published in the Scientific Revolution

Panel A: Oxford	Log share of each topic in student publications		
	(1)	(2)	(3)
	Mean top.	Mean top.	Mean top.
Log share of each topic in teacher publications	0.345***	0.0961*	0.100*
	(0.0957)	(0.0525)	(0.0530)
Log share of teacher publications in all topics of the Scient Rev.	-0.165	-0.0918	
	(0.101)	(0.0846)	
Year fixed effects	Yes	Yes	No
College fixed effects	Yes	Yes	No
Topic fixed effects	No	Yes	Yes
Student fixed effects	No	No	Yes
Observations	1611	1611	1611
R-squared	0.04	0.20	0.21
Panel B: Cambridge	Log share of each topic in student publications		
	(1)	(2)	(3)
	Mean top.	Mean top.	Mean top.
Log share of each topic in teacher publications	0.405***	0.156**	0.162**
	(0.114)	(0.0667)	(0.0700)
Log share of teacher publications in all topics of the Scient Rev.	-0.0536	0.0346	
	(0.0945)	(0.0882)	
Year fixed effects	Yes	Yes	No
College fixed effects	Yes	Yes	No
Topic fixed effects	No	Yes	Yes
Student fixed effects	No	No	Yes
Observations	1458	1458	1458
R-squared	0.06	0.25	0.26

Notes: The table shows results from estimating equation 1 while limiting the sample only to students who published in any of the topics of the Scientific Revolution. The table then successively uses different definitions of the fields of the Scientific Revolution. In column 2 it uses the standard definition of this paper that includes the fields of astronomy, almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments. Next, in column 2 it uses the same definition, but excludes medicine. Lastly in column 3, it uses the "core of the Scientific Revolution" consisting of astronomy, applied physics, and mathematics. It then estimates the effects of teachers' research fields on students' research fields. The strength of teachers' research fields within each of these fields is calculated as the share of all teachers' publications within field τ of all publications within all fields at college c at time t. The strength of students' research fields is calculated as the share of student i's publications in field τ out of all publications from student i. The model includes student-, topic-, and cohort fixed effects. Standard errors are multi-way clustered at the college $\times$ topic level and included in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 26: Effect of teachers' research fields on students' research fields

Panel A: Oxford	Log share of each topic in student publications				
	(1)	(2)	(3)	(4)	(5)
	Scientific Revolution	Art	Religion	Public sphere	Classical education
Log share of each topic in teacher publications	0.0194**	0.0277	0.00430	0.0302	-0.00392
	(0.00907)	(0.0232)	(0.0185)	(0.0197)	(0.00621)
Topic fixed effects	Yes	Yes	Yes	Yes	Yes
Student fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	14184	4728	12608	6304	11032
R-squared	0.16	0.44	0.38	0.33	0.20
Panel B: Cambridge	Log share of each topic in student publications				
	(1)	(2)	(3)	(4)	(5)
	Scientific Revolution	Art	Religion	Public sphere	Classical education
Log share of each topic in teacher publications	0.0107*	0.0182	0.0307**	-0.000409	-0.00424
	(0.00558)	(0.0209)	(0.0125)	(0.0144)	(0.00580)
Topic fixed effects	No	Yes	Yes	Yes	Yes
Student fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	15408	5136	13696	8560	11984
R-squared	0.17	0.47	0.38	0.33	0.18

Notes: The table shows results from estimating equation 1 on different groups of subject fields, *the Scientific Revolution*, *art*, *religion*, and *the public sphere*, and *classical education*. The fields of the Scientific Revolution are defined as *astronomy, almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments*. The group of art is composed of the fields of *poetry, music, and drama*. Religion is composed of *theology, dissenting theology, Catholic theology, Jewish theology, sermons, church administration, prophecies, and supernatural occurrences*. The public sphere is composed of *administration, the law, reports of current events, and moral tales*, finally classical learning is composed of *philosophy, political philosophy, classical education (greek and roman), rhetorics, foreign languages, and pedagogical education*. The strength of teachers' research fields within each of these fields is calculated as the share of all teachers' publications within field τ of all publications within all fields at college c at time t. The strength of students' research fields is calculated as the share of student i's publications in field τ out of all publications from student i. Student and teacher shares are transformed using the natural logarithm from equation 2. The model includes cohort-, topic- and student-fixed effects. Standard errors are multi-way clustered at the college $\times$ topic level and included in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 27: Direction of teachers' research on students' general publication success

Panel A: Oxford	Student lifetime publishing		
	(1)	(2)	(3)
	Ever published	Log number publi	Innovativeness
Log share of teacher publications in the Scientific Revolution	-0.000770	0.0193	-0.000550
	(0.00159)	(0.0366)	(0.000838)
Teacher controls	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
College fixed effects	Yes	Yes	Yes
Observations	31696	1372	1368
R-squared	0.02	0.11	0.09
Mean dep. var.	0.04	1.29	1.00
Panel B: Cambridge	Student lifetime publishing		
	(1)	(2)	(3)
	Ever published	Log number publi	Innovativeness
Log share of teachers' publications in the Scientific Revolution	-0.00112	-0.0579	-0.00115
	(0.00180)	(0.0502)	(0.00139)
Teacher controls	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
College fixed effects	Yes	Yes	Yes
Observations	32575	1486	1477
R-squared	0.02	0.08	0.09
Mean dep. var.	0.05	1.18	1.00

Notes: The table shows results from estimating equation 1 on the college × cohort level. It estimates the effects of the average of teachers' research fields in the Scientific Revolution on the average of students' research fields in the Scientific Revolution. The fields of the Scientific Revolution are defined as astronomy, almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments. The model applies college- and cohort-fixed effects. Student publication numbers and teacher shares are transformed using the natural logarithm from equation 2. Teacher controls includes the number of teacher publications, the number of fellows, and the cohort size. Column 1 estimates the effect of teachers' average publication share in the Scientific Revolution on whether a student ever published. Column 2 estimates the effect of teachers' average publication share in the Scientific Revolution on a student's log-transformed number of publication. Column 2 estimates the effect of teachers' average publication share in the Scientific Revolution on a student's average innovativeness. Standard errors clustered at the college level in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

TABLE 28: Effect of teachers' research in the Scientific Revolution on lifetime career outcomes

Panel A: Oxford	University degrees		Career in the church			Other careers		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Medicine degr.	Law degr.	Rector	Vicar	Prebendary	Physician	Law	D.N.B.
Log share of teacher publications in all topics of the S.R.	0.00216	0.00271	0.00201	-0.00259	0.000112	0.000656	-0.00203	-0.000980
	(0.00146)	(0.00195)	(0.00206)	(0.00357)	(0.000574)	(0.000535)	(0.00381)	(0.00103)
Teacher controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
College fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	31696	31696	31696	31696	31696	31696	31696	31696
R-squared	0.02	0.05	0.18	0.11	0.01	0.01	0.12	0.01
Mean dep. var.	0.016	0.022	0.206	0.145	0.005	0.004	0.146	0.015
Panel B: Cambridge	University degrees		Career in the church			Other careers		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Medicine degr.	Law degr.	Rector	Vicar	Prebendary	Physician	Law	D.N.B.
Log share of teacher publications in all topics of the S.R.	0.000650	-0.000759	-0.00743**	0.00170	0.00170	0.00102	0.00325	0.00249
	(0.00154)	(0.00130)	(0.00262)	(0.00226)	(0.00226)	(0.00117)	(0.00439)	(0.00216)
Teacher controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
College fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	32575	32575	32575	32575	32575	32575	32575	32575
R-squared	0.01	0.08	0.19	0.11	0.11	0.03	0.11	0.01
Mean dep. var.	0.019	0.013	0.211	0.158	0.158	0.021	0.126	0.034

