Seeds of Knowledge: Premodern Scholarship, Academic Fields, and European Growth

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Abstract

Academic human capital is widely believed to be important for economic growth, both historically and today. However, different fields of knowledge—such as theology, law, or science—are not equally important. Using a novel database of premodern European academics (1000–1800), we apply machine learning to classify scholars' fields based on publication titles. We compare these constructed fields to scholars' teaching disciplines and trace how their shares evolved, highlighting the Humanistic Revolution, Reformation, Scientific Revolution, and Enlightenment. As an application, we measure the historical relationship between scholarly output and economic growth. We find that an increase in scholarly output equivalent to a thousand minor scholars is associated with a 20.56% higher income per capita in the scholars' regions of birth by 1900. Furthermore, regions with a higher share of scholars in science and botany show stronger income growth. To address endogeneity, we instrument scholarly activity using exogenous variation from forced migration. We propose a mechanism consistent with these findings: scholars foster human capital accumulation among their fellow natives.

JEL codes: N33, O47, I23

1 Introduction

The accumulation of knowledge is a crucial factor in economic development. It helps explain the West's prosperity and disparities in income among countries (Mokyr 2002, 2016; Galor 2022). Europe has had a strong tradition of scholarship, reaching back to the earliest Medieval universities. However, the link between historical scholarship and economic development is unclear. First, it is hard to quantify academic knowledge, as it covers diverse subjects and can be embedded in various forms. Second, it is unclear what types of formal scholarship would eventually lead to practical applications in the economy.

In this study, we propose a novel method to quantify the knowledge produced by premodern academia.To unravel which types of knowledge was more conducive to economic development, we group scholars in different clusters using a machine learning algorithm, with each cluster representing one academic field. We find a particularly strong association between growth and the field related to mathematics and physical sciences and the field related to botany and life sciences. Then, to mitigate endogeneity concerns, we develop an instrumental variable strategy based on three distinct historical episodes of forced migration. This strategy provides evidence of a causal link between local knowledge production and future growth. Finally, we investigate the underlying mechanisms linking past scholarship to regional income, hypothesizing that scholars serve as catalysts for inspiration among successive generations, fostering the pursuit and application of knowledge.

Our dataset contains sixty thousand scholars compiled from five hundred secondary sources on the members of universities and academies. To measure the productivity of these scholars, we count every edition of every work attributed to them in WorldCat Identities. This approach is complementary to that of De Courson, Thouzeau, and Baumard (2023), who use Wikipedia as both the index of individuals and the measure of output, or to Borowiecki, Kristensen, and Law (2024) who used the length of their entry in a music encyclopedia to measure output of classic music composers. The important difference is in which individuals are assigned a measure of productivity. Our sample is both more exclusive, in that it only considers members of academia, and more inclusive, in that we are not selecting based on retroactive notability. Our approach is also complementary to that of Johnson, Thomas, and Taylor (2023), who use texts as a measure of the local adoption of printing presses. We focus on the locations of authors, not publishers, and thus measure the human capital of scholars instead of the physical capital of printing presses.

Beyond measuring the quantity of academic knowledge in general, we also consider the types of knowledge produced. It has been argued that specific types of knowledge were important for economic growth. For example, scientific knowledge pushed the envelope of propositional knowledge, leading to future economic applications (Wootton 2015; Danna 2022). Academic knowledge contributed to building better political and economic institutions as far back as the Middle Ages (Mitterauer 2010). Theologians promoted nuclear family structures (Henrich 2020; Schulz et al. 2019; Schulz 2022), held beliefs compatible with the spirit of capitalism (Weber 1930), and encouraged education to read the Bible (Becker and Woessmann 2009). Lawyers developed Roman and civil law encouraging trade (Cantoni and Yuchtman 2014) and physicians laid the ground for advances in botany (Hill 1915).

Our fields of study are based on a list of subjects associated with the works by or about the author from the WorldCat Identities database. The subjects are based on the FAST subject terminology schema developed by OCLC (the organization that develops WorldCat) and the Library of Congress. Using these subjects, we use an unsupervised machine learning algorithm — k-means clustering — to assign each author to a cluster. This approach is similar in spirit to Grajzl and Murrell (2023), Almelhem et al. (2023), Koschnick (2023), and Johnson and Taylor (2023). Their algorithms classify texts into topics. In our work, we classify scholars into fields based on their associated topics. These papers also share an interest in how types of knowledge matter for economic growth. Our paper is complementary, as we focus on the production of knowledge in academia and look at the regional impact across Europe.

While our database of scholars ends in 1800, estimates of income are too sparse before 1900 to compare all regions where scholars were born. Thus, we focus on outcomes in 1900, using estimates of GDP per capita for the contemporary NUTS2 European regions from the Rosés-Wolf database on regional GDP (Rosés and Wolf 2021).[1] One advantage of this approach is we are looking at gains from both the First and Second Industrial Revolutions. While during the First Industrial Revolution there was a major role for the human capital and idiosyncrasies of craftsmen and inventors, the Second Industrial Revolution saw a more direct pipeline between scientific knowledge, applied innovations, and an educated workforce (Cinnirella and Streb 2017).

To mitigate endogeneity concerns from omitted variables, we identify refugee scholars originating from the expulsion of the Huguenots from France, the flight of British Catholics post-Reformation, and the escape of Byzantine scholars following the fall of Constantinople. Exiles and expatriates have been shown to matter in the history of knowledge (Burke 2017) and have already been used to solicit exogenous changes in human capital (in the context of Jewish scholars and Nazi Germany, see Moser, Voena, and Waldinger (2014) and Waldinger (2012)). By instrumenting the aggregated output of scholars from a region with the number

1. The NUTS2 regions in Rosés and Wolf (2021) do not perfectly correspond to 2015 NUTS2 regions, as several regions have been aggregated when necessary to compute GDP.

of refugee scholars, we find slightly stronger effects of local scholarship on growth, consistent with attenuation bias from measurement error. These migrants belonged to the intellectual elite, and we also know that forced migrants shift their investment towards human capital because it is portable (Becker et al. 2020). In each case, scholars appeared to have resettled based on physical proximity, not factors strongly correlated with economic growth.[2] Moreover, we find that refugees did not select their destination based on previous regional levels of scholarship.

Finally, we explore the underlying mechanisms that establish a connection between past scholarship and regional income. Although there is a considerable literature documenting local effects from universities in modern contexts (e.g., the studies by Kantor and Whalley (2014) and Dittmar and Meisenzahl (2022)), the discovery of a correlation between scholarly output far back in the past and future development at the local level remains intriguing, as one might expect the impact of figures like Galileo or Adam Smith to transcend their birthplace and influence the entirety of Europe.

We hypothesize that scholars serve as catalysts for inspiration among successive generations, fostering the pursuit and application of knowledge. Unlike other historical studies which focused on how teachers inspire students (Borowiecki 2022; Koschnick 2023), our paper considers inspiration mainly taking place at the birth location. Under this hypothesis, towns and regions where great scholars were born will produce more scholars later on, hence showing more economic development through investment in human capital. This is not to say that scholars born elsewhere were irrelevant or that there are not other potential approaches. Aggregating scholars by birth location is simply our preferred way to measure the local impact of scholarship. Our approach gains support from three observations. First, more of the variation in regional development is explained when scholars are aggregated by birthplace rather than their activity or death location. Second, scholars who remain in proximity to their origins exhibit a stronger association with development compared to those who relocate or meet an untimely demise. Third, areas with a greater number of scholars born had higher general population numeracy in the late 19th century. Finally, we bolster our argument with numerous anecdotes that underscore the existence of a role model effect.

2 Academic Scholars

The full database of scholars we built and used contains information on 60,145 scholars over the period 1000–1800. The data were harvested manually from 535 different

2. While some scholars migrated fairly long distances, our results are very similar if we exclude migrants with distances greater than two-thousand kilometers.

sources. We did not select scholars based on their ex-post achievements (unlike, for example, Wikipedia/Wikidata-based research, see Laouenan et al. (2022) and Serafinelli and Tabellini (2022)), but rather on membership lists from or secondary sources about the main higher education institutions. The institutions considered are of three types: universities (listed in Frijhoff (1996), see De la Croix et al. (2024)), scientific academies (listed in McClellan (1985), see Zanardello (2024)), and other types of institutions we found related to universities (for example, the language academies, the most important Italian Renaissance academies from British Library (2021), and several other higher education institutions which conferred academic degrees).

Before 1000, higher learning happened in urban schools (*scholae*), monasteries, and cathedral schools (e.g., Notre-Dame de Paris). The growing mobility of students and masters in cities fostered associations: students formed nations by origin and, with masters, guild-style corporations—*universitates magistrorum et scholarium*. These bodies had statutes and autonomy from both city and church, becoming true corporate institutions. Over the period 1000–1199, Paris (theology) and Bologna (law) dominate; Montpellier and Salerno (medicine) and Chartres (cathedral school) are notable. Oxford and Cambridge appear in the orbit of Paris. From 1200 to 1348, the core adds Padua, Avignon (helped by the papal court), and Toulouse. Universities still remain within the old Roman Empire's footprint. After the Black Death, it is the Italian Renaissance — Florence, Rome/Sapienza, Parma rise; many other Italian foundations flourish. In the Holy Roman Empire, new waves include Vienna and Louvain; Salamanca and Valladolid stay peripheral; St Andrews appears in Scotland. There are many newcomers during the pre-Reformation period, 1451–1522, like Leipzig, Greifswald, Wittenberg. With the Reformation, Protestant universities diversify (Anglican/Lutheran/Calvinist/Presbyterian) and Jesuit universities emerge on the Catholic side. Over 1598–1685 (the Edict of Nantes era): A clear split appears between Catholic vs. Protestant. Thirty Years' War disrupts many German schools. Finally, over 1686–1793, Lutheran universities — especially Göttingen and Halle — become most important, followed by Dutch Calvinist centers (Rashdall 1895; Verger and Charle 2012; De la Croix and Morault 2025).

Medieval universities concentrated on four main fields: theology, law, arts and humanities, and medicine. Their impact on society is well described by Pedersen (1992): "The faculty of arts gave a basic education to grammar school boys, many of whom would become teachers themselves and contribute to the increase in literacy of the population at large. Others would go on to one of the higher faculties to prepare themselves for other professions. The faculty of medicine produced medical practitioners; the faculty of laws created future administrators with expert knowledge in canon or civil law, and the faculty of theology provided teachers for the episcopal schools, were the ordinary parish priests were educated."

Academies emerged later than universities. A first wave—largely in Italy between 1450–1650—grew out of the humanist movement (e.g., the Pomponiana) and the early Scientific Revolution (e.g., the Lincei, the Cimento) Maylender (1930). A second wave in the seventeenth and eighteenth centuries responded to the need for research in fields not traditionally taught at universities (McClellan 1985). These academies ranged from clubs of amateur naturalists and local historians to eminent learned societies that gathered leading scholars, published journals, and cultivated networks of corresponding members within the Republic of Letters (Mokyr 2016; Cervellati et al. 2025).

Putting together this database, we cover the production of propositional knowledge extensively. We also cover some aspects of the development of knowledge-how, mainly through academies, but sometimes also in universities (see for example in De Lucca (2012) how the Jesuits applied mathematical knowledge to teach how to build stronger fortifications, in a class called *De Re Militari* (Studies in Military Matters)). As stressed in Zanardello (2024), many 18th century academies specialized in applied sciences, such as cartography (Academy of Copenhagen, (Pedersen 1992)), mechanics and engineering (Royal Society of London, (Sorrenson 1996)), or shipbuilding (Academy of Brest, (Académie de Marine 2011)). The scientific advances produced by the institutions surveyed here may have aided the engineers of the Industrial Revolution (Hanlon 2025), but those engineers were generally not academy members in the eighteenth century.

To assemble the list of scholars from each academy and university we use secondary sources, i.e. books on the history of institutions and their members based on primary sources. For academies, this task is usually straightforward, as comprehensive lists of members are often available (our data on academies have already been used in Blasutto and De la Croix (2023) for Italian academies and in De la Croix and Goñi (2024) for father-son pairs in academies and universities). These lists encompass various membership statuses, including ordinary members, corresponding members, and honorary members. Corresponding members are individuals who do not attend academy meetings but contribute to its work from a distance. Honorary members typically include local authorities such as bishops, wealthy merchants, and governors, who provide support and protection to the academy. To ensure that our results are not influenced by publications concerning these sometimes prominent figures, we exclude anyone with honorary status or individuals who are clearly not scholars or intellectuals (such as Napoleon, who was elected to the Académie des Sciences in 1797).

For universities, our goal is to include scholars who have participated in teaching in some capacity. This encompasses various positions, from royal chairs in France to fellowships in England. More detailed information on the criteria for including university scholars in our database can be found in De la Croix et al. (2024), while additional global statistics are provided in De la Croix (2021) and in various issues of the *Repertorium Eruditorum Totius Europae*.

The resulting database is accessible at https://shiny-lidam.sipr.ucl.ac.be/scholars/. Notably, the gender distribution heavily favors male scholars, with only 108 women (De la Croix and Vitale 2023).

To assign a measure of productivity to each scholar, we use the Worldcat Identities search engine which provides references to the collections of thousands of libraries around the world. To measure the quality of each author, we count the number of publications by the author. This measure thus cover both output of the scholar and impact, as it includes new editions, translations, etc. This allows Adam Smith to be measured as a highly productive author (ranked 62nd) although he only wrote two books in his life. On the whole, Worldcat provides a good approximation of the population of known European authors. For example, Chaney (2020) compares the Universal Short Title Catalogue (St. Andrews 2019) to the references in the Virtual International Authority File (VIAF), on which WorldCat is based. Chaney successfully locates 81% of USTC authors in the VIAF. Thus, scholars with missing Worldcat publications were likely unproductive.

Finally, we use secondary sources to document each scholar's academic field. For university professors, this corresponds to their area of instruction, while for academicians, it is derived from the descriptions provided in the sources. We categorize scholars into the following broad fields: lawyers, physicians, theologians, scientists, applied scientists, and arts and humanities scholars. These classifications align with the traditional higher faculties of early universities, with the addition of the arts faculty, where the prominence of scientists grew over time. While these collected fields typically provide valuable insights, they are not without imperfections. For instance, for some contexts it may have made sense to include more nuanced distinctions, such as differentiating between canon law and civil law within the field of law. Additionally, some scholars' teaching roles may not fully represent their expertise; for example, Gassendi, who received the doctorate in theology and taught Aristotelian philosophy at Aix-en-Provence, obtained a chair in Mathematics at the Royal College and was a key figure of the Scientific Revolution (for Applebaum (2003), he redefined the goal of empirical science as determining probable, rather than certain, results).

In the case of academicians, we assigned the field of "law" to members of courts of justice, such as the regional French Parliaments, which may not always accurately reflect their actual skills. A similar issue arises with individuals associated with the Church, to whom attributed field of "theology" regardless of their broader interests. This critique extends to Protestant countries as well; for instance, many fellows in Oxford hold a D.D. (Doctor of Divinity) but may have pursued teaching and research in other fields, as evidenced by Gunther (1937). Hence, there is a need for a better identification of academic fields based on actual publications.

3 Identifying Academic Fields

For each scholar with a WorldCat Identities page,[3] we collected the tag cloud of their "Associated Subjects" (excluding the persons who are honorary members). We then drop subjects associated with fewer than 30 scholars or that are about a specific country (e.g. "French history"). This leaves us with 1,360 subjects and 16,149 scholars with at least one subject.

WorldCat assigns each subject a relative importance. We quantify the importance of a subject from 1 to 5. Thus, for each scholar i and subject j, we have weights $\gamma_{ij} \in \{0, 1, 2, 3, 4, 5\}$. We then construct a data matrix Γ of dimensions $1,360 \times 16,149$ containing every γ_{ij}. Each row is an academic, each column a subject.

We use the k-means algorithm which treats each row of Γ as the coordinate points in a $1,360$-dimensional space. It partitions the data into k clusters, minimizing the total within-cluster sum of squared deviations (TWCSS). This is the sum of squared deviation of each point from the centroid of its cluster.

K-means must be estimated using numerical methods as there is no closed-form solution. We use the default R package which implements the Hartigan and Wong (1979) algorithm. This algorithm starts with random guesses for the centroids of each cluster and then iteratively improves the centroids until a certain convergence threshold is reached. As the improvements converge to a local optimum, not a global optimum, we repeat the estimation 500 times, picking the replication with the lowest TWCSS.