Notes: The table estimates the effects of teachers' publication shares in the Scientific Revolution on students' choice of advanced degrees, career choices, and lifetime outcomes based on information in Foster (1891) and Venn and Litt (1952). The fields of the Scientific Revolution are defined as astronomy, almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments. Column 1-2 present results for the dependent variable of students taking an advanced degree in either medicine (B.Med., M.D., D.Med.) or law (B.C.L., LL.B, D.C.L., L.L.D.). Column 3-7 present results for different realized career choices of students. Column 3-5 present results for careers within the Church of England as either a rector, vicar, or prebendary. Column 5-6 present results for careers either as a physician or lin law. Finally column 8 presents results for students being included in the Dictionary of National Biography (D.N.B.) — a measure of upper-tail notability (Laouenan et al., 2022). Teacher shares are transformed using the natural logarithm from equation 2. Teacher controls includes the number of teacher publications, the number of fellows, and the cohort size. All controls are transformed using the natural logarithm from equation 2. Student controls include dummies for whether a student graduated with a B.A. or M.A. Standard errors clustered at the college level in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 29: Effect of teachers' research fields on students' research fields for different time periods

Panel A: Oxford	1600–1640	1640–1720	1720–1780
	(1)	(2)	(3)
	Mean top.	Mean top.	Mean top.
Log share of each topic in teacher publications	0.00861	0.0160*	0.00247
	(0.0186)	(0.00914)	(0.0152)
Topic fixed effects	Yes	Yes	Yes
Student fixed effects	Yes	Yes	Yes
Observations	4347	9972	9459
R-squared	0.16	0.16	0.16

Panel B: Cambridge	1600–1640	1640–1720	1720–1780
	(1)	(2)	(3)
	Mean top.	Mean top.	Mean top.
Log share of each topic in teacher publications	0.00635	0.0145*	-0.0108
	(0.0199)	(0.00751)	(0.0125)
Topic fixed effects	Yes	Yes	Yes
Student fixed effects	Yes	Yes	Yes
Observations	4788	10719	8577
R-squared	0.18	0.17	0.18

Notes: The table shows results from estimating equation 1. It estimates the effects of teachers' research fields on students' research fields for the 9 fields of the Scientific Revolution. The fields of the Scientific Revolution are defined as astronomy, almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments. The table reports results for different time periods. Column 1 reports results for the pre-civil war period, 1600–1640. Column 2 reports results for the classical period of the English Scientific Revolution in England, 1640–1720, including both the interregnum and restorian period. Column 3 reports results for the classical enlightenment period, 1720–1780. Teacher and student shares are transformed using the natural logarithm from equation 2. Teacher controls include the log-transformed number of teacher publications, the log-transformed number of fellows at a college at a student's time of matriculation, and the log-transformed cohort size at a student's time of matriculation. Student controls include a student's log-transformed number of publications, and indicator variables taking the value of one if a student graduated with a B.A. or M.A, as well as a variable capturing the mean of all student publications that were predicted using machine learning. Standard errors are clustered at the college-topic level and included in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 30: Effect of teachers' research fields on students' research fields - different m(0) values for equation 2

Panel A: Oxford	Log share of each topic in student publications		
	(1)	(2)	(3)
	Mean top., m(0)=-1	Mean top., m(0)=-0.5	Mean top., m(0)=-0.1
Log share of each topic in teacher publications, m(0)=-1	0.0194**		
	(0.00907)		
Log share of each topic in teacher publications, m(0)=-0.5		0.0226**	
		(0.0108)	
Log share of each topic in teacher publications, m(0)=-0.1			0.0258**
			(0.0128)
Topic fixed effects	Yes	Yes	Yes
Student fixed effects	Yes	Yes	Yes
Observations	14184	14184	14184
R-squared	0.16	0.16	0.16
Panel B: Cambridge	Log share of each topic in student publications		
	(1)	(2)	(3)
	Mean top., m(0)=-1	Mean top., m(0)=-0.5	Mean top., m(0)=-0.1
Log share of each topic in teacher publications, m(0)=-1	0.0134*		
	(0.00710)		
Log share of each topic in teacher publications, m(0)=-0.5		0.0137*	
		(0.00735)	
Log share of each topic in teacher publications, m(0)=-0.1			0.0136*
			(0.00767)
Topic fixed effects	Yes	Yes	Yes
Student fixed effects	Yes	Yes	Yes
Observations	15408	15408	15408
R-squared	0.17	0.17	0.17

Notes: The table shows results from estimating equation 1 with full student and topic fixed effects. The specification is identitical to column 3 in table 2. It estimates the effects of teachers' research fields on students' research fields for the 9 fields of the Scientific Revolution. The fields of the Scientific Revolution are defined as astronomy, almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments. Student publication numbers and teacher shares are transformed using the natural logarithm from equation 2 following Chen and Roth (2024). The table reports results for different values of m(0) for the dependent and independent variable. Teacher controls include the log-transformed number of teacher publications, the log-transformed number of fellows at a college at a student's time of matriculation, and the log-transformed cohort size at a student's time of matriculation. Student controls include a student's log-transformed number of publications, and indicator variables taking the value of one if a student graduated with a B.A. or M.A, as well as a variable capturing the mean of all student publications that were predicted using machine learning. Standard errors are clustered at the college-topic level and included in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

TABLE 31: Effect of teachers' research fields on students' research fields - log(x+0.01) specification

Panel A: Oxford	Log share of each topic in student publications		
	(1)	(2)	(3)
	Mean top.	Mean top.	Mean top.
Log share of each topic in teacher publications	0.0510***	0.0217**	0.0203**
	(0.0146)	(0.00961)	(0.0101)
Log share of teacher publications in all topics of the Scient Rev.	-0.00949	0.000438	
	(0.00633)	(0.00612)	
Teacher and college level controls	Yes	Yes	No
Student publication controls	Yes	Yes	No
Year fixed effects	Yes	Yes	No
College fixed effects	Yes	Yes	No
Topic fixed effects	No	Yes	Yes
Student fixed effects	No	No	Yes
Observations	14184	14184	14184
R-squared	0.02	0.04	0.16
Panel B: Cambridge	Log share of each topic in student publications		
	(1)	(2)	(3)
	Mean top.	Mean top.	Mean top.
Log share of each topic in teacher publications	0.0460***	0.0149*	0.0148**
	(0.0118)	(0.00763)	(0.00747)
Log share of teacher publications in all topics of the Scient Rev.	-0.00895	0.00342	
	(0.00816)	(0.00687)	
Teacher and college level controls	Yes	Yes	No
Student publication controls	Yes	Yes	No
Year fixed effects	Yes	Yes	No
College fixed effects	Yes	Yes	No
Topic fixed effects	No	Yes	Yes
Student fixed effects	No	No	Yes
Observations	15408	15408	15408
R-squared	0.02	0.04	0.17

Notes: The table shows results from estimating equation 1. It estimates the effects of teachers' research fields on students' research fields for the 9 fields of the Scientific Revolution. The fields of the Scientific Revolution are defined as astronomy, almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments. Column 1 estimates results for a baseline specification including teacher and student publication controls with college and college cohort effects. Column 2 adds topic fixed effects. Column 3 adds student fixed effects. Student and and teacher shares are transformed using a $log(x + 0.01)$ transformation. Teacher controls include the log-transformed number of teacher publications, the log-transformed number of fellows at a college at a student's time of matriculation, and the log-transformed cohort size at a student's time of matriculation. Student controls include a student's log-transformed number of publications, and indicator variables taking the value of one if a student graduated with a B.A. or M.A, as well as a variable capturing the mean of all student publications that were predicted using machine learning. Standard errors are clustered at the college-topic level and included in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 32: Effect of teachers' research fields on students' research fields - arcsinh specification

Panel A: Oxford	Log share of each topic in student publications		
	(1)	(2)	(3)
	Mean top.	Mean top.	Mean top.
Arcsinh share of each topic in teacher publications	0.0483***	0.0202**	0.0186*
	(0.0140)	(0.00905)	(0.00957)
Arcsinh share of teacher publications in all topics of the Scient Rev.	-0.00871	0.000213	
	(0.00583)	(0.00570)	
Teacher and college level controls	Yes	Yes	No
Student publication controls	Yes	Yes	No
Year fixed effects	Yes	Yes	No
College fixed effects	Yes	Yes	No
Topic fixed effects	No	Yes	Yes
Student fixed effects	No	No	Yes
Observations	14184	14184	14184
R-squared	0.02	0.04	0.16
Panel B: Cambridge	Log share of each topic in student publications		
	(1)	(2)	(3)
	Mean top.	Mean top.	Mean top.
Arcsinh share of each topic in teacher publications	0.0424***	0.0136*	0.0136*
	(0.0112)	(0.00718)	(0.00700)
Arcsinh share of teacher publications in all topics of the Scient Rev.	-0.00758	0.00334	
	(0.00733)	(0.00634)	
Teacher and college level controls	Yes	Yes	No
Student publication controls	Yes	Yes	No
Year fixed effects	Yes	Yes	No
College fixed effects	Yes	Yes	No
Topic fixed effects	No	Yes	Yes
Student fixed effects	No	No	Yes
Observations	15408	15408	15408
R-squared	0.02	0.04	0.17

Notes: The table shows results from estimating equation 1. It estimates the effects of teachers' research fields on students' research fields for the 9 fields of the Scientific Revolution. The fields of the Scientific Revolution are defined as astronomy, almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments. Column 1 estimates results for a baseline specification including teacher and student publication controls with college and college cohort effects. Column 2 adds topic fixed effects. Column 3 adds student fixed effects. Student and and teacher shares are transformed using an inverse hyperbolic sine (arcsinh) transformation. Teacher controls include the arcsinh-transformed number of teacher publications, the arcsinh-transformed number of fellows at a college at a student's time of matriculation, and the arcsinh-transformed cohort size at a student's time of matriculation. Student controls include a student's arcsinh-transformed number of publications, and indicator variables taking the value of one if a student graduated with a B.A. or M.A, as well as a variable capturing the mean of all student publications that were predicted using machine learning. Standard errors are clustered at the college-topic level and included in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 33: Level level specification of baseline specification

Panel A: Oxford	Log share of each topic in student publications		
	(1)	(2)	(3)
	Mean top.	Mean top.	Mean top.
Share of each topic in teacher publications	0.119***	0.0706**	0.0706**
	(0.0370)	(0.0329)	(0.0321)
Share of teacher publications in all topics of the Scient Rev.	-0.0587*	-0.0105	
	(0.0330)	(0.0261)	
Teacher and college level controls	Yes	Yes	No
Student publication controls	Yes	Yes	No
Year fixed effects	Yes	Yes	No
College fixed effects	Yes	Yes	No
Topic fixed effects	No	Yes	Yes
Student fixed effects	No	No	Yes
Observations	14184	14184	14184
R-squared	0.02	0.03	0.13

Panel B: Cambridge	Log share of each topic in student publications		
	(1)	(2)	(3)
	Mean top.	Mean top.	Mean top.
Share of each topic in teacher publications	0.103***	0.0349*	0.0349*
	(0.0254)	(0.0186)	(0.0194)
Share of teacher publications in all topics of the Scient Rev.	-0.0654	0.00310	
	(0.0479)	(0.0328)	
Teacher and college level controls	Yes	Yes	No
Student publication controls	Yes	Yes	No
Year fixed effects	Yes	Yes	No
College fixed effects	Yes	Yes	No
Topic fixed effects	No	Yes	Yes
Student fixed effects	No	No	Yes
Observations	15408	15408	15408
R-squared	0.02	0.03	0.14

Notes: The table shows results from estimating equation 1 in a level-level specification. Standard errors are clustered at college × topic level and included in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

TABLE 34: Robustness with different imputational values for missing end years of fellowships

Panel A: Oxford	Log share of each topic in student publications				
	(1)	(2)	(3)	(4)	(5)
	Mean top.	Mean top.	Mean top.	Mean top.	Mean top.
Log share of each topic in teacher publications (imp. length: 9)	0.0217*				
	(0.0115)				
Log share of each topic in teacher publications (imp. length: 10)		0.0191*			
		(0.0113)			
Log share of each topic in teacher publications (imp. length: 11)			0.0203**		
			(0.0101)		
Log share of each topic in teacher publications (imp. length: 12)				0.0189*	
				(0.00983)	
Log share of each topic in teacher publications (imp. length: 13)					0.0178*
					(0.00975)
Topic fixed effects	Yes	Yes	Yes	Yes	Yes
Student fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	14184	14184	14184	14184	14184
R-squared	0.16	0.16	0.16	0.16	0.16

Panel B: Cambridge	Log share of each topic in student publications				
	(1)	(2)	(3)	(4)	(5)
	Mean top.	Mean top.	Mean top.	Mean top.	Mean top.
Log share of each topic in teacher publications (imp. length: 9)	0.0128				
	(0.00810)				
Log share of each topic in teacher publications (imp. length: 10)		0.0180**			
		(0.00755)			
Log share of each topic in teacher publications (imp. length: 11)			0.0148**		
			(0.00747)		
Log share of each topic in teacher publications (imp. length: 12)				0.0141*	
				(0.00737)	
Log share of each topic in teacher publications (imp. length: 13)					0.0129*
					(0.00734)
Topic fixed effects	Yes	Yes	Yes	Yes	Yes
Student fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	15408	15408	15408	15408	15408
R-squared	0.17	0.17	0.17	0.17	0.17