The choice of k can be made using various criteria. We minimize the Bayesian information criterion (BIC): $TWSS_k + \log(I)Jk$, where $I = 16,149$ and $J = 1,360$. This is minimized at $k = 10$. More details are in Appendix A.5. Ten clusters are thus the most informative yet parsimonious way to describe academic fields.

Since our procedure assigns each scholar to a single academic field, one might wonder how we account for individuals active across multiple disciplines. This is naturally captured by the K-means clustering: each field corresponds to a cluster, which can be represented as a vector of loadings across the 1,360 topics. For instance, Cluster 7, which we label Philosophy, does not only load heavily on the topic philosophy (4.27), but also on others—for

3. Sadly, the 2 million pages of the WorldCat Identities project were suddenly retired in March 2023. This is bad news for those interested in measuring human capital from publications data. For the future however, we found a viable alternative using statistics drawn from the VIAF platform. See Curtis and De la Croix (2023) for more details.

example, mathematics enters with a loading of 0.20, thus capturing philosophers who also engaged in mathematical work. Likewise, Cluster 5, which we label Sciences, includes the topic philosophy with a loading of 0.38 (while loading mathematics at 3.41). Consider Roger Bacon, who was both a theologian and a natural philosopher, contributing to optics, mathematics, and experimental science while holding a degree in theology. He is assigned to Cluster 7 (Philosophy) because his topic profile is closer to that cluster than to others, yet the cluster still incorporates a mathematical component.

Table 1 presents the ten clusters. The first column contains a description we chose to represent the various subjects included in the cluster. Column 2 gives the total number of published scholars in each cluster. One cluster is much bigger than the others, Classics; it appears to contain both humanists, classicists and scholars who were unrelated to any other cluster. The smallest cluster is Botany, with 543 persons.

To better grasp the nature of each cluster, we show in Column 3 the average number of subjects per author. Classics is again an outlier here, with its authors being characterized by five subjects on average instead of 9 to 15 in the other clusters. Column 4 shows the names of the scholars belonging to the cluster who published the most. Column 5 gives the median number of publications of scholars in each cluster. Theology 2 leads and Classics lags. Column 6 shows the date of activity of the earliest scholar in each cluster. It shows that all ten clusters started before 1200, thus having deep roots in the Middle Ages. The last column shows the median year of activity in the cluster. Law is the cluster with the earliest median date, while Politics is the cluster with the most recent median date.

The clusters are further explored in the Appendix. The most important topics and scholars by cluster are described in Appendix A.1. Most clusters are strongly associated with a few key terms, however the Classics cluster is not. Classics contains authors who write on many diverse topics. Appendix A.2 plots the shares of scholars by cluster over time. In Appendix A.3, we provide ten graphs with names of published scholars over time by cluster, allowing to see through whom each field has medieval roots.

Theology is the only field to have two clusters (see the maps in Appendix A.4). The division between Theology 1 and Theology 2 is related to the Catholic-Protestant divide, but is not a simple denominational split. In Theology 1, we find some leading figures of Catholicism such as Aquinas (professor at University of Paris 1252–72 and Naples 1272–4), Bossuet (member of Académie Française 1671–1704), and Robert Bellarmin (professor at the Gregorian University in Rome 1576–1593) but also some unorthodox Catholics such as Pascal (member the Mersenne academy of c. 1639, close to Jansenism, a controversial Catholic movement with similarities to Calvinism) and some important Protestant figures such as Gilbert Burnet (professor of Divinity at the University of Glasgow 1669–74, and member of

Table 1: Clusters of WorldCat Topics

Cluster / Field	No. Scholars	Avg. No. subjects	Top 3 Names	Median N. Publ.	Earliest Year	Med. Year
Theology 1	1581	12	Aquinas, Bossuet, Pascal	143	975	1615
Theology 2	940	13	Luther, Melanchthon, Wesley	315	1039	1671
Politics	990	12	Swift, Machiavelli, Corneille	184	1043	1756
Law	727	9	Stryk, Bentham, Bohmer	156	1090	1593
Science	661	15	Newton, Euler, Galilei	177	1116	1714
Classics	7317	5	Schiller, Erasmus, Pope	54	970	1712
Philosophy	653	15	Rousseau, Kant, Diderot	258	980	1700
Botany	543	11	Linnaeus, Bernardin, Trew	189	1176	1753
Culture	1086	12	Arouet, Humboldt, Homman	211	1140	1749
Medicine	1651	9	Haller, Hohenheim, Gessner	125	1025	1698

Note: Clusters estimated by k-means clustering. Top 3 Names are the top three scholars assigned to a cluster based on their number of publications.

the Royal Society). Theology 2 is led by the main figures of Protestantism, such as Luther (professor at University of Wittenberg 1508–46), Melanchthon (professor at University of Tübingen 1512–18 and Wittenberg 1518–60), John Wesley (fellow of Lincoln College at University of Oxford 1725–7), and Jean Calvin (professor at the University of Geneva 1541–64). But it also includes medieval (Catholic) theologians such as Hugues de Saint-Victor (University of Paris 1133–41). Hence, interpreting Theology 2 as purely Protestantism would be an oversimplification. Looking at the subjects most strongly related to both clusters, we find "Catholic Church" and "Clergy" in Theology 1, and "Bible" and "Jesuis-Christ" in Theology 2. "Theology, doctrinal" belongs to both clusters, with about the same weight, as shown in Appendix A.1.

Scientific fields are split in three clusters. The cluster Sciences is strongly related to the subjects "Mathematics," "Astronomy," "Geometry," "Physics," led by Newton (professor at University of Cambridge 1661–1696, member of several academies), Euler (professor at University of St Petersburg 1727–41, member of several academies), and Galilei (professor at University of Pisa 1589–92 and Padua 1592–1610). The cluster Botany is strongly related to the subjects "Plants" and "Natural History," and is led by Linnaeus (professor at University of Uppsala 1742–78, and member of many academies). The cluster Medicine is strongly related to subjects "Human anatomy" and "Surgery". Together with the clusters on Politics, Law, and Philosophy, the clustering procedure seems to lead to a very coherent set of academic fields. Only Classics and Culture have vague boundaries. We are thus confident interpreting these clusters as academic fields.

We compare the clusters derived from Worldcat data to the fields based on the descriptions in historical sources in Table 2. Each entry delineates the distribution of authors within specific clusters across diverse fields. Notably, the two theology clusters exhibit a balanced composition, with approximately half of their members documented as theologians in the primary sources. Furthermore, 30-40% of these members are affiliated with humanities, reflecting instances such as Jesuit scholars who, while publishing theological works, engage in teaching Hebrew or rhetoric. The Politics cluster predominantly comprises individuals associated with humanities (39%), yet a substantial proportion is also linked with law (27%) and theology (11%), indicating a presence of scholars specializing in public law. Conversely, the Law cluster is predominantly entrenched in the field of law (83%), signifying its clear disciplinary demarcation. Scholars within the Science cluster predominantly align with scientific disciplines (68%), although some are affiliated with humanities, likely due to the interdisciplinary nature of subfields like logic or metaphysics. Both the Classics and Culture clusters exhibit a diverse membership spanning across various fields, echoing the widespread scholarly interest in antiquity post the humanistic revolution, as well as engagements in poetry, travel literature, and related genres. The Philosophy cluster demonstrates a strong affinity with humanities, yet a notable percentage of its members are also associated with theology (16%) and sciences (13%), illustrating interdisciplinary intersections. Botany encompasses two fields mentioned in the primary sources: medicine (39%) and science (44%). This convergence reflects the historical development of botanical gardens alongside medical schools to advance medicinal knowledge. Finally, the Medicine cluster primarily consists of individuals from the medical field (70%), underscoring its distinct identity.

We now examine the evolution of academic field shares over time to assess their alignment with our prior understanding of key events in the early modern period.

Figure 1 shows the shares of selected fields over the period 1350-1800. On the left panel, we see the negative trend in the share of Theology 1, and a rise of Classics, the field including those publishing on the authors of the antiquity. Classics rise above theology and maintain their dominance from 1400 on. This revived interest in the classical authors is often labelled the Humanistic Revolution, the intellectual and cultural shift during the Renaissance that emphasized individualism, secularism, and the revival of classical learning.

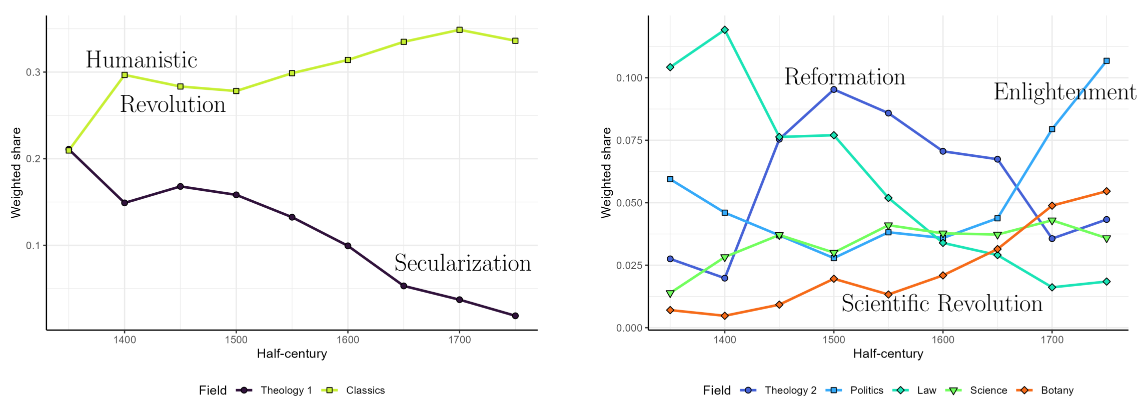
The right panel of Figure 1 shows the evolution of other fields. Theology 2 received a boost with the Reformation, which lasted several periods, to go back to low levels only in 1700. Secularization in Protestant regions was partly fueled by the founding of new universities (De la Croix and Morault 2025) and partly by the growth of academies. For example, the University of Halle (Koch 2008), established in 1694, placed greater emphasis

Table 2: Mapping between Clusters of WorldCat Topics and Fields from sources

	Field from source							
Cluster	Theology	Law	Humanities	Medicine	Sciences	Appl. Sc.	Soc. Sc.	unknown
Theology 1	**45%**	13%	33%	2%	4%	0%	0%	3%
Theology 2	**53%**	3%	39%	2%	3%	0%	0%	1%
Politics	11%	27%	**39%**	6%	8%	3%	**5%**	3%
Law	3%	**83%**	11%	1%	1%	0%	0%	1%
Science	4%	1%	18%	5%	**68%**	3%	1%	1%
Classics	16%	14%	**40%**	11%	13%	3%	1%	3%
Philosophy	16%	5%	**59%**	4%	13%	0%	1%	1%
Botany	3%	0%	10%	**39%**	**44%**	2%	1%	1%
Culture	8%	8%	**45%**	7%	22%	4%	3%	3%
Medicine	2%	2%	12%	**70%**	12%	0%	0%	2%

on secular disciplines than older institutions, which often maintained strong ties to religious authorities. Halle became a pioneer of the Humboldtian model of education, promoting academic freedom and a research-oriented approach that later influenced universities across Europe.

Figure 1: Shares of selected fields over time



In parallel with the decline of both theologies in the eighteenth century, we observe a rise in the field of Politics. This shift is closely tied to the Enlightenment movement, particularly its emphasis on reason, governance, and individual rights. Notable figures such as Adam Smith (economics) and David Hume (philosophy) challenged traditional religious orthodoxy, promoting secular frameworks of thought that further propelled the institution's transition away from religious dominance.

As far as the Scientific Revolution is concerned, we do not observe a surge in the field

Science. This is probably because there has always been some sciences in universities, and the Scientific Revolution is more a change in paradigm than a change in fields. We observe, however, a sustained rise in the field Botany.

4 Academic knowledge and regional development

We now analyze whether academic knowledge is associated with historical economic development at the subnational level. This allows us to determine if scholarship matters both at a local and a national level. We interpret a higher GDP per capita in 1900 as evidence of economic growth. Before 1800, GDP per capita was governed by Malthusian logic, albeit with some geographic and temporal variation (a Malthusian regime does not exclude relatively long periods of expansion or decline, see Lagerlöf (2019)). We control for the logarithm of the region's average ruggedness from Nunn and Puga (2012), the logarithm of the region's average post-1500 caloric suitability index of land from Galor and Özak (2015, 2016) and Galor, Özak, and Sarid (2017), and the logarithm of the area of the region in square kilometers. With these controls, and given the low initial levels of development, we interpret a higher GDP in 1900 as evidence of stronger 19th century economic growth.

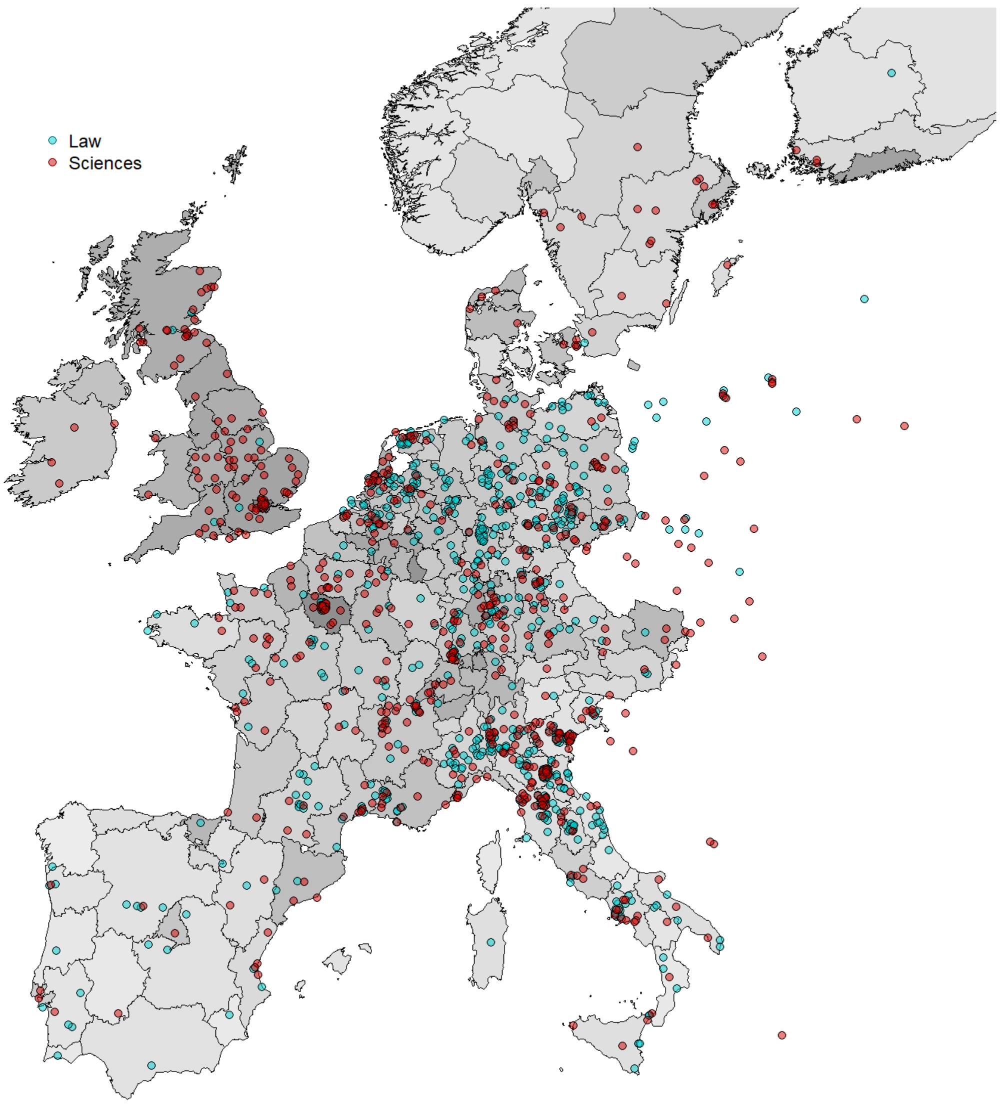
Figure 2 shows the geographical area we cover with the NUTS2 regions.[4] The map's background color for each region reflects its GDP per capita in 1900, with darker shades indicating higher levels. Color dots indicate the place of birth of scholars belonging to two example fields. Red dots correspond with scholars belonging to the field of Law, blue dots with scholars belong to the field of Science.