Notes: The table shows results from estimating equation 1. It estimates the effects of teachers' research fields with different values for imputed fellowship lengths on students' research fields for the 9 fields of the Scientific Revolution. The fields of the Scientific Revolution are defined as astronomy, almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments. Column 1 estimates results for a baseline specification including teacher and student publication controls with college and college cohort effects. Column 2 adds topic fixed effects. Column 3 adds student fixed effects. For convenience, student and and teacher shares are transformed using a $log(x + 0.01)$ transformation. Standard errors are clustered at the college-topic level and included in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

D.2 Alternative mechanisms: Teacher innovativeness and distance to research frontier

Next, the paper considers alternative channels to the direction of research through which teachers could have influenced their students. First, the paper considers teacher innovativeness. It is plausible that innovative teachers might have been able to create new research agendas and inspired their students to follow up on them (Waldinger, 2010). Innovative teachers might also have had a role model effect on their students (Akerlof and Kranton, 2002; Bettinger and Long, 2005). Second, the paper considers proximity to the research frontier. In line with the concept of an "education-innovation gap" (Biasi and Ma, 2022), we would expect that teachers who are publishing at the research-frontier of the Scientific Revolution would increase students' chances to both publish in the fields of the Scientific Revolution as well to publish at the frontier of the Scientific Revolution. To capture proximity to the research frontier we measure students' and teachers' textual distance to the *Philosophical Transactions*, the journal of the Royal Society and the only scientific journal in Britain for the period under consideration.

Teachers' innovativeness in field j is measured as the field-specific maximum of their innovativeness index as defined in section C.7. Intuitively, the innovativeness index captures how much an author's publication changed the field in the future, by dividing its forward similarity to all other titles in the future by the backward similarity to all the papers in the past. For calculating the index, this paper uses a twenty-year period of backward- and forward-comparison. The paper then adds teachers' average innovativeness as an additional regressor to the model from equation 1.[67] To capture teachers' proximity to the research frontier (Biasi and Ma, 2022), the paper constructs an NLP-based measure of the proximity of teachers' publications to the publications in the *Philosophical Transactions*. Section C.8. further evaluates the innovation index by showing that there is a positive association between students' innovation index and students' likelihood of being included in the Dictionary of National Biography or being a fellow of the Royal Society. Students' *similarity* to the *Philosophical Transactions* is defined analogously in section C.7.

Table 35 presents the results for these alternative channels of knowledge transmission on students' direction of research. The table compares four different channels: (1) the extensive margin of being exposed to at least one teacher who published at least once in a given field of the Scientific Revolution, (2) teachers' direction of research as estimated in table 2, (3) teachers innovativeness for the fields of the Scientific Revolution, and (4) teachers' proximity to the research frontier. We find that for Oxford, both teachers' innovativeness and proximity to the research research frontier are positively and significantly associated with students' publication shares in the fields of the Scientific Revolution. For Cambridge, only teachers' innovativeness is positively associated with students' direction of research. However, the coefficients are generally smaller than the effect of teachers'

[67]Formally, the paper constructs a vector of teacher innovativeness across the dimensions of the fields of the Scientific Revolution. The vector of teacher-innovativeness, ι, is defined as an author's average innovativeness in field j, ι_j, across all fields, f: $v = (\iota_1, \iota_2, \ldots \iota_n)$. The vector of teacher innovativeness is then defined as the average of innovativeness in field j across all teachers, analogous to teachers' direction of research, p in section 4.1. The vector of similarity to the *Philosophical Transactions* is constructed analogously.

direction of research from column (2). Increasing teachers' innovativeness or teachers' proximity to the research frontier by 1% is associated with a 0.01% increase in students' publication shares at Oxford. Increasing teachers' innovativeness by 1% is associated with a 0.006% increase in students' publication shares at Cambridge. Likewise, increasing teachers' similarity to the *Philosophical Transactions* by 1% is associated with a 0.011% increase at Oxford. The coefficient for teachers' similarity to the *Philosophical Transactions* is insignificant at Cambridge.

Altogether, table 35 suggests that for the fields of the Scientific Revolution, teachers' direction of research was a stronger predictor of students' direction of research than teachers' innovativeness or teachers' proximity to the research frontier. Yet, table 35 can also be taken as evidence that knowledge transmission might have happened across multiple dimensions of knowledge production, with teachers' direction of research being a major but not singular factor.

Table 35: Effect of teachers' innovativeness on students' direction of research

Panel A: Oxford	Share of each topic in student publications			
	(1)	(2)	(3)	(4)
	Mean top.	Mean top.	Mean top.	Mean top.
Indicator var for teacher pub. in topic	0.0541**			
	(0.0253)			
Log share of each topic in teacher publications		0.0194**		
		(0.00907)		
Log teacher innovation index			0.00962**	
			(0.00462)	
Log teacher proximity to Philosophical				0.0117**
				(0.00591)
Topic fixed effects	Yes	Yes	Yes	Yes
Student fixed effects	Yes	Yes	Yes	Yes
Observations	14184	14184	14184	14184
R-squared	0.16	0.16	0.16	0.16

Panel B: Cambridge	Share of each topic in student publications			
	(1)	(2)	(3)	(4)
	Mean top.	Mean top.	Mean top.	Mean top.
Indicator var for teacher pub. in topic	0.0363			
	(0.0222)			
Log share of each topic in teacher publications		0.0134*		
		(0.00710)		
Log teacher innovation index			0.00711*	
			(0.00406)	
Log teacher proximity to Philosophical Transactions				0.00862
				(0.00523)
Topic fixed effects	Yes	Yes	Yes	Yes
Student fixed effects	Yes	Yes	Yes	Yes
Observations	15408	15408	15408	15408
R-squared	0.17	0.17	0.17	0.17

Notes: The table shows results from estimating equation 1 while further adding a measure of teachers' average innovativeness. It estimates the effects of teachers' research fields on students' research fields for the 9 fields of the Scientific Revolution. The fields of the Scientific Revolution are defined as astronomy, almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments. The strength of teachers' research fields within each of these fields is calculated as the share of all teachers' publications within field τ of all publications within all fields at college c at time t. The strength of students' research fields is calculated as the share of student i's publications in field τ out of all publications from student i. Likewise, teacher's average innovativeness in field j, ι_j is measured as the field-specific average of the innovativeness index introduced in section 3.5. The model includes student-, topic-, and cohort fixed effects. All main explanatory variables are transformed using the log transformation from equation 2. Standard errors are clustered at the college $\times$ topic level and included in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

D.3 Robustness: Instrumental variable approach

D.4 Balancedness and different parameters for uniqueness conditions

Table 36: Balancedness for geo information, 1600–1720

Variable	(1) Students without geo info	(2) Students with geo predictions	(3) Difference
Student graduates with B.A.	0.528	0.562	0.035***
	(0.499)	(0.496)	(0.006)
Student graduates with M.A.	0.322	0.313	-0.009*
	(0.467)	(0.464)	(0.005)
Student graduates with doctoral degree	0.044	0.039	-0.006**
	(0.206)	(0.193)	(0.002)
Cohort size	23.290	24.296	1.006***
	(16.014)	(14.518)	(0.177)
armiger	0.137	0.115	-0.022***
	(0.344)	(0.319)	(0.004)
baronet	0.003	0.004	0.000
	(0.058)	(0.061)	(0.001)
clerici	0.104	0.098	-0.006*
	(0.305)	(0.297)	(0.004)
comitis	0.000	0.000	-0.000**
	(0.021)	(0.000)	(0.000)
doctoris	0.009	0.006	-0.003***
	(0.094)	(0.076)	(0.001)
episcopi	0.000	0.000	-0.000
	(0.011)	(0.000)	(0.000)
eques auratus	0.008	0.002	-0.006***
	(0.088)	(0.045)	(0.001)
equitis	0.014	0.009	-0.004***
	(0.117)	(0.097)	(0.001)
gentilis	0.310	0.290	-0.019***
	(0.462)	(0.454)	(0.006)
militis fil	0.008	0.001	-0.007***
	(0.087)	(0.025)	(0.001)
militis	0.009	0.006	-0.003**
	(0.094)	(0.078)	(0.001)
pauper puer	0.035	0.084	0.049***
	(0.184)	(0.277)	(0.003)
pauper	0.014	0.022	0.009***
	(0.116)	(0.147)	(0.002)
plebeii	0.316	0.363	0.047***
	(0.465)	(0.481)	(0.006)
servus	0.034	0.000	-0.034***
	(0.181)	(0.018)	(0.002)
Number of student's publications'	0.357	0.277	-0.080*
	(4.137)	(2.506)	(0.043)
Share of fields of the Scientific Revolution in a student's publications	0.007	0.006	-0.001
	(0.023)	(0.023)	(0.001)
Number fellows	10.049	9.168	-0.880***
	(9.350)	(8.260)	(0.103)
Teacher publications	22.307	22.617	0.311
	(36.321)	(36.425)	(0.414)
Share of fields of the Scientific Revolution in teacher's publications	0.006	0.006	-0.001***
	(0.016)	(0.017)	(0.000)
Observations	26,576	10,889	37,465

Notes: For an overview of the status categories, see table 14.

TABLE 37: Instrumental variable approach — with minimum numbers of student per hundred >10

	Baseline	With geo info	First stage	IV
	(1)	(2)	(3)	(4)
	Mean top.	Mean top.	Mean top.	Mean top.
Log share of each topic of teacher publications	0.0194**	0.0510**		0.0966*
	(0.00907)	(0.0237)		(0.0546)
Log share of each topic of predicted teacher publications			0.0325*	
			(0.0175)	
Topic fixed effects	Yes	Yes	Yes	Yes
Student fixed effects	Yes	Yes	Yes	Yes
Observations	14184	3051	3051	3051
R-squared	0.161	0.149	0.147	0.001
Centered R-squared				
Kleibergen Paap F-statistic				30.74

Notes: The table shows results from estimating equation 1 in an instrumental variable approach. The instrument of expected teacher shares given students' place of origin is defined in equation 3. The table shows results when alternatively defining the uniqueness criterion as a college share > 20% and a minimum number of students per hundred as > 10. The table reports estimates of the effects of teachers' research fields on students' research fields for the fields of the Scientific Revolution. Column 1 estimates results for the baseline specification from table 2 for the sample of 1600–1720, excluding the period of the Civil War and interregnum 1642–1660, see appendix B.3 for a description of changes in recording practices of geo-information. Column 2 estimates the same specification for the sub-sample of all students with available geo-information and coming from parishes with strong college-ties. Column 3 presents first stage results for the instrument of predicted teacher publication shares based on a student's home parish. Column 4 presents the IV coefficients for the instrumental variable regression. Standard errors are clustered at the college-topic level and included in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 38: Instrumental variable approach — with minimum numbers of student per hundred >1

	Baseline	With geo info	First stage	IV
	(1)	(2)	(3)	(4)
	Mean top.	Mean top.	Mean top.	Mean top.
Log share of each topic of teacher publications	0.0194**	0.0464***		0.0736**
	(0.00907)	(0.0158)		(0.0315)
Log share of each topic of predicted teacher publications			0.0285**	
			(0.0122)	
Topic fixed effects	Yes	Yes	Yes	Yes
Student fixed effects	Yes	Yes	Yes	Yes
Observations	14184	5166	5166	5166
R-squared	0.161	0.161	0.159	0.002
Centered R-squared				
Kleibergen Paap F-statistic				51.73

Notes: The table shows results from estimating equation 1 in an instrumental variable approach. The instrument of expected teacher shares given students' place of origin is defined in equation 3. The table shows results when alternatively defining the uniqueness criterion as a college share $> 20\%$ and a minimum number of students per hundred as > 1. The table reports estimates of the effects of teachers' research fields on students' research fields for the fields of the Scientific Revolution. Column 1 estimates results for the baseline specification from table 2 for the sample of 1600–1720, excluding the period of the Civil War and interregnum 1642–1660, see appendix B.3 for a description of changes in recording practices of geo-information. Column 2 estimates the same specification for the sub-sample of all students with available geo-information and coming from parishes with strong college-ties. Column 3 presents first stage results for the instrument of predicted teacher publication shares based on a student's home parish. Column 4 presents the IV coefficients for the instrumental variable regression. Standard errors are clustered at the college-topic level and included in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

TABLE 39: Instrumental variable approach — with uniqueness condition of college share > 30%

	Baseline	With geo info	First stage	IV
	(1)	(2)	(3)	(4)
	Mean top.	Mean top.	Mean top.	Mean top.
Log share of each topic of teacher publications	0.0194**	0.0638**		0.103**
	(0.00907)	(0.0265)		(0.0455)
Log share of each topic of predicted teacher publications			0.0404**	
			(0.0175)	
Topic fixed effects	Yes	Yes	Yes	Yes
Student fixed effects	Yes	Yes	Yes	Yes
Observations	14184	2727	2727	2727
R-squared	0.161	0.157	0.153	0.005
Centered R-squared				
Kleibergen Paap F-statistic				34.13

Notes: The table shows results from estimating equation 1 in an instrumental variable approach. The instrument of expected teacher shares given students' place of origin is defined in equation 3. The table shows results when alternatively defining the uniqueness criterion as a college share > 30% and a minimum number of students per hundred as > 5. The table reports estimates of the effects of teachers' research fields on students' research fields for the fields of the Scientific Revolution. Column 1 estimates results for the baseline specification from table 2 for the sample of 1600–1720, excluding the period of the Civil War and interregnum 1642–1660, see appendix B.3 for a description of changes in recording practices of geo-information. Column 2 estimates the same specification for the sub-sample of all students with available geo-information and coming from parishes with strong college-ties. Column 3 presents first stage results for the instrument of predicted teacher publication shares based on a student's home parish. Column 4 presents the IV coefficients for the instrumental variable regression. Standard errors are clustered at the college-topic level and included in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 40: Instrumental variable approach — with uniqueness condition of college share > 40%