When aggregating scholarship at the regional level, we weight each scholar by a function of the number of his publications.[5] The number of publications given by Worldcat includes multiple editions and translations and ranges from 1 to 111,660 (Martin Luther). Having multiple editions is a nice feature as it allows to capture the quality of each writing — a book in high demand will be reedited and translated. (In Appendix B.1, Tables B1 and B2, we find similar results using two different measures of publications which do not include editions.) But, given these values, it is not reasonable to weight scholars by their number of publications in levels. It would imply that Luther worth a hundred thousand theologians with only one publication. If, instead of the number of publications, we take its logarithm,

4. A NUTS2 region is a geographical classification level used in the European Union's Nomenclature of Territorial Units for Statistics (NUTS). The NUTS system has three main levels of regional division, each representing progressively smaller geographic areas. NUTS2 regions typically cover provinces or groups of districts with populations generally between 800,000 and 3 millions.

5. We use masculine pronouns for scholars because the vast majority are male (but not all, see De la Croix and Vitale (2023).)

Figure 2: Map of Birthplace of Law and Science Scholars



Note: Every scholar is assigned a field and a birth NUTS 2 region. GDP per capita from the Rosés-Wolf database on regional GDP Rosés and Wolf 2021.

Luther would be worth 11.2 theologians with one publication. However, a handful of scholars are notable enough to have a WorldCat page but no WorldCat publications. Thus, to deal with zeros, we use the inverse hyperbolic sine function.[6] Then, Luther would be worth 12.3 theologians with one work. Galileo would be worth 9.5 mathematicians with one publication. We adopt this last formula, which gives a weight from 1 to 12.3 to each scholar.

When aggregating scholars, we normalized the sum by dividing by 1,000 times the inverse hyperbolic sine of 1, to put the coefficients in terms of a thousand scholars with only one publication. This corresponds to 1.99 standard deviations of the sum without normalization.

For our main regression, we estimate the following:

$$y_{r,s} = \alpha_0 + \alpha_1 n_{r,s} + \sum_{c=1}^{10} \beta_c share^c_{r,s} + \beta X_{r,s} + \phi_s + \epsilon_{r,s} \tag{1}$$

where $n_{r,s}$ is the sum of the inverse hyperbolic sine of the number of publications over all scholars born in region r in country s from 1000 to 1800, normalized by dividing by 1,000 times the inverse hyperbolic sine of 1; c is one of the ten fields identified by the K-means algorithm; $share^f_{r,s}$ is the share of $n_{r,s}$ that belong to field f; $X_{r,s}$ is a vector of controls, ϕ_s is a country fixed effect, and $\varepsilon_{r,s}$ is an error term. For the country fixed effects, use borders in 1900. We assign contemporary NUTS2 regions to countries based on where the majority of the regions lie.

We include as controls variables related to pre-industrial economic potential: the logarithm of the region's average ruggedness from Nunn and Puga (2012), the logarithm of the region's average post-1500 calorie suitability index from Galor and Özak (2016), and the logarithm of the region's area.

While time-varying measures of pre-industrial development exist, such as city populations (Buringh 2021), we do not want to control for them directly as they could be mechanisms by which scholarship affected development in 1900 (Zanardello 2024).

Table 3 presents the results. Standard errors are clustered at the country level to mitigate concerns about spatial autocorrelation.As shown in the first line, we find an overall association between $n_{r,s}$ before 1800 (the weighted sum of published scholars) and GDP per capita in 1900. An increase equivalent to 1,000 scholars with one publication between 1000 and 1800 in region i is associated with on average a 20.56 percent increase in GDP per capita in 1900, all else equal. This shows that human capital in the past is associated with future growth. Below, we argue that this is likely a causal effect. Regardless of the exact mechanism, our findings lend credence to theoretical frameworks in which human capital

6. If we instead use the logarithm of the number of publications if positive, zero otherwise, our results are very similar.

Table 3: Regional GDP per capita and academic fields

	log GDP per capita in 1900				in 2015
	(1)	(2)	(3)	(4)	(5)
Local scholarship	0.187**	0.135**	0.171***	0.129*	0.166***
	(0.086)	(0.060)	(0.043)	(0.067)	(0.046)
Share Theology 1			0.215	0.028	0.151
			(0.222)	(0.173)	(0.178)
Share Theology 2			1.440***	0.381	0.163
			(0.415)	(0.501)	(0.224)
Share Politics			0.417	0.049	-0.065
			(0.321)	(0.131)	(0.209)
Share Law			-0.850***	-0.427*	-0.081
			(0.255)	(0.208)	(0.157)
Share Science			1.451***	1.215***	0.631*
			(0.470)	(0.312)	(0.323)
Share Philosophy			-0.029	-0.107	0.230*
			(0.265)	(0.126)	(0.111)
Share Botany			0.856**	0.649***	0.677***
			(0.353)	(0.199)	(0.143)
Share Culture			0.102	-0.108	-0.162
			(0.277)	(0.358)	(0.205)
Share Medicine			0.075	-0.425	-0.055
			(0.371)	(0.525)	(0.270)
N	172	172	172	172	165
Adj. R Squared	0.332	0.630	0.458	0.656	0.709
Controls:					
Country FEs	No	Yes	No	Yes	Yes
Ruggedness, CSI, and area	Yes	Yes	Yes	Yes	Yes

Note: $^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$. Standard errors clustered by country in parentheses. The unit of observation is a NUTS2 region. GDP per capita from the Rosés-Wolf database on regional GDP (Rosés and Wolf 2021) and from Eurostat. For comparison, regions with GDP in 2015 but not in 1900 are omitted. $n_{r,s}$ is the weighted total output of scholars. Shares are the weighted share of the total scholars who are assigned to a given field. GDP per capita from the Rosés-Wolf database on regional GDP (Rosés and Wolf 2021). All regressions include regional controls: log ruggedness from Nunn and Puga (2012), log post-1500 calorie suitability index from Galor and Özak (2016), and the log of the region's area.

plays a role in development.

When we additionally look at the shares of the different fields (Column 3), we find that the fields Theology 2, Science, and Botany have a positive association with growth.[7] The field Law has a negative association. In that regression, the reference category is the share of scholars in Classics. All else equal, a ten percentage point increase in the number of scholars that are in the fields of Theology 2, Law, Science, and Botany (at the expense of Classics) are associated with a 15.49 percent. -8.15 percent, 15.62 percent, and 8.93 percent change in GDP per capita in 1900.[8]

In the classic engineers vs. lawyers debate, à la Murphy, Shleifer, and Vishny (1991), it is argued that economies grow faster when top talent goes into entrepreneurship/engineering rather than rent-seeking professions (proxies like the share of engineers vs. lawyers). Cantoni and Yuchtman (2014) defend lawyers in medieval times and Maloney and Valencia Caicedo (2022) defend engineering in more modern times. Here our analysis at the aggregate level shows than on average (over time and space), sciences dominate.

We also still estimate the impact of the total number of scholars (Figure 3 Column 3), with an increase equivalent to 1,000 scholars with one publication between 1000 and 1800 in region i being associated with on average an 18.66 percent increase in GDP per capita in 1900, *ceteris paribus*. Therefore, the coefficients for the shares are estimating the *additional* impact from specialization in a field compared to the others. Scholarship, regardless of field, is associated with higher GDP per capita.

Theology 2 and Law appear to vary substantially across countries. Theology 2 is more common in Protestant countries, and Law is rare in common law Britain (Figure 2). As Protestantism and common law are commonly studied as determinants of growth, the associations we find might be related to more broad factors relating to religious mix and legal systems (Weber 1930; Porta, Lopez-de-Silanes, and Shleifer 2008). To control for any country-specific characteristics, we add country fixed effects (based on borders in 1900).[9] The association disappears for Theology and is weakened for Law. For Science and Botany, the relation survives the inclusion of country fixed effects, and the changes associated with a 10 percentage point increase are 12.92 percent and percent. This suggests that Theology and Law related to growth through some mechanism occurring at the national level.

7. There are *ex-ante* reasons from the literature to consider the significance of each of these specific shares separately. However, testing the significance of all 9 shares independently could lead to a family-wise error rate of greater than 0.05. To account for this multiple comparisons problem, we can apply a conservative Bonferroni correction; Share Science remains significant at the 0.05 level.

8. In Appendix B.1 Table B3, we find some associations that suggest that there may be diminishing returns from the marginal scholar in Science and Botany.

9. If we apply a conservative Bonferroni correction, as discussed above, Share Science remains significant at the 0.05 level and Share Botany is significant at the 0.10 level.

In the last column we also look at GDP per capita in 2015 (from Eurostat). The positive overall association remains. An increase equivalent to 1,000 scholars with one publication between 1000 and 1800 in region i is associated with a 20.56 percent increase in GDP per capita in 2015. Having a high share of scholars in Science gave regions an initial advantage, and while the advantage is smaller and only borderline significant in 2015, the other regions have not fully converged.[10] Perhaps scientists were particularly important for the early adoption of the technologies of the Industrial Revolution, leading to an initial but temporary edge. On the other hand, scholars in Botany are still strongly associated with a higher level of GDP.

Note that we do not interpret these coefficients as direct causal effects. Both the productivity of a scholar and their academic interests was likely influenced by the cultural and intellectual environment they were raised in. (Though in Table B4 we find similar associations dropping all regions with an academy or university within our period of study.) These factors could in turn be endogenously related to economic growth (and were likely influenced by the work of previous scholars). Concern about endogeneity is reasonable, and we later introduce an instrumental variable strategy. However, we believe that these results demonstrate that by measuring the types and quantity of scholarship, we are measuring something of importance to the premodern economy. Our preferred interpretation, outlined in our model, is that upper-tail human capital inspires future generations to invest in their own human capital. However, we would still argue that our findings are interesting if the true underlying causes of growth are deeper cultural and intellectual factors. In that case, academic output is a useful proxy that we can categorize and quantify.

5 Endogeneity

Many economic growth models view GDP per capita and human capital as two endogenous variables evolving together along their dynamical path (Azariadis and Drazen 1990; Lucas 1988). If we interpret each region as a closed economy starting from specific initial conditions, these models imply a positive correlation across locations between regional GDP per capita and regional human capital, which is the result we find in the analysis above. More generally, we can imagine that both upper tail human capital and GDP per capita in 1900 depend on common unobserved variables. An example is provided in De Pleijt, Koschnick, and Wallis (2023). The authors argue that upper tail human capital depended on high school foundations in the region after the death of wealthy donors. Such schools affect academic

10. If we apply a conservative Bonferroni correction, as discussed above, Share Botany remains significant at the 0.01 level.

human capital but may also affect GDP directly through enhancing basic skills.

To evaluate the extent of a possible endogeneity bias, we rely on the following strategy. Shocks to a region's stock of human capital were frequent in history. We exploit three of them to build an instrumental variable for the total output of scholars born within a NUTS2 region. The coefficient of interest in the IV regressions are greater than that in the OLS regression. We suspect this is due to attenuation bias, likely related to measurement errors in the number of publications.

The exclusion restriction of this instrumental variable strategy assumes that migrants are not selecting their destinations based on future growth potential. It also assumes that there is not an alternative channel by which refugees affect growth. Both of these assumptions are examined in detail below.

One limitation of this instrumental variable strategy is that it only allows us to identify the effect of total scholarly output. We do not have separate instruments for the field shares in Table 3 Columns 3–5.

5.1 Constructing the instrument

Our instrument is based on forced migration linked to the following episodes: the fall of the Eastern Roman Empire, the Reformation in England, and the revocation of the Edict of Nantes. Using these three migration waves gives us a set of plausibly exogenous variation in local scholarship that spans a large area of Europe: 73 out of 172 NUTS2 regions have an academic refugee active or dying.

Many of the Byzantine Greek scholars in European academia were refugees from the collapse of the Eastern Roman Empire and the progressive conquest of the Greek islands by the Ottomans. We consider all scholars born in modern Turkey, Greece, Cyprus, and Albania, and who died between 1389 (the battle of Kosovo) and 1699 (to allow using a full century of scholars as the endogenous variable) as potential refugees. As shown in Figure 3, most of them settled in the closest cities, in Italy. There is a literature stressing their importance in bringing books and knowledge from the Greek Antiquity, fostering the Italian Renaissance (Harris 1995; Link 2023).

Several British Catholic scholars departed to the continent in the decades after the Church of England split from Rome in 1534. We consider all scholars born in Britain, died between 1558 (the coronation of Queen Elizabeth I) and 1699 who worked or died in a Catholic region potential refugees.[11] As shown in Figure 4, they mostly settled in France, Belgium, and Italy.

Many Huguenots scholars left France in the 17th century in response to religious suppres-

11. Modern France, Belgium, Italy, Spain, Portugal, Austria, and Czechia.

sion, most notably the Siege of La Rochelle and the revocation of the Edict of Nantes (1685). We consider all scholars born in France, who died between 1572 (the Bartholomew's Day massacre) and 1699, and who worked or died in a region where Protestantism was at least tolerated, if not the State religion, potential refugees.[12] Figure 5 shows their migrations.

In most cases, the refugees did not just remain as temporary exiles. A significant number of them became citizens of the city they settled in. The case of Geneva is well documented (Burke 2017). Thousands of Huguenots fled to Geneva, especially after the 1550s, seeking both religious freedom and safety from violence. To become citizens, the refugees had to conform to strict moral codes which emphasized piety, hard work, and adherence to Protestant doctrine. The influx of French Protestants into Geneva played a key role in spreading Calvinist ideas and texts, as Geneva became a hub for Protestant publishing and a center of intellectual life. A similar pattern applies to British refugees on the Continent, where they built colleges and convents which spread Catholic ideas (*The English Catholic refugees on the Continent 1558-1795,* n.d.).