	Baseline	With geo info	First stage	IV
	(1)	(2)	(3)	(4)
	Mean top.	Mean top.	Mean top.	Mean top.
Log share of each topic of teacher publications	0.0194**	0.0948*		0.153*
	(0.00907)	(0.0528)		(0.0863)
Log share of each topic of predicted teacher publications			0.0585**	
			(0.0287)	
Topic fixed effects	Yes	Yes	Yes	Yes
Student fixed effects	Yes	Yes	Yes	Yes
Observations	14184	1827	1827	1827
R-squared	0.161	0.155	0.150	0.007
Centered R-squared				
Kleibergen Paap F-statistic				26.21

Notes: The table shows results from estimating equation 1 in an instrumental variable approach. The instrument of expected teacher shares given students' place of origin is defined in equation 3. The table shows results when alternatively defining the uniqueness criterion as a college share > 40% and a minimum number of students per hundred as > 5. The table reports estimates of the effects of teachers' research fields on students' research fields for the fields of the Scientific Revolution. Column 1 estimates results for the baseline specification from table 2 for the sample of 1600–1720, excluding the period of the Civil War and interregnum 1642–1660, see appendix B.3 for a description of changes in recording practices of geo-information. Column 2 estimates the same specification for the sub-sample of all students with available geo-information and coming from parishes with strong college-ties. Column 3 presents first stage results for the instrument of predicted teacher publication shares based on a student's home parish. Column 4 presents the IV coefficients for the instrumental variable regression. Standard errors are clustered at the college-topic level and included in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

D.5 Growth of teacher publication shares and regional development

Table 41: Growth rates of teacher publications and Bairoch city size

	Almanacs	Astronomy	Physics	Biology	Chemistry	Geography	Instruments	Math	Medicine
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares
Log Bairoch city size, 1600	0.0000965	0.00169	0.000329	-0.000219	-0.000873	-0.000134	-0.0000178	-0.00108	-0.00323
	(0.0000966)	(0.00909)	(0.00379)	(0.000331)	(0.00125)	(0.000111)	(0.0000206)	(0.00220)	(0.00448)
Log Bairoch city size, 1700	0.0000779	-0.00678	0.00171	0.000184	0.000526	0.00000224	-0.000000426	0.000214	0.00310
	(0.000106)	(0.00720)	(0.00260)	(0.000238)	(0.000985)	(0.0000941)	(0.00000680)	(0.00165)	(0.00290)
Area, lon, lat controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	272	272	272	272	272	272	272	272	272
R-squared	0.01	0.25	0.02	0.02	0.04	0.02	0.01	0.15	0.06
Mean dep. var.	-0.000	0.037	0.023	-0.000	0.007	-0.000	0.000	0.018	0.034

Notes: The table estimates the growth of predicted teacher shares for each hundred and topic from equation 3 on Bairoch city size as a proxy for economic development. Annualized growth in fellows' publication shares per topic is given in percentage points. City size from Bairoch (1988) transformed using the natural logarithm. To account for zeros, we use the Chen and Roth (2024) definition from equation 2. The table addresses the concern that college shares of teacher publications might have been associated with the economic development of regions that colleges had close ties to. Robust standard errors in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 42: Growth rates of teacher publications and Bairoch city size

	Almanacs	Astronomy	Physics	Biology	Chemistry	Geography	Instruments	Math	Medicine
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares
Total growth in city size, 1600–1700	0.0000448	-0.00362	0.00124	0.0000301	0.000228	-0.0000107	-0.00000122	0.000135	0.00119
	(0.0000380)	(0.00253)	(0.00102)	(0.0000762)	(0.000400)	(0.0000340)	(0.00000351)	(0.000585)	(0.00108)
Area, lon, lat controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	272	272	272	272	272	272	272	272	272
R-squared	0.00	0.25	0.02	0.02	0.03	0.02	0.01	0.15	0.06
Mean dep. var.	-0.000	0.037	0.023	-0.000	0.007	-0.000	0.000	0.018	0.034

Notes: The table estimates the growth of predicted teacher shares for each hundred and topic from equation 3 on Bairoch city size as a proxy for economic development. Annualized growth in fellows' publication shares per topic is given in percentage points. City size growth between Bairoch (1988) cities in 1600 and 1700 is given as the absolute difference in population in 1,000s. The table addresses the concern that college shares of teacher publications might have been associated with the economic development of regions that colleges had close ties to. Robust standard errors in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 43: Growth rates of teacher publications and Langton city size

	Almanacs	Astronomy	Physics	Biology	Chemistry	Geography	Instruments	Math	Medicine
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares
Log Langton city size, end of 17th cent.	-0.0000111	0.00148	0.000742	-0.0000759*	0.0000422	-0.0000151	0.0000119	0.000315	-0.000148
	(0.0000346)	(0.000908)	(0.000578)	(0.0000431)	(0.000191)	(0.0000152)	(0.0000119)	(0.000444)	(0.000646)
Area, lon, lat controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	272	272	272	272	272	272	272	272	272
R-squared	0.00	0.25	0.02	0.03	0.03	0.02	0.01	0.15	0.06
ymean	-0.000	0.037	0.023	-0.000	0.007	-0.000	0.000	0.018	0.034

Notes: The table estimates the growth of predicted teacher shares for each hundred and topic from equation 3 on Langton city size as a proxy for economic development. Annualized growth in fellows' publication shares per topic is given in percentage points. City size from Langton (2000) is transformed using the natural logarithm. To account for zeros, we use the Chen and Roth (2024) definition from equation 2.. The table addresses the concern that college shares of teacher publications might have been associated with the economic development of regions that colleges had close ties to. Robust standard errors in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 44: Growth rates of teacher publications and number of ports

	Almanacs	Astronomy	Physics	Biology	Chemistry	Geography	Instruments	Math	Medicine
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares
Ports in 1680	0.000223*	0.000556	-0.00179	0.0000592	0.000236	-0.0000240	-0.0000564	-0.00379	-0.000549
	(0.000122)	(0.00419)	(0.00346)	(0.000164)	(0.000864)	(0.0000596)	(0.0000577)	(0.00245)	(0.00259)
Area, lon, lat controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	272	272	272	272	272	272	272	272	272
R-squared	0.01	0.25	0.02	0.02	0.03	0.02	0.01	0.16	0.06
Mean dep. var.	-0.000	0.037	0.023	-0.000	0.007	-0.000	0.000	0.018	0.034

Notes: The table estimates the growth of predicted teacher shares for each hundred and topic from equation 3 on the number of ports from Alvarez-Palau and Dunn (2019) as a proxy for economic development. Annualized growth in fellows' publication shares per topic is given in percentage points. The table addresses the concern that college shares of teacher publications might have been associated with the economic development of regions that colleges had close ties to. Robust standard errors in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 45: Growth rates of teacher publications and distance to ports

	Almanacs	Astronomy	Physics	Biology	Chemistry	Geography	Instruments	Math	Medicine
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares
Log distance to ports in 1680	-0.0000188	-0.00169	0.00115	-0.0000373	0.000121	-0.0000119	-0.00000455	0.000953*	0.000643
	(0.0000237)	(0.00159)	(0.000748)	(0.0000626)	(0.000245)	(0.0000148)	(0.00000545)	(0.000489)	(0.000801)
Area, lon, lat controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	272	272	272	272	272	272	272	272	272
R-squared	0.00	0.25	0.02	0.02	0.03	0.02	0.01	0.16	0.06
Mean dep. var.	-0.000	0.037	0.023	-0.000	0.007	-0.000	0.000	0.018	0.034

Notes: The table estimates the growth of predicted teacher shares for each hundred and topic from equation 3 on distance to ports from Alvarez-Palau and Dunn (2019) as a proxy for economic development. Annualized growth in fellows' publication shares per topic is given in percentage points. Distance to ports is transformed using the natural logarithm. To account for zeros, we use the Chen and Roth (2024) definition from equation 2. The table addresses the concern that college shares of teacher publications might have been associated with the economic development of regions that colleges had close ties to. Robust standard errors in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 46: Growth rates of teacher publications and Unitarian congregations, 1618–1720

	Almanacs	Astronomy	Physics	Biology	Chemistry	Geography	Instruments	Math	Medicine
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares	Teach. shares
Log number of Unitarian congregations	0.000223*	-0.0158***	-0.0000864	-0.000394**	0.000145	-0.000164	-0.0000254	0.00361	0.00172
	(0.000119)	(0.00587)	(0.00279)	(0.000198)	(0.000909)	(0.000108)	(0.0000272)	(0.00233)	(0.00308)
Area, lon, lat controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	272	272	272	272	272	272	272	272	272
R-squared	0.01	0.27	0.02	0.03	0.03	0.02	0.01	0.16	0.06
Mean dep. var.	-0.000	0.037	0.023	-0.000	0.007	-0.000	0.000	0.018	0.034

Notes: The table estimates the growth of predicted teacher shares for each hundred and topic from equation 3 on the count of Unitarian congregations from the Unitarian Historical Society (2020) as a proxy for religious reform. Annualized growth in fellows' publication shares per topic is given in percentage points. The count of Unitarian is transformed using the natural logarithm. To account for zeros, we use the Chen and Roth (2024) definition from equation 2. The table addresses the concern that college shares of teacher publications might have been associated with the economic development of regions that colleges had close ties to. Robust standard errors in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

D.6 Robustness: Stacked difference in differences

TABLE 47: Stacked difference-in-differences results for teachers leaving their college — omitting years around leaving event

Panel A: Oxford	Full sample	omit [0,1]	omit [-1,2]	omit [-2,3]
	(1)	(2)	(3)	(4)
	Mean top.	Mean top.	Mean top.	Mean top.
Log share of each topic in teacher publications	0.0594**	0.0591**	0.0771**	0.0827**
	(0.0275)	(0.0253)	(0.0348)	(0.0386)
Stack fixed effects	Yes	Yes	Yes	Yes
Year x stack fixed effects	Yes	Yes	Yes	Yes
Topic x stack fixed effects	Yes	Yes	Yes	Yes
Student fixed effects	Yes	No	No	No
Observations	1098	1035	927	837
R-squared	0.25	0.19	0.22	0.24
Panel B: Cambridge	Full sample	omit [0,1]	omit [-1,2]	omit [-2,3]
	(1)	(2)	(3)	(4)
	Mean top.	Mean top.	Mean top.	Mean top.
Log share of each topic in teacher publications	0.0294**	0.0362**	0.0335**	0.0367*
	(0.0137)	(0.0164)	(0.0160)	(0.0188)
Stack fixed effects	Yes	Yes	Yes	Yes
Year x stack fixed effects	Yes	Yes	Yes	Yes
Topic x stack fixed effects	Yes	Yes	Yes	Yes
Student fixed effects	Yes	Yes	Yes	Yes
Observations	1394	1223	1151	997
R-squared	0.20	0.22	0.23	0.24

Notes: The table shows results from estimating equation 4. The dependent variable is student publication shares in the topics of the Scientific Revolution. Treatment is defined as teacher publication shares of before the event of a teacher leaving the college. The table presents results for omitting time periods around the leaving event. Standard errors are clustered at the stack $\times$ topic level and included in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 48: Cambridge: Balancedness around leaving event of fellows, Oxford

Variable	(1) Pre leaving event	(2) Post leaving event	(3) Difference
Student characteristics			
Student graduated with BA degree	0.686	0.682	-0.003
	(0.465)	(0.466)	(0.026)
Student graduated with MA degree	0.579	0.638	0.059**
	(0.494)	(0.481)	(0.027)
Student graducated with doctoral degree	0.252	0.336	0.084***
	(0.435)	(0.473)	(0.026)
Cohort size	9.129	9.127	-0.002
	(1.069)	(1.061)	(0.060)
Number teachers	11.857	10.887	-0.970**
	(6.393)	(8.384)	(0.419)
Student status			
armiger	0.128	0.067	-0.061***
	(0.334)	(0.249)	(0.018)
baronet	0.014	0.000	-0.014***
	(0.118)	(0.000)	(0.005)
clerici	0.215	0.181	-0.033
	(0.411)	(0.385)	(0.024)
comitis	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
doctoris	0.000	0.050	0.050***
	(0.000)	(0.218)	(0.009)
episcopi	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
eques auratus	0.016	0.035	0.019**
	(0.125)	(0.184)	(0.009)
equitis	0.000	0.002	0.002
	(0.000)	(0.043)	(0.002)
gentilis	0.270	0.275	0.006
	(0.444)	(0.447)	(0.027)
militis fil	0.016	0.017	0.001
	(0.125)	(0.128)	(0.008)
militis	0.000	0.033	0.033***
	(0.000)	(0.180)	(0.008)
pauper puer	0.032	0.081	0.049***
	(0.176)	(0.274)	(0.014)
pauper	0.018	0.000	-0.018***
	(0.132)	(0.000)	(0.006)
plebeii	0.277	0.242	-0.034
	(0.448)	(0.429)	(0.026)
servus	0.016	0.017	0.001
	(0.125)	(0.128)	(0.008)
Unrelated publication topics			
Student publication shares in topic *Law*	0.060	0.055	-0.005
	(0.201)	(0.200)	(0.011)
Student publication shares in topic *Poetry*	0.054	0.049	-0.005
	(0.185)	(0.158)	(0.010)
Student publication shares in topic *Drama*	0.041	0.033	-0.008
	(0.164)	(0.130)	(0.008)
Student publication shares in topic *Clasical education*	0.018	0.022	0.004
	(0.120)	(0.123)	(0.007)
Observations	630	639	1,269

Notes: Balancedness of student observations before and post fellow's leaving events from section 5.2. The sample consists of all publishing students that are part of a leaving-stack. The time frame of the sample is 1600–1720.