Figure 3: Byzantine Academic Refugees, 1389–1699

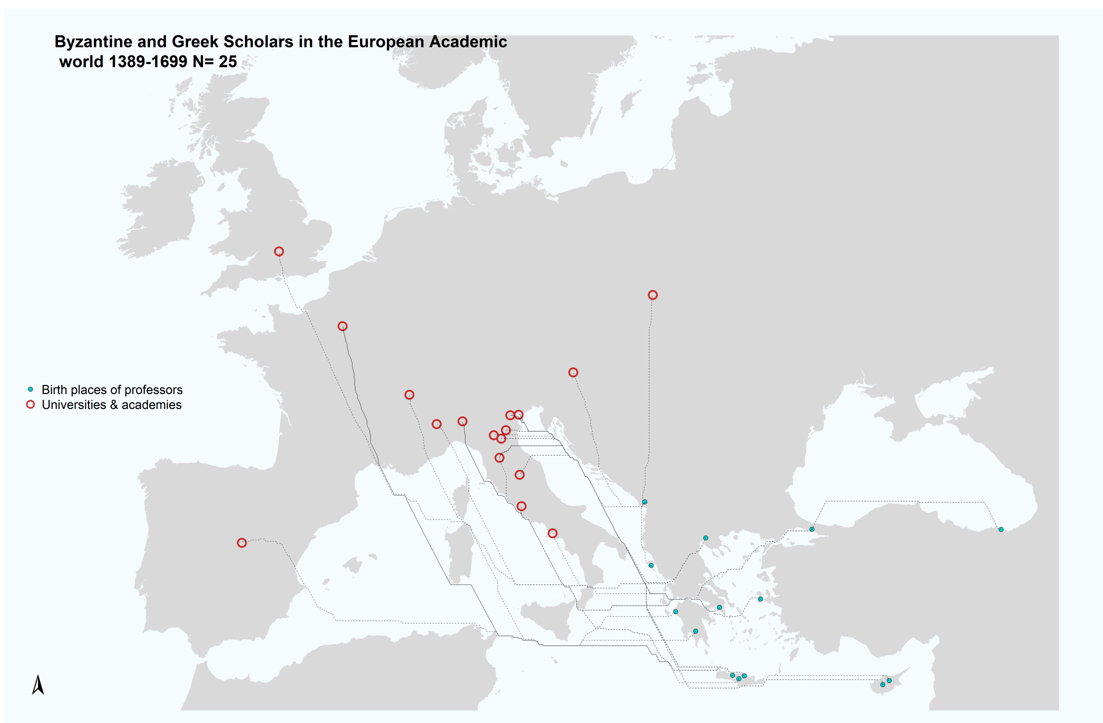


Figure 4: British Catholic Academic Refugees, 1389–1699

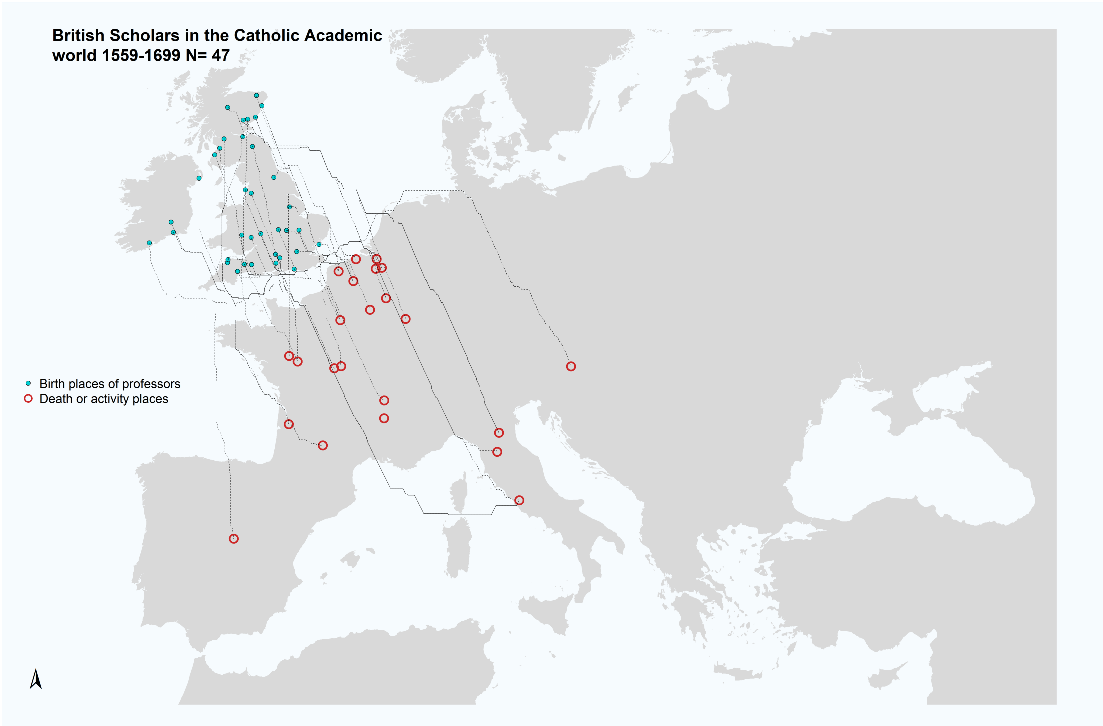


Figure 5: Huguenot Academic Refugees, 1572–1699

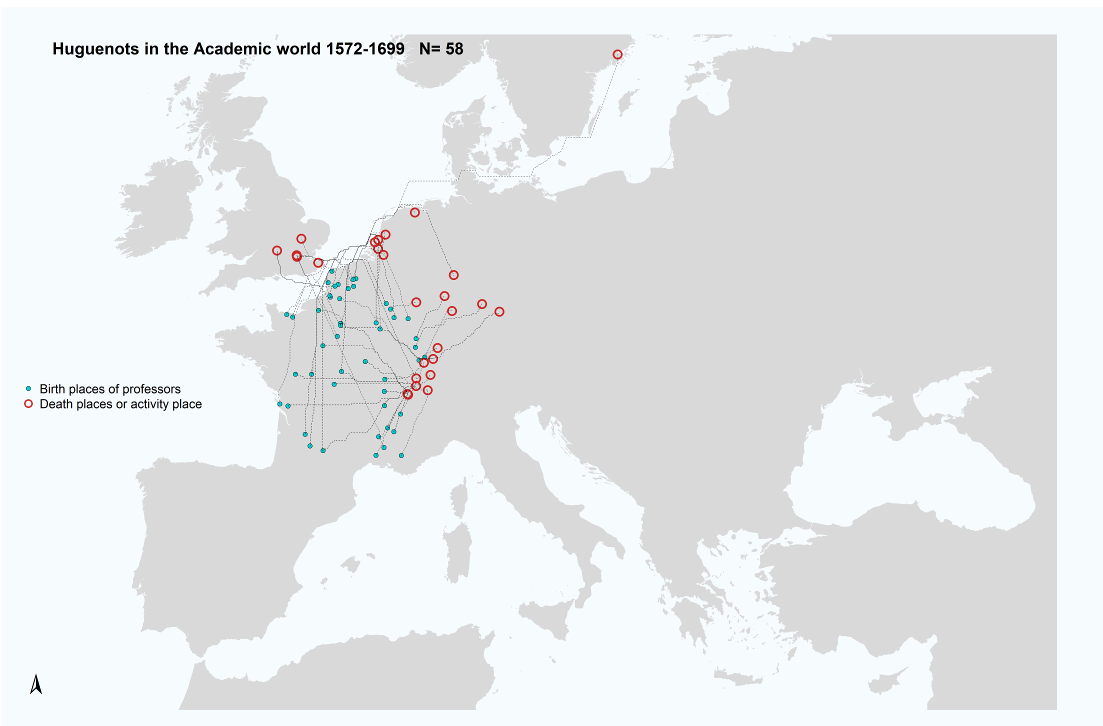


Table 4: Refugee scholars as an instrument for total scholarly output

	log GDP per capita, 1900				
Panel A: IV	(1) OLS	(2) IV	(3) IV	(4) IV	(5) IV
Local scholarship	0.135**	0.307***	0.237***	0.395***	0.348*
	(0.060)	(0.102)	(0.041)	(0.089)	(0.161)
Panel B: First-stage		Local scholarship			
		(2)	(3)	(4)	(5)
N Refugees		0.446**			
		(0.160)			
N Byzantines			0.943***		
			(0.265)		
N Huguenots				0.381**	
				(0.129)	
N British Catholics					0.409*
					(0.206)
N		172	172	172	172
Controls:					
Country FEs		Yes	Yes	Yes	Yes
Regional		Yes	Yes	Yes	Yes
1st stage F-stat.		28.45	61.27	13.84	13.09

Note: $^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$. Standard errors clustered by country in parentheses. The unit of observation is a NUTS2 region. GDP per capita from the Rosés-Wolf database on regional GDP (Rosés and Wolf 2021). Local scholarship is the weighted total of scholars born in the region. N refugees, N Byzantines, N Huguenots, and N British Catholics are the number of scholars of a group that was active or died in the region; see text for details. All regressions include regional controls: log ruggedness from Nunn and Puga (2012), the log post-1500 calorie suitability index from Galor and Özak (2016), and the log of the region's area.

5.2 Instrumental variable regressions

Table 4 displays the results. In Column 2, we show the results when the three refugee waves are pooled. In Columns 3–5, each wave is used as a separate instrument. For each IV regression, we use the number of refugee scholars who were active or died in the region as an instrument for the total weighted output of scholars born in that region. As shown by the first stage regression, the Huguenot and British Catholic instruments are relatively weak by themselves.

The coefficients of interest in the IV regressions are all greater than that in the OLS regression. This is consistent with OLS suffering from attenuation bias caused by measurement error in the local scholarship variable. Alternatively, there could be an omitted variable which increased scholarship and decreased growth (or vice versa). As the potential endogeneity concerns discussed above would bias upwards the OLS coefficient, we suspect that attenuation bias is the most likely explanation of the relative magnitude of the IV coefficient.

The IV results are robust to restricting the regressions to regions in countries (using 1900s borders) with at least one refugee and to including pre-migration wave. They are also, with the exception of the British Catholics, robust to including total urban population as a control (Appendix B.2 Tables B6 and B7).

5.3 Was migration selected on growth potential?

For the instrument to be valid, the exclusion restriction requires that the refugee scholars affect GDP per capita in 1900 only through the academic output of the region. One potential violation would be if the refugees choose their destination region for a reason correlated with economic growth, such as local culture or institutions.

Looking at the map (Figures 3, 4,5), we suspect that scholars likely chose their destination based on physical distance, which would not be particularly associated with economic growth.

We can also look at the effect of the refugees on subsequent scholarship in an event study. This allows us to rule out significant pre-trends, suggesting that scholars did not choose their destination based on academic output.[13] It also allows us to illustrate the dynamics of the effect of a migrant.

For region r in period t, let $D^h_{r,t}$ be an indicator that is one if the region is "treated" h periods in the future with exposure to a refugee scholar. We do not always know the exact date of arrival. To be confident that a scholar was not exposed to a refugee, we consider any

12. Modern Germany, the Netherlands, Great Britain, Sweden, Denmark, and Switzerland.

13. The lack of pre-trends could also be interpreted as a series of placebo tests with the treatment set to dates before the migrant actually arrived.

cohort of scholars who died in a period before the refugee was born as not treated. Then we estimate:

$$n_{r,t} = \sum_{h=-K}^{K} \beta^h D^h_{r,t} + \alpha_1 D^{>K}_{r,t} + \alpha_2 D^{<-K}_{r,t} + \phi_r + \rho_t + \varepsilon_{r,t} \tag{2}$$

$n_{r,t}$ is the sum of published scholars born in r during period $t+1$, weighted by the inverse hyperbolic sine of their number of publications, normalized by dividing by 1,000 times the inverse hyperbolic sine of 1; β^h are the event study coefficients; $D^{>K}_{r,t}$ and $D^{<K}_{r,t}$ capture treatment outside the window of interest; ϕ_r is a region fixed effect; ρ_t is a time fixed effect; and $\varepsilon_{r,t}$ is an error term (clustered by period). We set K equal to 5 and use the first lag is the reference period.[14]

We also estimate a stacked event study to avoid issues with negative weights in two-way fixed effects (Cengiz et al. 2019; Dube et al. 2023).[15] For each potential period of treatment c, we take a subset of the data where either the region is treated for the first time in period c or has not yet been treated. In other words, the sample includes observations where:

$$D_{it} = \begin{cases} \text{newly treated} & \Delta D^c_{r,t} = 1 \\ \text{clean control} & D^c_{r,t} = 0 \end{cases} \tag{3}$$

Then, we "stack" all the subsets into one dataset and estimate:

$$n_{r,t,c} = \sum_{h=-K}^{K} \beta^h D^h_{r,t,c} + \alpha_1 D^{>K}_{r,t,c} + \alpha_2 D^{<-K}_{r,t,c} + \phi_{s\times c} + \rho_{t\times c} + \varepsilon_{r,t,c} \tag{4}$$

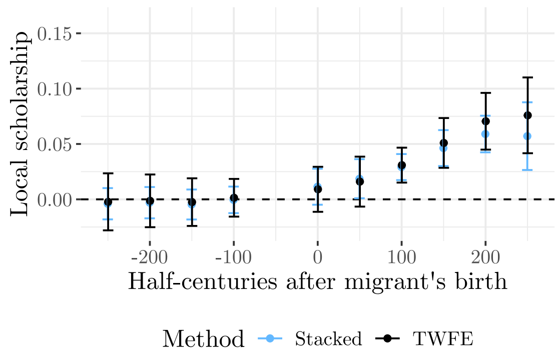
This is the equivalent of the previous regression except the fixed effects are now subset specific. The results of both regressions are shown in Figure 6. There appears to be no obvious pre-trends before the arrival of a refugee scholar. Afterwards the level of academic output appears to be increasing for at least 200 years.

We interpret the event study as evidence that the refugees cause locals to produce more scholarship. The lack of pre-trends is reassuring for our instrumental variable strategy, as it suggests the refugees are not selecting destinations based on their scholarly output. If migrants selected regions based on factors related to potential growth, it would be strange

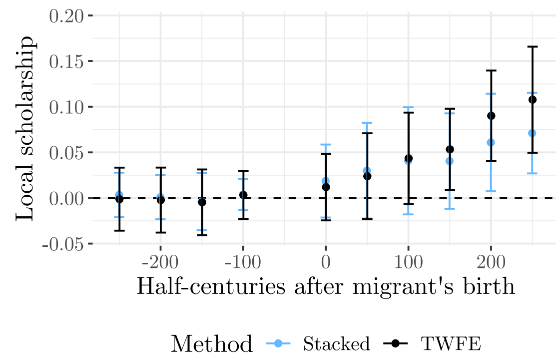
14. The last refugee was born in 1647 and the last scholar died in 1879. However, the last birth in the dataset was in 1783, so the panel is potentially unbalanced for young refugees and higher order leads. However, the median refugee was born in 1545 and, for each region, we consider only the first refugee born. Using shorter periods, a smaller K, or only refugees born before 1600 does not substantially change the results.

15. If the effects are heterogenous, then the stacked difference-in-difference estimate is a weighted combination of the average treatment effects on the treated. However, by using only "clean" controls it avoids any issues with negative weights.

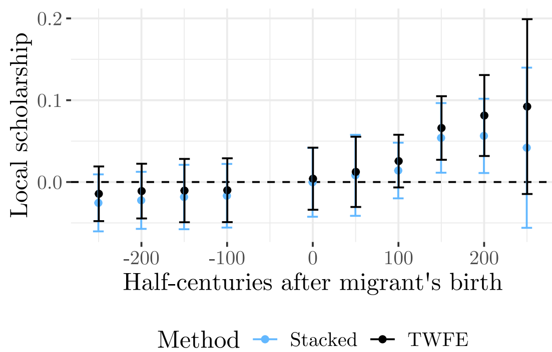
Figure 6: Refugee scholars and academic output, event study



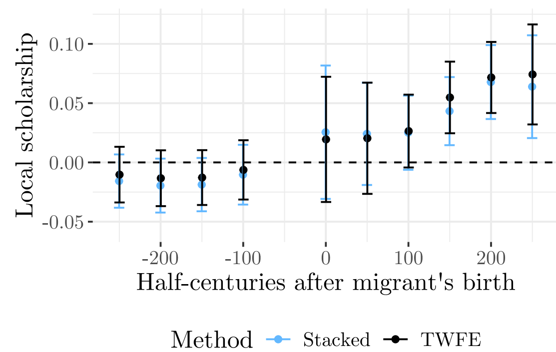
(a) All refugees



(b) Byzantines



(c) Huguenots



(d) British Catholics

Note: Coefficients are from event-study difference-in-difference regressions of the weighted total of scholars who were born in a region and died within a 50-year period on lags and leads of a treatment variable that is one if a refugee scholar either died or was active in the region and was born in or before the period. 95% confidence intervals constructed using period-clustered standard errors are displayed.

that other scholars did not.

A second potential exclusion restriction violation would be if refugees affected growth through another channel. For example, Huguenot scholars may have arrived in a location in a group with other Huguenots, who in turn had a beneficial impact on local development (Hornung 2014). This is a concern, however, only if we take a narrow interpretation of our measure of local scholarly output. If it is interpreted narrowly as only human capital in universities or academies, then the exclusion restriction requires no effect from any accompanying non-scholars. If scholarly output is a measure of upper-tail human capital, then we would argue the exclusion restriction still holds; non-migrant scholars were surely also embedded in high human capital communities.

Even with a narrow interpretation, we show in the Appendix that, given plausible values from the literature, that our IV estimates are unlikely to be severely biased by this channel

(Appendix B.2 Figure B1).

5.4 Heterogeneity by field

Unfortunately, there were very few refugee scholars in Theology 2, Law, Science, and Botany. We cannot, therefore, use them as an instrument for the share variables in Table 3.

However, the three groups of refugees differ substantially in terms of academic fields:

- Byzantines are mostly humanists scholars, active in Classics (46%), Philosophy (18%) and Culture (14%)
- Huguenots are mostly in Classics (30), Theology 1 (18%) and 2 (21%), and Culture (11%). They also have some strong persons in Science such as Denis Papin and Abraham de Moivre, and in Philosophy such as René Descartes.[16]
- British Catholics are mostly in Theology 1 (51%) and in Classics (23%).