TABLE 49: Cambridge: Balancedness around leaving event of fellows, Cambridge

Variable	(1) Pre leaving event	(2) Post leaving event	(3) Difference
Student characteristics			
Student graduated with BA degree	0.748	0.685	-0.062**
	(0.435)	(0.465)	(0.027)
Student graduated with MA degree	0.704	0.636	-0.068**
	(0.457)	(0.482)	(0.028)
Student graducated with doctoral degree	0.294	0.338	0.045
	(0.456)	(0.474)	(0.028)
Cohort size	10.373	10.246	-0.127
	(3.239)	(3.111)	(0.190)
Number teachers	39.305	37.738	-1.567
	(20.594)	(20.704)	(1.238)
Student status			
Fellow commoner	0.048	0.083	0.035**
	(0.215)	(0.276)	(0.016)
Pensioner	0.508	0.519	0.011
	(0.501)	(0.500)	(0.033)
Sizar	0.444	0.398	-0.046
	(0.497)	(0.490)	(0.032)
Unrelated publication topics			
Student publication shares in topic *Law*	0.041	0.027	-0.014
	(0.163)	(0.136)	(0.009)
Student publication shares in topic *Poetry*	0.047	0.042	-0.005
	(0.168)	(0.154)	(0.010)
Student publication shares in topic *Drama*	0.016	0.012	-0.003
	(0.069)	(0.056)	(0.004)
Student publication shares in topic *Clasical education*	0.015	0.018	0.002
	(0.098)	(0.125)	(0.007)
Observations	531	585	1,116

Notes: Balancedness of student observations before and post fellow's leaving events from section 5.2. The sample consists of all publishing students that are part of a leaving-stack. The time frame of the sample is 1600–1720.

D.7 Robustness: Parliamentary visitation shock

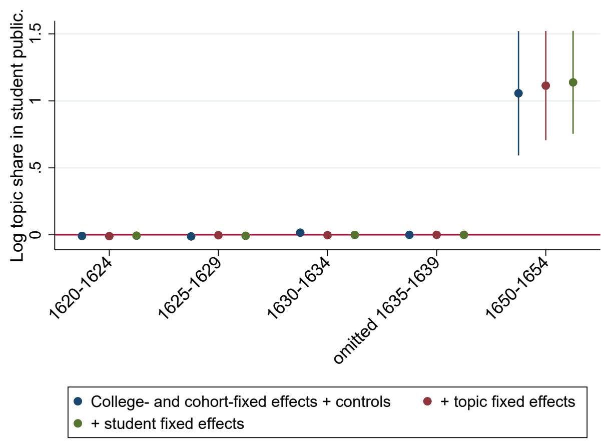


FIGURE 18: Visitation shock and publication shares by all teachers

Notes: The figure presents results from estimating equation 5 with the teacher publication shares in the topics of the Scientific Revolution in the dependent variable and visitation shock publication shares as the treatment. The fields of the Scientific Revolution are defined as astronomy, almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments. Results are shown for three specification. A baseline model with college- and cohort-fixed effects as well as teacher- and student-control, a second specification with additional student-, and topic-fixed effects, and a third specification with cohort-, topic-, and student-fixed effects fully saturated at the college level — similar to equation 4 in section 5.2. The treatment period is 1650–1654. We exclude the periods overlapping with the Civil War, 1640–1644 and 1645–1650, when the university was physically besieged. $N = 2,227$. *Standard errors are clustered at the college* $\times$ *topic level. Confidence intervals are shown at the 90% level.*

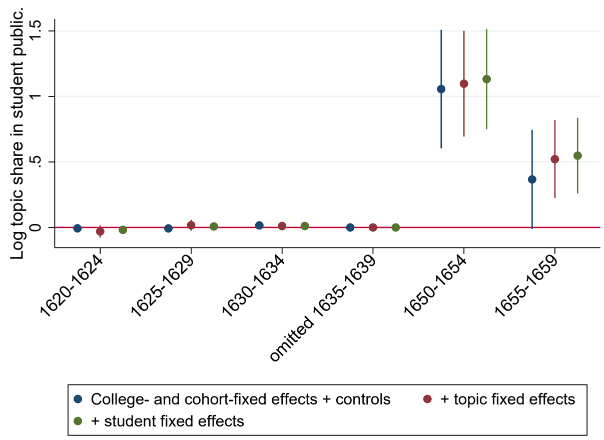


FIGURE 19: Visitation shock and publication shares by all teachers - extended time period

Notes: The figure presents results from estimating equation 5 with the teacher publication shares in the topics of the Scientific Revolution in the dependent variable and visitation shock publication shares as the treatment. Results are shown for the extended period until 1659. The fields of the Scientific Revolution are defined as astronomy, almanacs, applied physics, mathematics, chemistry, biology, geography, medicine, and scientific instruments. Results are shown for three specification. A baseline model with college- and cohort-fixed effects as well as teacher- and student-control, a second specification with additional student-, and topic-fixed effects, and a third specification with cohort-, topic-, and student-fixed effects fully saturated at the college level — similar to equation 4 in section 5.2. The treatment period is 1650–1654. We exclude the periods overlapping with the Civil War, 1640–1644 and 1645–1650, when the university was physically besieged. $N = 2,736$. *Standard errors are clustered at the college* $\times$ *topic level. Confidence intervals are shown at the 90% level.*

D.8 Additional material: Intergenerational transmission process

Table 50: Students' likelihood of becoming a fellow given students' publication outcomes in the Scientific Revolution

Panel A: Oxford	Log share of each topic in student publications	
	(1)	(2)
	Mean top.	Mean top.
Indicator variable for student published in the Scientific Revolution	0.0600**	
	(0.0232)	
Student publication shares in all topics of the Scientific Revolution		0.0223**
		(0.00906)
Teacher and college level controls	Yes	Yes
Student publication controls	Yes	Yes
Year fixed effects	Yes	Yes
College fixed effects	Yes	Yes
Observations	2794	2794
R-squared	0.23	0.23
Panel B: Cambridge	Log share of each topic in student publications	
	(1)	(2)
	Mean top.	Mean top.
Indicator variable for student published in the Scientific Revolution	0.0609**	
	(0.0267)	
Student publication shares in all topics of the Scientific Revolution		0.0281***
		(0.00963)
Teacher and college level controls	Yes	Yes
Student publication controls	Yes	Yes
Year fixed effects	Yes	Yes
College fixed effects	Yes	Yes
Observations	2785	2785
R-squared	0.27	0.27

Notes: The table shows results from regressing student's likelihood of becoming a fellow on students' publications in the Scientific Revolution. Students' publication are measured as (1) an indicator variable of whether students published at least one work in the Scientific Revolution and (2) publication shares in the Scientific Revolution. Standard errors are clustered at college level and included in parenthesis. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.