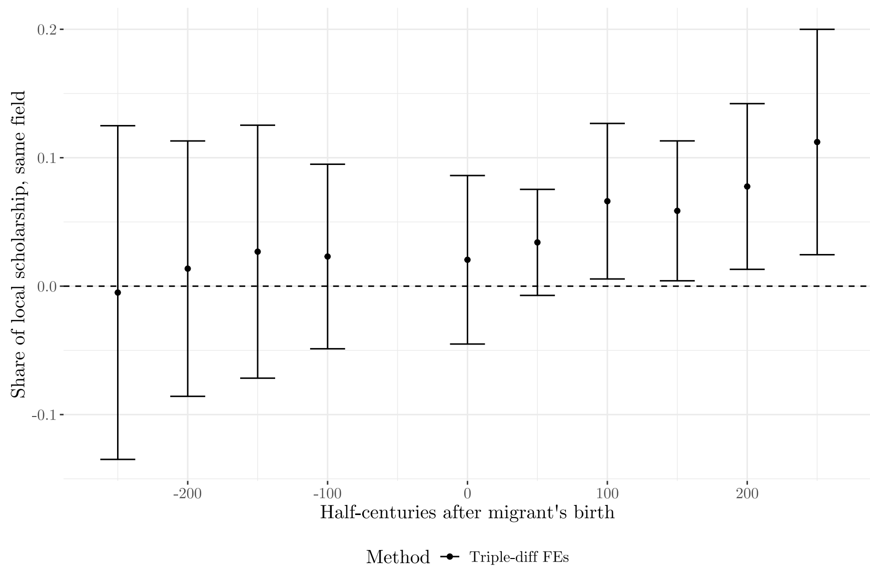
We can look at the effect of refugees on future scholarship in their specific field using a triple difference-in-difference event study. For field f in region r during period t, let $D^h_{f,r,t}$ be an indicator that is one if the region is "treated" h periods in the future with exposure to a refugee scholar in field f. As before, in order to be confident that a scholar was not exposed to a refugee, we consider any cohort of scholars who died in a period before the refugee was born as not treated. Then we estimate:

$$n_{f,r,t} = \sum_{h=-K}^{K} \beta^h D^h_{f,r,t} + \alpha_1 D^{>K}_{f,r,t} + \alpha_2 D^{<-K}_{f,r,t} + \phi_{f\times r} + \rho_{r\times t} + \gamma_{f\times t} + \varepsilon_{f,r,t} \tag{5}$$

$n_{f,r,t}$ is the sum of published scholars born in r during period $t+1$, weighted by the inverse hyperbolic sine of their number of publications, normalized by diving by 1,000 times the inverse hyperbolic sine of 1 ; β^h are the event study coefficients; $D^{>K}_{f,r,t}$ and $D^{<K}_{f,r,t}$ capture treatment outside the window of interest; $\phi_{f\times r}$ are region × field fixed effects; $\rho_{r\times t}$ are region *times* time fixed effects; $\gamma_{f\times t}$ are field *times* time fixed effects; and $\varepsilon_{s,r,t}$ is an error term (clustered by period). Again, we set K equal to 5 and use the first lag as the reference period.

16. Denis Papin (1647–1713) was a physicist, mathematician and inventor. Abraham de Moivre (1667–1754) was a mathematician known for de Moivre's formula, a formula that links complex numbers and trigonometry, and for his work on the normal distribution and probability theory. He moved to England at a young age when persecution of Huguenots reached a climax in 1685. René Descartes (1596–1650) was a French philosopher, scientist, and mathematician, widely considered a seminal figure in the emergence of modern philosophy and science. He was urged by a French Cardinal to write an exposition of his new philosophy in some location beyond the reach of the Inquisition. He officially remained Catholic despite he served Protestant states, and his daughter was baptized as Protestant (cluster Philosophy).

Figure 7: Refugee scholars and academic output in their field



Note: Coefficients are from an event-study triple difference-in-difference regression of the weighted total of scholars who were born in a region, died within a 50-year period, and worked in a specific field on a lags and leads of a treatment variable that is one if a refugee scholar either died or was active in the region, was born in or before the period, and worked in that field. 95% confidence intervals constructed using period-clustered standard errors are displayed.

This regression asks if, after a refugee arrives, there is a disproportionate increase in scholarship in their particular field in their destination. As shown in Figure 7, this is indeed the case. We interpret this as evidence that the particular field of a scholar influenced the fields studied by following generations of scholars.

6 Mechanisms

We believe the most plausible mechanism behind our results is that scholars inspire fellow natives to invest in human capital. This was not our prior expectation, but rather a conclusion that emerged from the evidence we present. Consider that persons make an occupation choice, for example pursuing a career in the army, or in the Church, or in academia. Being exposed to the academic success of fellow natives increases the prestige of the career in academia, and leads people to accumulate more human capital. In this Section, we first present a microfoundation for this mechanism, embedded into a standard growth model, in order to have a frame of reference. We next show empirical support through three compelling observations. Firstly, regional development is better understood when scholars are aggregated by birthplace rather than their activity location. Secondly, scholars who stay closer to their roots demonstrate a stronger correlation with development compared to those who relocate or face an untimely demise. Thirdly, regions boasting a higher number of scholars born within them exhibited elevated levels of general population numeracy in the late 19th century, even after controlling for other productivity determinants.

There are of course other possible mechanisms by which scholars could influence other scholars. For example, regions could have agglomeration effects related to the density of scholars, or scholars may have spillover effects on each other's productivity. To keep our model parsimonious, here we focus on the inspiration channel.

6.1 Microfoundations

Embedding inspiration into a growth model can follow two paths. One is to make preferences time dependent, introducing habits or aspirations into utility (Ryder and Heal 1973; De la Croix and Michel 1999). The other is to make the depreciation rate of human capital endogenous along the lines proposed by Greenwood, Hercowitz, and Huffman (1988) and Aznar-Márquez and Ruiz-Tamarit (2001) for capital, depending on the level of inspiration. High levels of inspiration in a region would slow down the depreciation of human capital. The intuition is that future generations will be more likely to maintain the knowledge of past generations if they are inspired by it. We will follow this approach and show that, in such a model, two regions with identical total factor productivity and stock of capital can differ in output: the one with the highest stock of inspiration will produce more.

We consider one region. Production combines physical and human capital, K and H, through a Cobb-Douglas function:

$$Y = AK^{\alpha}H^{1-\alpha}$$

$A > 0$ denotes total factor productivity, and $\alpha \in (0, 1)$ is the elasticity of output to physical capital. The function displays constant returns to scale (homogeneity of degree one) with respect to K and H. Output Y can be used for consumption C, or investment in physical or human capital, I_K or I_H. The economy's resource constraint is

$$Y = C + I_K + I_H$$

and accumulation laws are

$$\dot{K} = I_K - \delta_K K, \quad \text{and} \quad \dot{H} = I_H - \bar{\delta}_H H \text{ with } K(0), H(0) \text{ given.}$$

The depreciation rate of physical capital $\delta_K \in [0, 1)$ is a parameter, while the depreciation rate of human capital $\bar{\delta}_H$ is a function which depends on the stock of inspiration per unit of human capital S/H, with elasticity $-\eta$:

$$\bar{\delta}_H = \delta_H \left(\frac{S}{H}\right)^{-\eta}.$$

$\delta_H \in [0, 1)$ is a parameter. Behind the function $\bar{\delta}_H$ there is the idea that if the "stock of inspirations" is important, people benefit more from what has been studied in the past, and the actual human capital depreciates less. The stock of inspirations reflects the past history of human capital. It evolves according to

$$\dot{S} = I_H - \delta_S S, \quad \text{with } S(0) \text{ given.} \tag{6}$$

with parameter $\delta_S \in [1, \delta_H)$. Inspiration is built from the same investment in human capital than actual human capital, but it depreciates at a slower rate. It thus particularly reflects all the human capital history of the region. Investing a large amount in human capital today has effects on the future through affecting the depreciation rate, which reflects the idea that, in a region with some inspirational figures, knowledge is forgotten less fast (e.g. the kids put more effort at school, the grandparents tell more stories related to human capital).

The endogenous depreciation rate of human capital introduces an externality. Although the region anticipates perfectly the path of $\bar{\delta}_H$, it fails to recognize the effect of its own action on its dynamics. The region maximizes the discounted flow of utility. Utility is defined over consumption. The maximization program of the region is detailed in Appendix C. Solving the program and working on the first-order-conditions leads to rewrite output at time t as:

$$Y = AK^{\alpha}\left(K\, g\left(\frac{S}{H}\right)\right)^{1-\alpha} \quad = AK\left(g\left(\frac{S}{H}\right)\right)^{1-\alpha}$$

Output thus obeys an AK production function with an additional factor depending on the stock of inspirations per unit of human capital. Two regions with identical TFP and stock capital can thus differ in output: the one with the highest stock of inspirations will produce more.

In the long-run, however, this relation does not hold anymore. A balanced growth path is characterized by $\dot{C} = \dot{Y} = \dot{K} = \dot{H} = \dot{S}$. $\dot{H} = \dot{S}$ implies that $\bar{\delta}_H H = \delta_S S$, which leads to a constant long run stock of inspirations per unit of human capital and a constant human to physical capital ratio. This approach can be generalized to accommodate more than one type of human capital (the academic fields).

This analysis suggests that cross-regional differences in output can be attributed to variations in inspiration, but only in the short and medium run. In the long run, however, such differences do not persist. By contrast, if regional output differences stem from persistent characteristics such as total factor productivity (TFP, A), then they will remain in the long run. Similarly, a shock to the initial stock of inspirations $S(0)$—for instance, through the arrival of refugees—should generate a positive effect on both human and physical capital. This effect rises, peaks, and then declines, ultimately vanishing in the long run. In the event studies shown in Figure 6, we observe that the effect levels off after some time, though the available horizon is too short to detect its eventual disappearance. Conversely, a shock to productivity A would permanently affect all components of growth, with no plateau.

6.2 Evidence

Let us first consider different ways of aggregating human capital. This will be informative on the mechanism at play. Table 3 above and Columns (1)-(2) of Table 5 reports the coefficients of human capital when it is aggregated by scholars' birth location.One might wonder about the effects of academic knowledge at the location of the university or academy where it was produced. This reduces the amount of geographic variation as institutions tend to be more centralized than scholar birthplaces (106 regions hosted a university or an academy, while 172 witnessed the birth of some scholars). Moreover, assigning scholars to locations based on activity is challenging, as many academies had corresponding members. To address this, we do two adjustments. First, we drop all corresponding members. Second, for scholars who were faculty at a university, we ignore their membership of any academies. Columns (3)-(4) of Table 5 shows the results. Compared to Table 3 in the main text, the coefficients on the weighted number of scholars is less than half the magnitude.

When we aggregate human capital by place of death, we obtain the coefficients in Column (5)-(6) of Table 5. Here, the coefficients are also significant, higher than in (3)-(4) but lower than in the benchmark case in Columns (1)-(2). Overall, the strongest results are obtained when scholars are allocated to their region of birth. We interpret this as evidence consistent with role-model effects, although inspiring others can also occur at work, and at death place. (In Appendix B.1 Table B5 we extend this to the regression with shares by field, with the same conclusions.)

Table 6 tests a key part of this inspiration mechanism: that growth is related to the connection between a scholar and his region of birth. The output of groups of scholars weakly attached to their home region had little to no association with growth. Because we control for the output of the more strongly attached scholars, we are indirectly controlling for

Table 5: Comparing different ways to aggregate human capital

	log GDP per capita, 1900					
	(1)	(2)	(3)	(4)	(5)	(6)
Local scholarship by						
birthplace	0.187**	0.135**				
	(0.086)	(0.060)				
activity place			0.040**	0.035**		
			(0.017)	(0.012)		
death place					0.111***	0.096***
					(0.028)	(0.019)
N	172	172	172	172	172	172
Adj. R Squared	0.33	0.63	0.30	0.63	0.32	0.64
Controls:						
Country FEs	No	Yes	No	Yes	No	Yes
Regional	Yes	Yes	Yes	Yes	Yes	Yes

Note: $^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$. Standard errors clustered by country in parentheses. The unit of observation is a NUTS2 region. GDP per capita from the Rosés-Wolf database on regional GDP (Rosés and Wolf 2021). Local scholarship is the weighted total of scholars who were born, were active, or died in the region 1700–1800. All regressions include regional controls: log ruggedness from Nunn and Puga (2012), the log post-1500 calorie suitability index from Galor and Özak (2016), and the log of the region's area.

any omitted variables that increased the demand for or supply of scholars. We thus argue the lack of effect suggests that it is scholars influencing development in their home region, not vice versa. Moreover, the measures of weak attachment that we use are particularly relevant for our inspiration mechanism. It is hard to picture a Catholic region building monuments to a Protestant emigrant, or a scholar who died young encouraging the next generation.

The first group are those who died after the Peace of Augsburg (1555) in a country with a different state religion than their home country (omitting Germany due to its religious heterogeneity). This group is a proxy for scholars who are forced to migrate due to a religious or political conflict in their home regions. The most prolific of these potential refugees was René Descartes, who was born in France and died in Sweden. He did not convert to Protestantism, but was placed on the *Index Librorum Prohibitorum* in 1663. Other notable examples are Helen Maria Williams, an English Girondin revolutionary, Alban Butler, an English Catholic priest, and Jacques Abbadie, a French Anglican minister. The second group has a more inclusive definition of migrant, consisting of any scholars who died in a different location from their birth. The third group are scholars who died before age 40. These scholars had less time to build a local reputation even if they had produced scholarly works.

The regressions are of the form:

$$y_{r,s} = \alpha_0 + \alpha_1 n_{r,s,i} + \alpha_2 n_{r,s,j} + \beta X_{r,s} + \phi_s + \varepsilon_{r,s} \tag{7}$$

Notation is the same as in Equation 1. $n_{r,s,i}$ is the sum of published scholars in the group i of interest, born in r from 1000 to 1800, weighted by the inverse hyperbolic sine of their number of publications, normalized by dividing by 1,000 times the inverse hyperbolic sine of 1; $n_{r,s,j}$ is the same but for scholars not in the group of interest. We also run the same regressions for regions of death.

As shown by the interaction term coefficients in Table 6, the output of those scholars weakly attached to their birthplace appear to have little to no association with growth after controlling for the output of the rest. Moreover, the coefficients for the output of scholars who were not weakly attached are very similar to the coefficient of the baseline regression. This suggests that the associations in Table 3 are driven by scholars with a close association with their birthplaces.

A contrasting result is found in the last two lines of Figure 6, which splits scholars born before and after 1600. This crude periodization attempts to split the sample roughly before and after the Scientific Revolution. A scholar born in 1600 could read Bacon's *Novum Organum* at age 20 and Galilei's *Dialogue Concerning the Two Chief World System* at age

Table 6: Analysis by strength of attachment to birth region

	log GDP per capita, 1900				
	(1)	(2)	(3)	(4)	(5)
Local scholarship	0.135**				
	(0.063)				
×potential refugee		1.601			
		(1.709)			
×not refugee		0.298***			
		(0.044)			
×died in other place			0.085		
			(0.097)		
×died in same place			0.236***		
			(0.068)		
×died before age 40				-1.959*	
				(0.998)	
×died after age 40				0.214**	
				(0.071)	
×born before 1600					0.175
					(0.150)
×born after 1600					0.127
					(0.127)
N	172	172	172	172	172
Controls:					
Country FEs	Yes	Yes	Yes	Yes	Yes
Regional	Yes	Yes	Yes	Yes	Yes
Share in first category		0.030	0.770	0.040	0.300

Note: 95% confidence intervals displayed. Standard errors clustered by country in parentheses. The unit of observation is a NUTS2 region. GDP per capita from the Rosés-Wolf database on regional GDP (Rosés and Wolf 2021). Local scholarship is the weighted total of scholars belonging to a subset of scholars. All regressions include regional controls: log ruggedness from Nunn and Puga (2012), log post-1500 calorie suitability index from Galor and Özak (2016), and the log of the region's area.

38. While neither coefficient are independently significant, the difference between the two is marginal.In other words, the output of pre-Scientific Revolution scholars seem as important as that of post-Scientific Revolution scholars.

These results suggest that there was a mechanism tying scholars to growth in their place of birth. One possibility is that successful scholars encouraged others from the same region to accumulate human capital. Early Modern Europe's "Republic of Letters" was a small elite network, but provided notable scholars with both prestige and financial patronage and was relatively open to new talent (Mokyr 2016). Examples of scholars born nearby may have been illustrative of the potential returns to human capital.

Going back to the event study of Figures 6, the picture they depict exactly matches the inspiration story: refugees arrive, settle and start a new life (as if they are reborn in a new place). They inspire future generations to accumulate human capital. And this ultimately leads to more development.

Further evidence of the inspiration chanel is our finding that areas with higher scholarship had higher *lower-tail* human capital in 1900. However, the sample size is much smaller, so the associations are only significant at the 0.1 level.[17] An increase equivalent to 1,000 scholars with one publication between 1000 and 1800 in region i is associated with on average an increase in the ABCC index of 3.30. This corresponds to a 2.64 percentage point decrease in people who round their reported age to 0 or 5.

Table 7: Human capital and general population numeracy

	Numeracy index c. 1900	
	(1)	(2)
Local scholarship	3.297*	3.085*
	(1.881)	(1.659)
N	62	102
Controls:		
Country FEs	Yes	Yes
Regional	Yes	Yes

Note: 95% confidence intervals displayed. Robust standard errors in parentheses. The unit of observation is a NUTS2 region. Numeracy is the ABCC index from Baten and Hippe (2018): $125(1-s)$, where s is the share of reported ages ending in 0 or 5. All regressions include regional controls: fixed effects for country, log ruggedness from Nunn and Puga (2012), log post-1500 calorie suitability index from Galor and Özak (2016), the log of the region's area, and the log of the population in 1900.

17. These results are also not robust to using clustered standard errors or standard errors that account for spatial autocorrelation. We suspect this is due to the substantially smaller sample size.

In addition to the suggestive evidence provided above, the inspiration channel is backed by numerous anecdotes. We report a few salient ones here.

This inspiration could be through social networks around the place of birth. Leonhard Euler was born in 1707 in Basel as the son of Paul Euler, a Reformed pastor. Paul had befriended Jacob and Johann Bernoulli (1655 and 1667, Basel). Johann later convinced him to let his son Euler study mathematics instead of theology. Both Bernoullis, notable mathematicians in their own right (they are the 82nd and 83rd most prolific members of the field Science), thus directly contributed to young Euler becoming the most second most productive member of our field Science (behind only Isaac Newton).

This inspiration could also be an indirect effect on future generations of academics. On February 5th, 1835, the Lincoln Mechanics' Institute received a bust of Isaac Newton (born in 1642 in Lincolnshire) from a wealthy benefactor. To celebrate, the 19-year-old son of the society's curator (and local shoemaker) gave a lecture on the "Life and Discoveries of Newton." (Burris 2022). The young man, George Boole, born in 1815 in Lincolnshire, would become the founder of modern algebraic logic. The story shows how there was interest from the local community in science, inspired by Newton, which in turn led to the birth of additional talents in the field.

Inspiration could be embedded in local culture. Pierre de Fermat (1605–1665), one of the greatest French Mathematicians, member of the Academy of Castres, was born in a small village, Beamont-de-Lomagne. His working life was spent in Toulouse at the Parliament (a court). Today, Beamont-de-Lomagne has a statue of him, a street named after him, a tourism office located in the house where he was born, and a yearly *fête des maths* in his honor. Every year kids learn to like mathematics at this festival.

Råshult is the name of trolley sold by IKEA, but it is also a village in Småland, Sweden, notable as the birthplace of the "father of modern taxonomy," Carl Linnaeus (1707–1778). Råshult has a monument to him, a reconstruction of the cottage where he was born, and garden based on his famous *Adonis Stenbrohultensis*, in which he first used taxonomy to classify every plant in his father's garden.

Even the medieval scholar Pierre Abelard (1079–1142), is honored in his hometown, the tiny Breton village of Le Pallet, with both a street name and a statue. His intellectual influence, philosophical writings, and his tragic romance with Héloïse have left a lasting impact over several centuries.

7 Conclusion

We find a strong relationship between economic growth and premodern European scholarship. Our findings support the view that upper tail human capital was important for growth (Squicciarini and Voigtländer 2015). Moreover, we find that certain fields of scholarship had a stronger influence on growth than others.

Perhaps it is not surprising that we find that Science and Botany were particularly important. Fundamental scientific research paved the way for future applied technologies. For example, engineering has been critical to the development of infrastructure and technology throughout history (Maloney and Valencia Caicedo 2022). Engineering was not part of curricula in the period we consider (1000–1800), but is strongly grounded in mathematics and physics, two important components of our field Science. Medical research and advancements have been crucial to improving public health, curing diseases, and extending lifespan, in particular in the nineteenth century. Modern medicine is based on natural sciences such as botany, which appears as a strong correlate of growth as well.

The negative role of Law is also interesting. It could be that studying law crowds out other form of scholarship that were more beneficial for growth. However, the negative association is only boderline significant when comparing within, not across, countries (Figure 3 Column 4). It could be that the share of law among academic scholars reflects the local legal system. Indeed, in common law countries, legal education and training are often not solely confined to universities, and there is more emphasis on practical training through apprenticeships, clerkships, and other forms of legal practice. Civil law countries have more lawyers in academia, and there is a large literature showing that these countries tend to perform less well than common law countries (Porta, Lopez-de-Silanes, and Shleifer 2008).

One theory for the rise of the West argues that universities and academics played a central role. However, there have been no quantitative studies of historical academia and growth for Europe as a whole. This paper develops a methodology to measure academic productivity using a large novel database of scholars 1000–1800. We find that the output of academics predicts 19th century economic growth, providing Europe-wide evidence that the sciences paved the way for the Industrial Revolution. Moreover, approaches to theology and legal systems also mattered for economic development. Despite the fact that ideas and written knowledge were highly mobile, the birthplaces of scholars in particular appear to have higher growth, suggesting scholars played a role-model for the next generations.

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Appendix A Data

Appendix A.1 Important topics by clusters

In this section, we provide some additional detail into our k-means clusters that explains how we assigned them their names. Table A1 displays the top terms by cluster. As described in the main text, for each scholar, every term is assigned an importance weight 0–5. The topics are ranked by the mean weight for scholars in the cluster, with the top 5 per cluster displayed. Note that these average weights can also be interpreted in terms of the k-means centroids. Each cluster has a centroid in the Cartesian coordinate system with one axis per topic. For topic t, the mean weight for cluster c is the coordinate of the centroid for c on the t-axis. One notable feature of these clusters is that the cluster we label "Classics" has no particular strong associations. It seems to be a cluster of scholars interested in a broad range of topics, perhaps related to the Humanistic Revolution.

Table A1: Top 5 terms associated with clusters 1-5

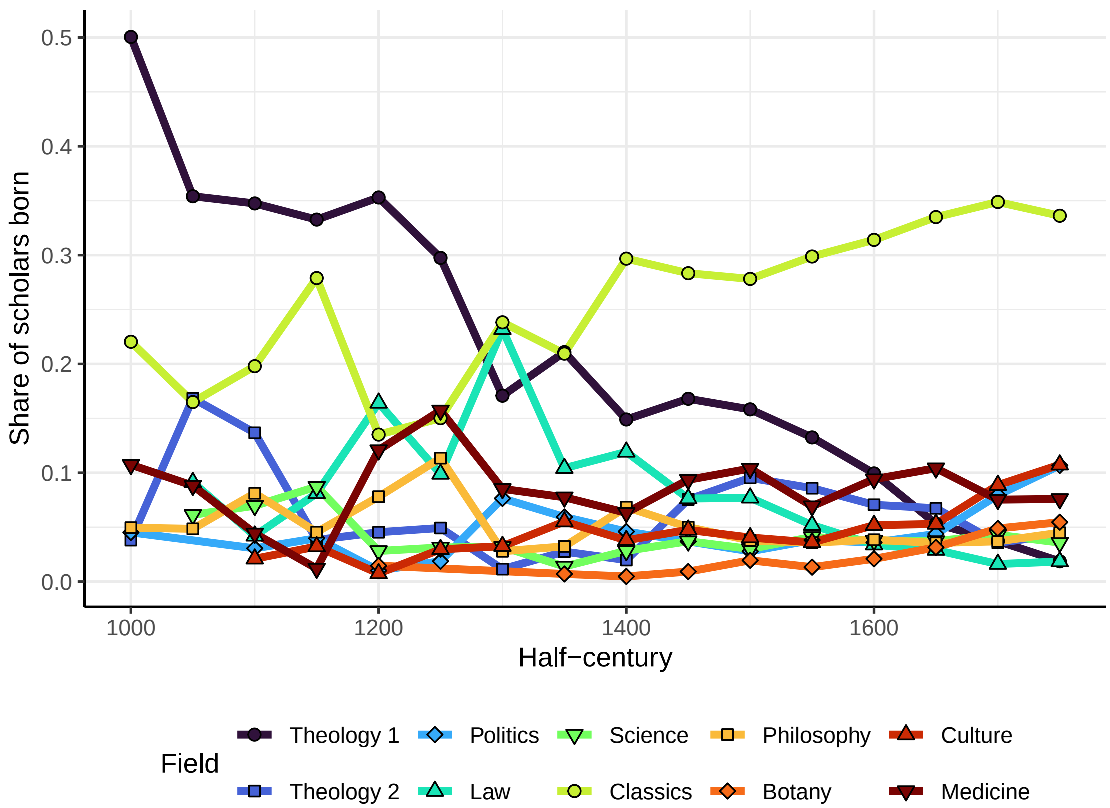
Cluster	Topic	Mean weight
Theology1	Catholic Church	4.69
Theology1	Theology, Doctrinal	1.91
Theology1	Theology	1.02
Theology1	Clergy	0.65
Theology1	Reformation	0.55
Theology2	Bible	3.36
Theology2	Theology	2.03
Theology2	Theology, Doctrinal	1.71
Theology2	Jesus Christ	1.01
Theology2	Bible.–Old Testament	0.95
Politics	Politics and government	4.51
Politics	Political science	0.76
Politics	Diplomatic relations	0.71
Politics	Economics	0.58
Politics	Catholic Church	0.58
Law	Roman law	4.55
Law	Law	2.05
Law	Canon law	1.54
Law	Civil law	1.14
Law	Digesta	0.81
Science	Mathematics	3.41
Science	Astronomy	2.68
Science	Geometry	2.06
Science	Science	1.79
Science	Physics	1.53

Table A2: Top 5 terms associated with clusters 6-10

Cluster	Topic	Mean weight
Classics	Rome (Empire)	0.24
Classics	Intellectual life	0.18
Classics	Law	0.18
Classics	Jesus Christ	0.14
Classics	Antiquities	0.13
Philosophy	Philosophy	4.27
Philosophy	Ethics	1.24
Philosophy	Logic	1.05
Philosophy	Science	0.90
Philosophy	Metaphysics	0.89
Botany	Botany	4.67
Botany	Plants	2.48
Botany	Natural history	1.87
Botany	Medicine	1.18
Botany	Botany, Medical	1.03
Culture	Travel	4.60
Culture	Antiquities	0.88
Culture	Manners and customs	0.74
Culture	Natural history	0.69
Culture	Voyages and travels	0.64
Medicine	Medicine	4.79
Medicine	Physicians	0.85
Medicine	Human anatomy	0.74
Medicine	Materia medica	0.67
Medicine	Surgery	0.62

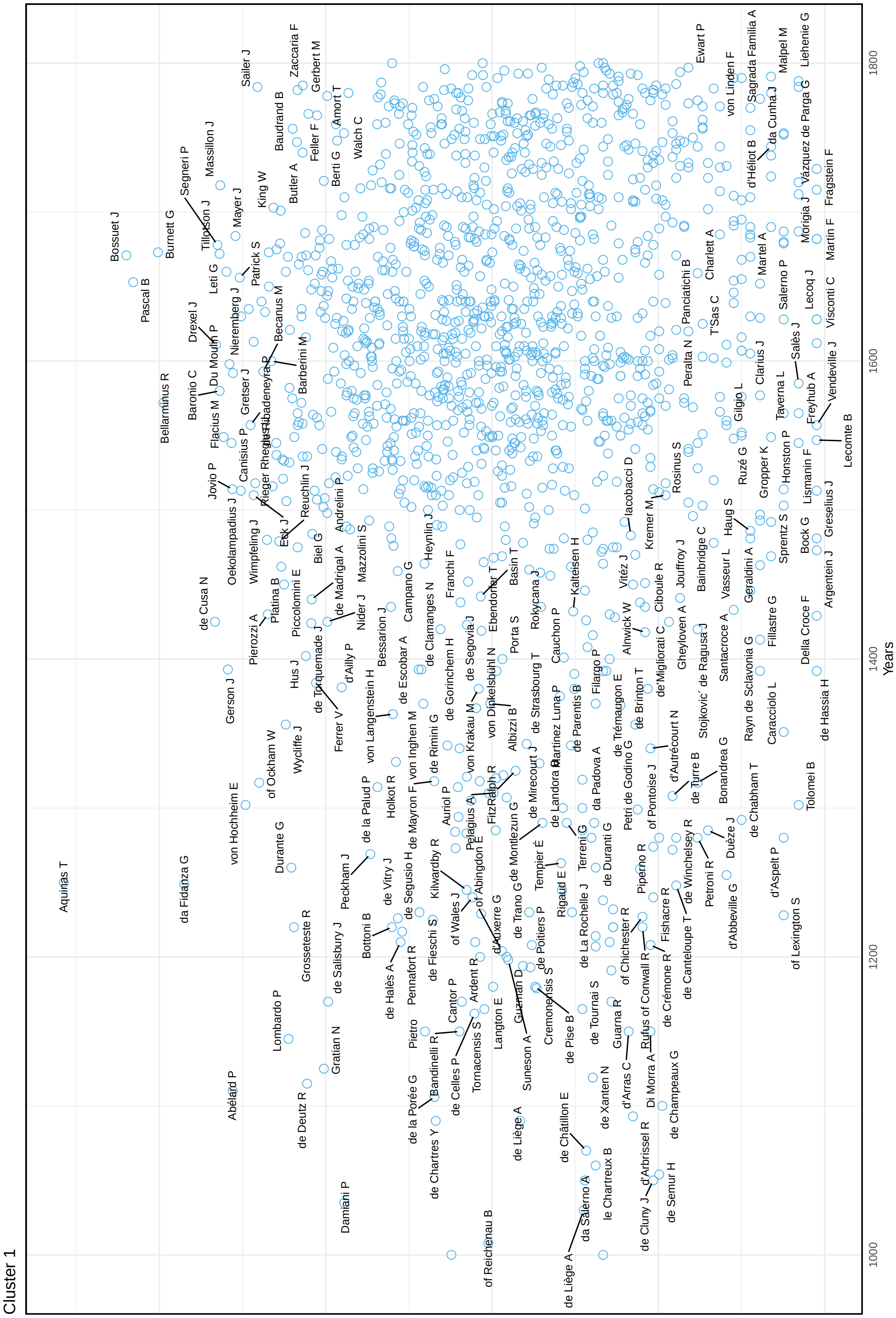
Appendix A.2 Academic fields over time

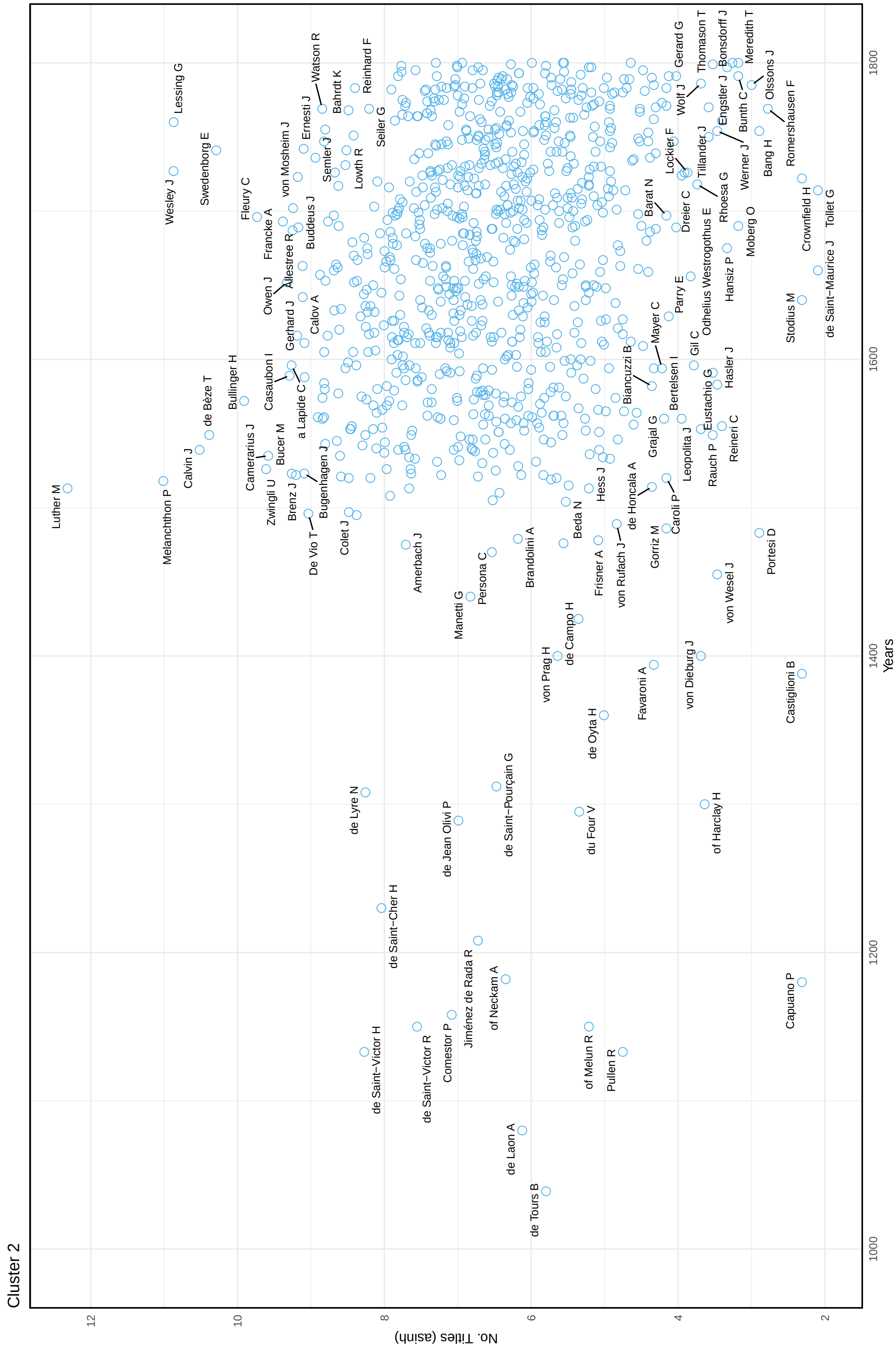
Figure A1: Shares of academic fields over time



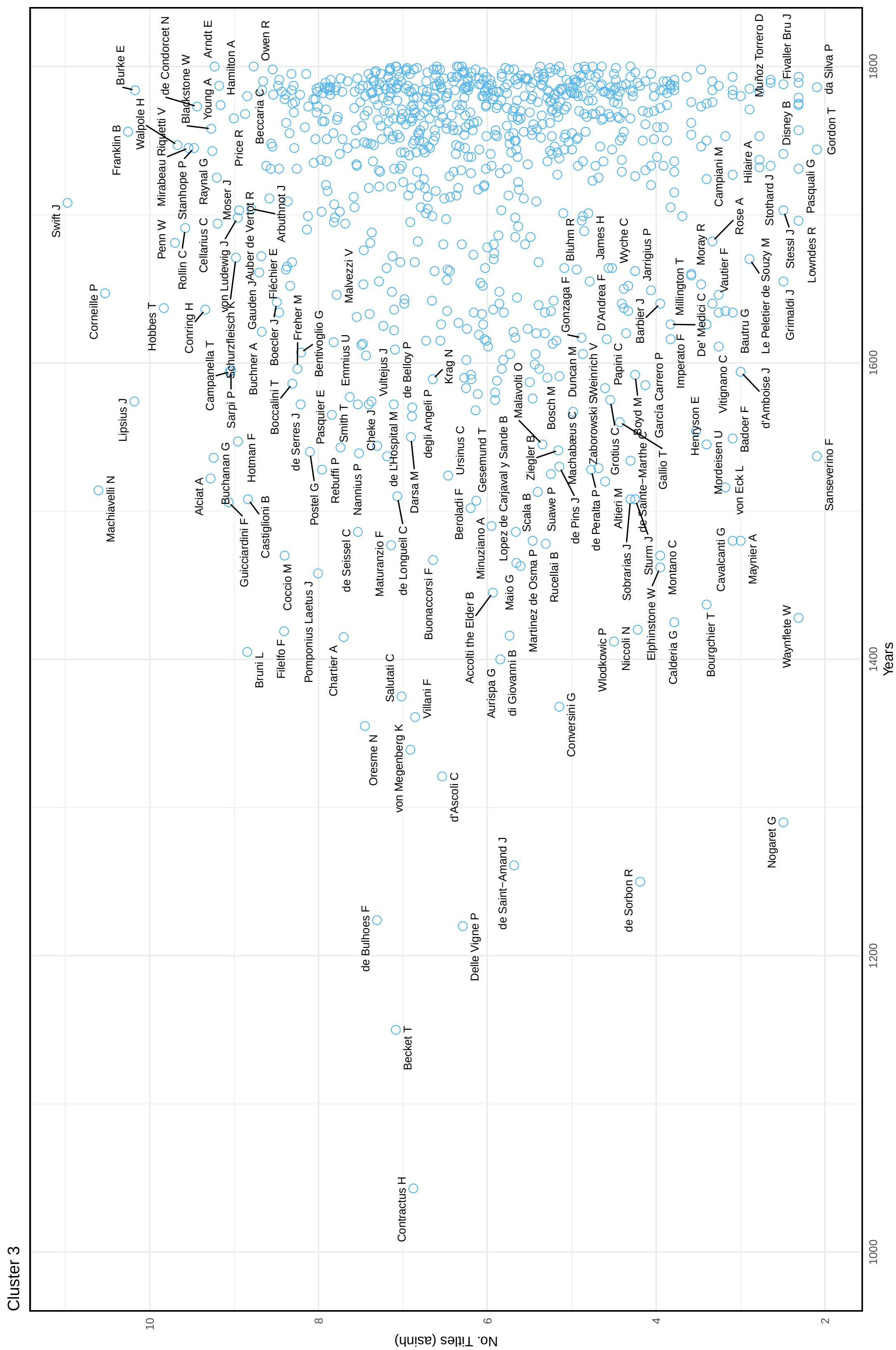
Note: Fields estimated by k-means clustering.

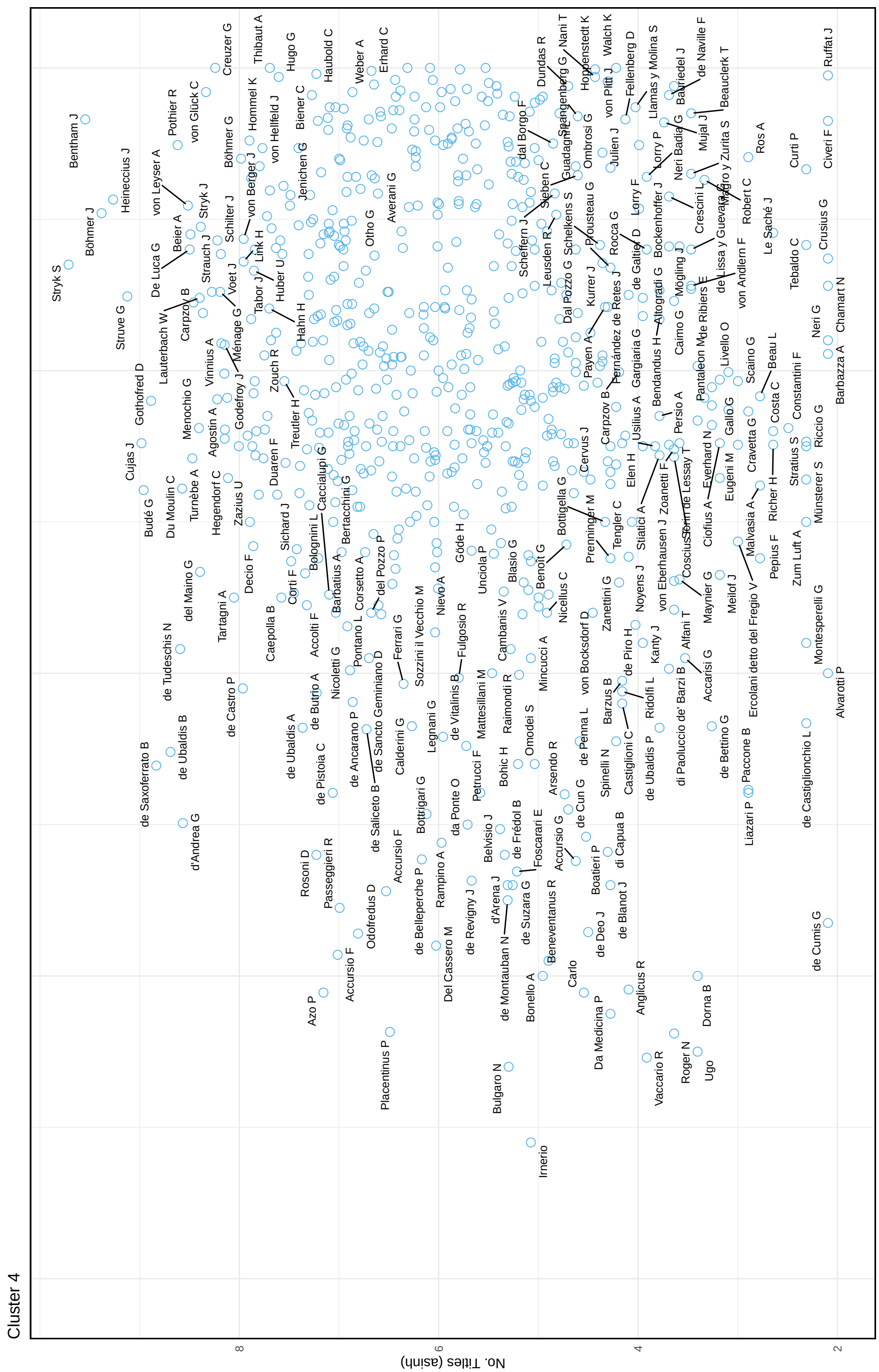
Appendix A.3 Publishing Scholars over Time by Cluster

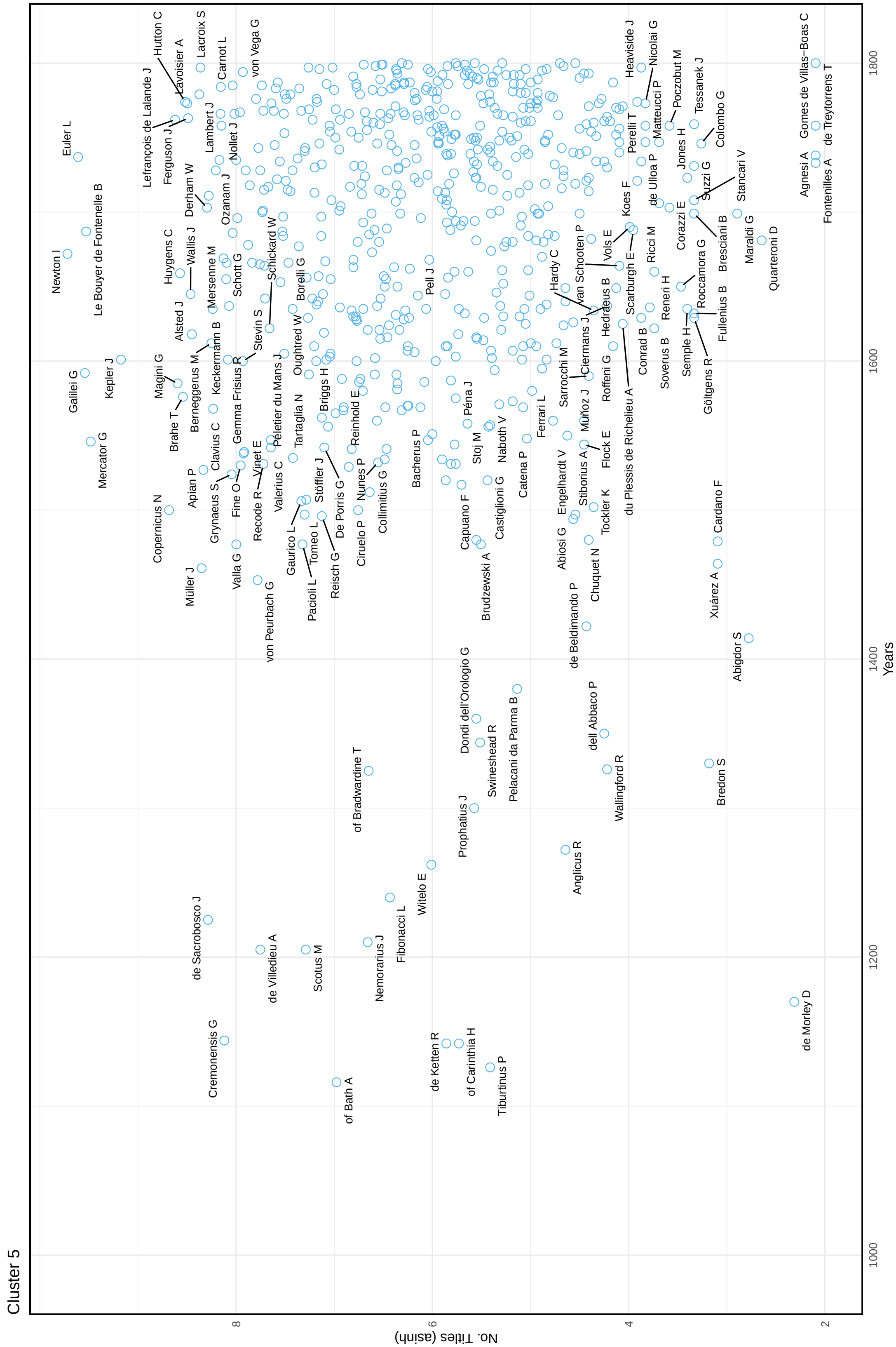




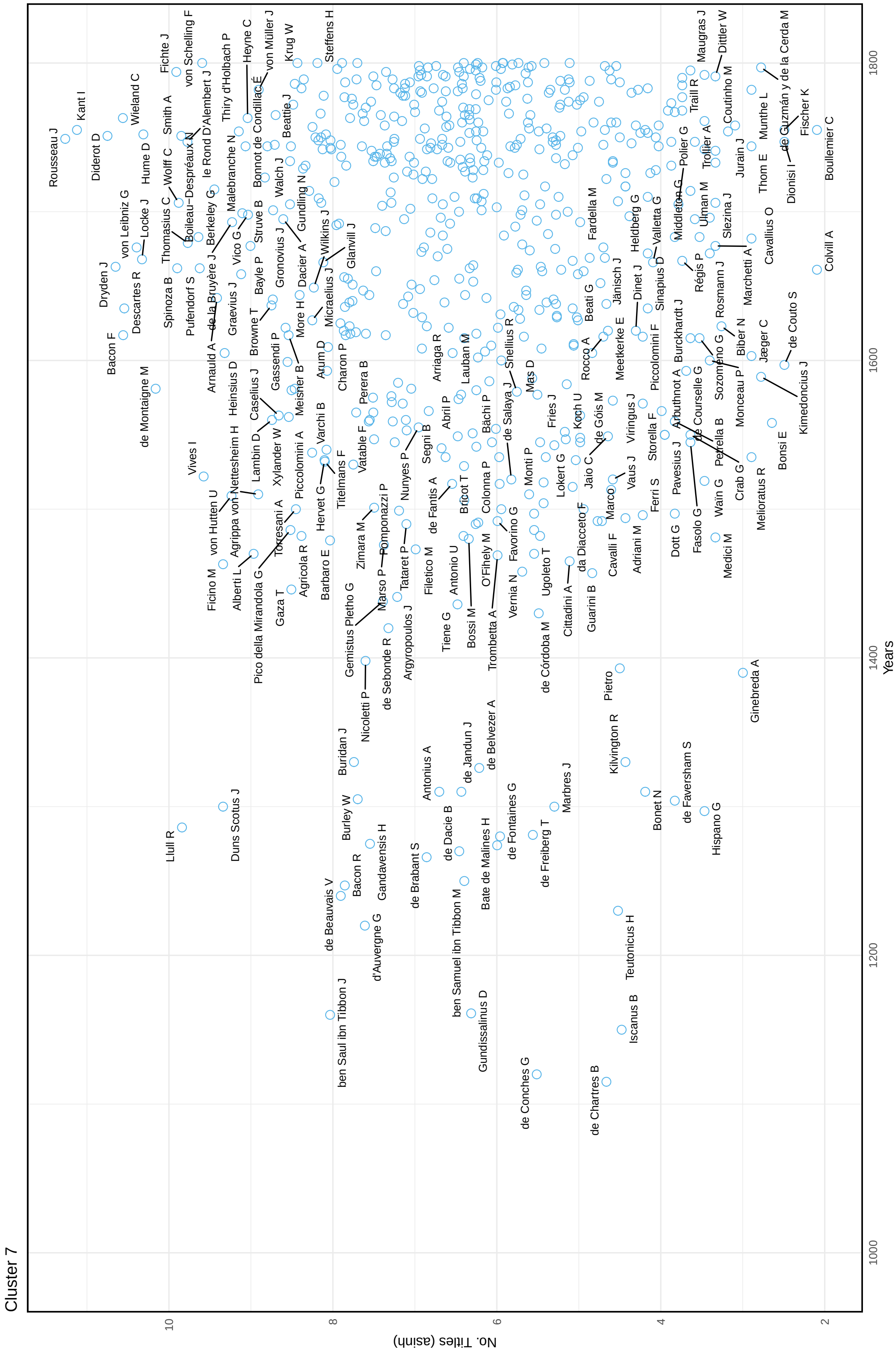
Cluster 2
No. Titles (asinh)
Years
2
4
6
8
10
12
1000
1200
1400
1600
1800
Luther M
Melanchthon P
Wesley J
Lessing G
Swedenborg E
Calvin J
de Bèze T
Bullinger H
Camerarius J
Fleury C
Zwingli U
Bucer M
Casaubon I
Owen J
Francke A
Brenz J
Gerhard J
Allestree R
von Mosheim J
De Vio T
a Lapide C
Bugenhagen J
Calov A
Buddeus J
Ernesti J
Semler J
Watson R
Colet J
Bahrdt K
Lowth R
Reinhard F
Seiler G
Amerbach J
Persona C
Manetti G
Brandolini A
Beda N
Frisner A
Hess J
von Rufach J
de Honcala A
Gorriz M
Caroli P
Grajal G
Biancuzzi B
Mayer C
Barat N
Leopolita J
Bertelsen I
Gil C
Parry E
Lockier F
Dreier C
Wolf J
Gerard G
Rauch P
Eustachio G
Odhelius Westrogothus E
Tillander J
Thomason T
Reineri C
Hasler J
Hansiz P
Rhoesa G
Engstler J
Bonsdorff J
Werner J
Bunth C
Meredith T
Moberg O
Bang H
Olssons J
Romershausen F
Portesi D
Stodius M
Crownfield H
de Saint−Maurice J
Tollet G
von Wesel J
von Prag H
de Campo H
von Dieburg J
Favaroni A
Castiglioni B
de Oyta H
de Lyre N
de Jean Olivi P
de Saint−Pourçain G
du Four V
of Harclay H
de Saint−Cher H
Jiménez de Rada R
of Neckam A
de Saint−Victor H
de Saint−Victor R
Comestor P
of Melun R
Pullen R
Capuano P
de Laon A
de Tours B

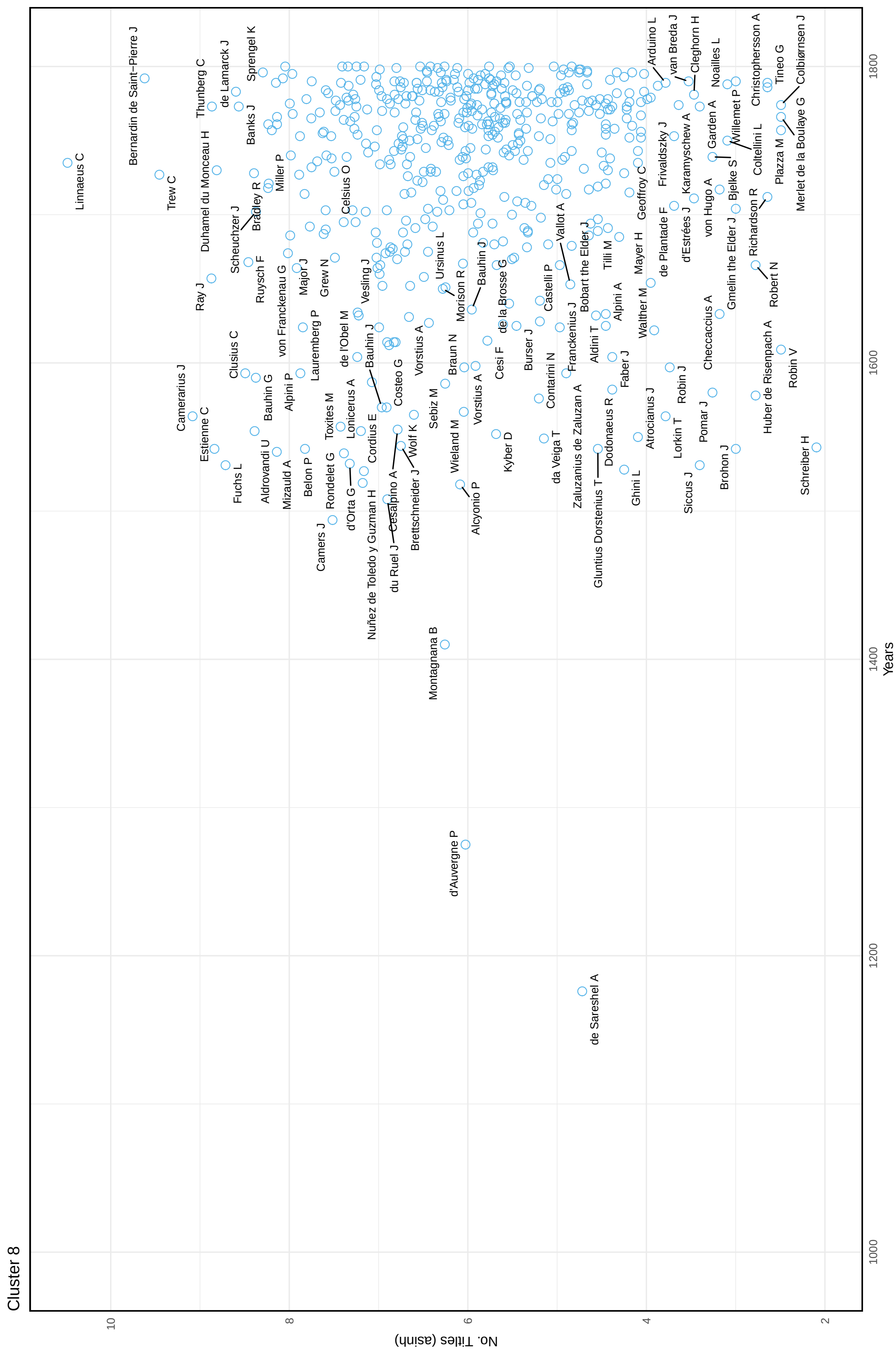

Cluster 3
Years
No. Titles (asinh)
1000
1200
1400
1600
1800
2
4
6
8
10

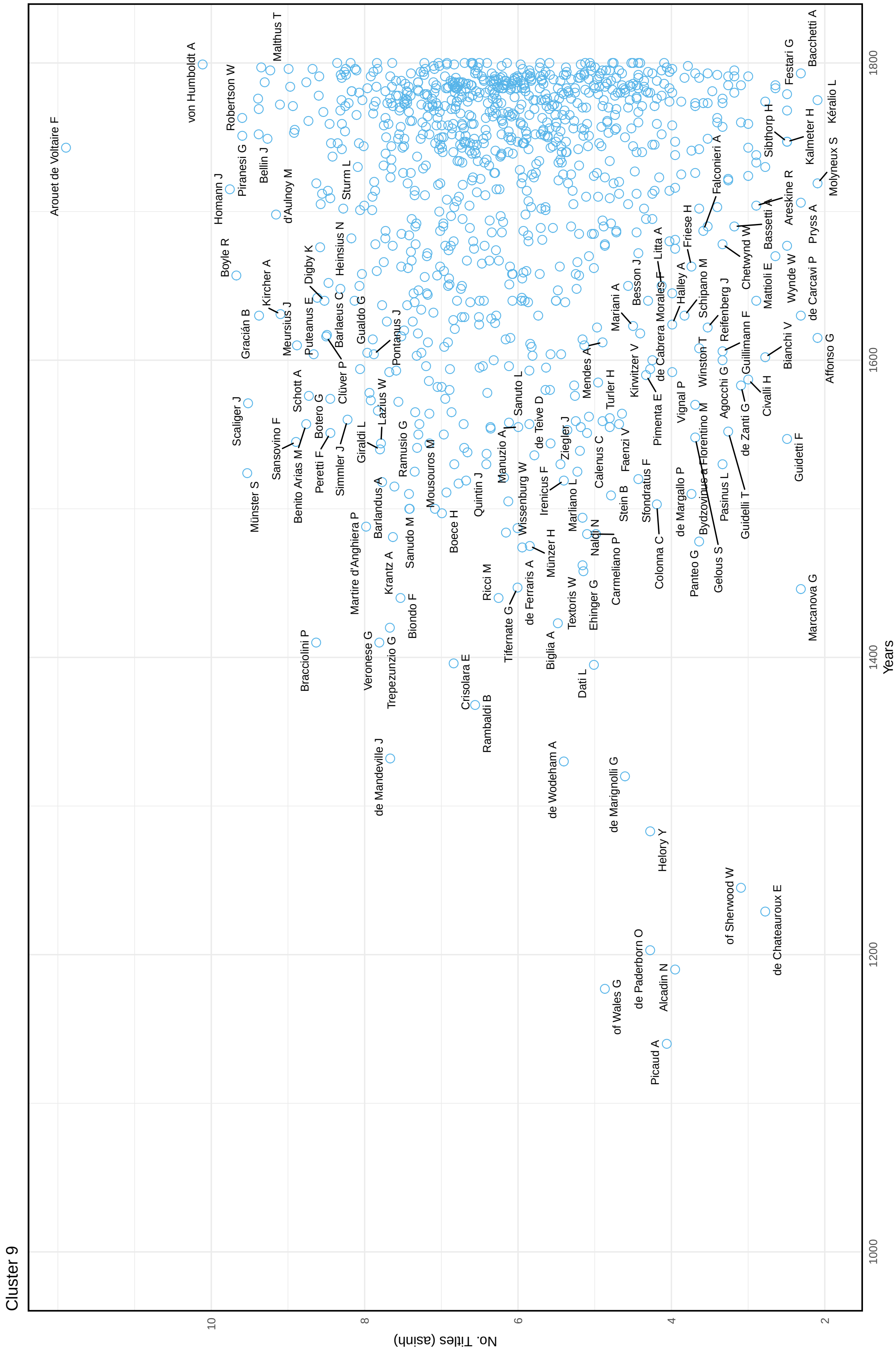

Cluster 4
Years
No. Titles (asinh)
1000
1200
1400
1600
1800
2
4
6
8

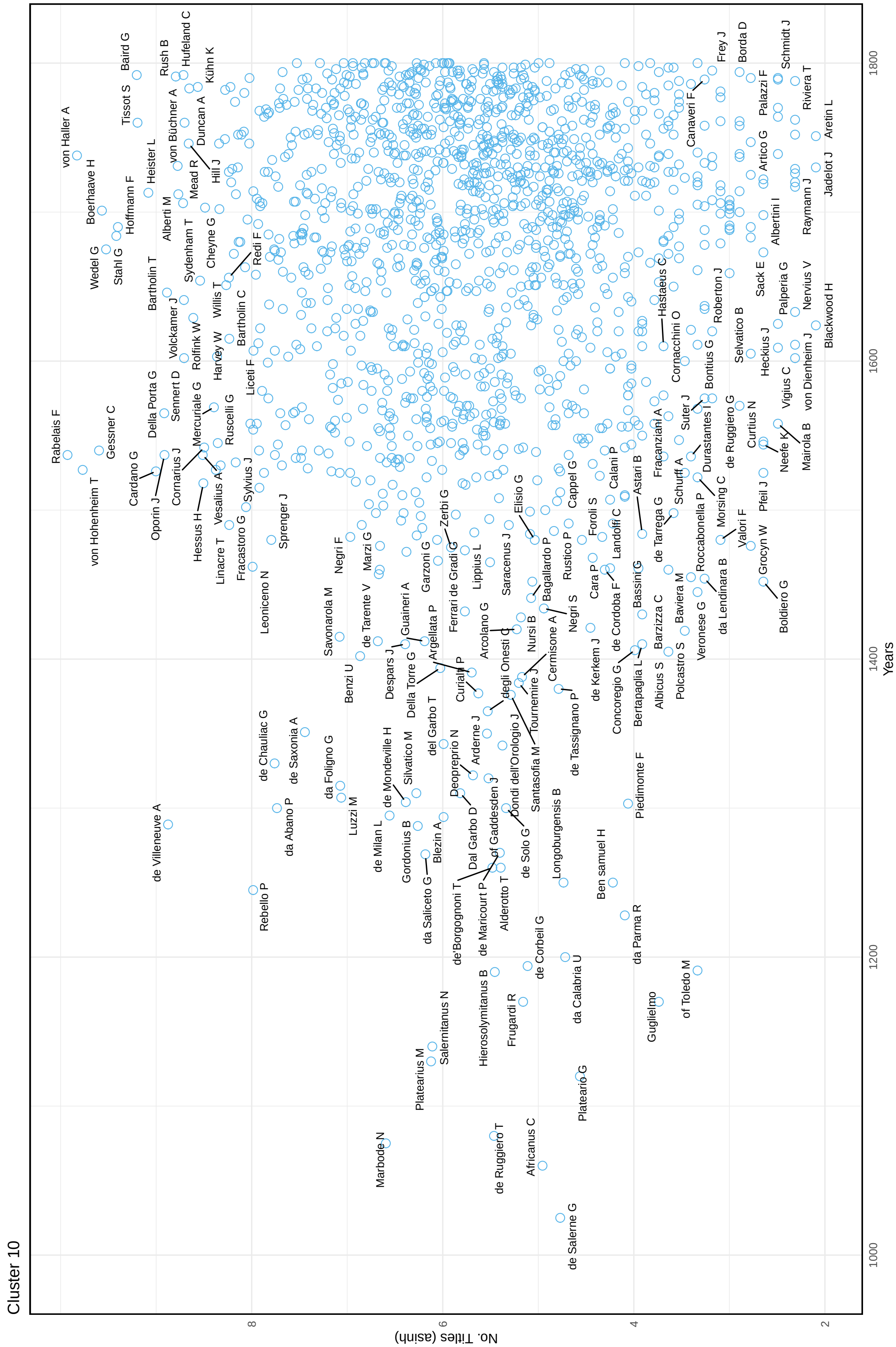

Cluster 5
Years
No. Titles (asinh)
1000
1200
1400
1600
1800
2
4
6
8

Cluster 6
Years
No. Titles (asinh)
1000
1200
1400
1600
1800
2
4
6
8
10
von Schiller J
Erasmus D
Boccaccio G
Magnus A
Romanus A
Pope A
Metastasio P
Racine J
de La Fontaine J
Rameau J
Perrault C
Montesquieu C
von Herder J
Leclerc de Buffon G
von Schlegel A
Gibbon E
Claris de Florian J
Nicolai F
Bürger G
Priestley J
Gray T
Gottsched J
Holberg L
Delisle G
Mather C
Muratori L
Corneille T
Quinault P
Evelyn J
de Groot H
de Quevedo Villegas F
Vossius G
Rivetus A
Estienne H
Bruno G
Tasso T
Manuzio P
de La Ramée P
Suarez F
Manuzio A
Bembo P
Ambrogini A
Brant S
Beroaldi F
de Nebrija A
Pontano G
Valla L
Villon F
Perotti N
Landino C
Celtis C
Flaminio M
Regio R
Beccadelli A
Barzizza G
Roselli A
Eiximenis F
Zabarella F
Vergerio P
Corsier J
Crespques J
Antonio G
Bonsignori G
Horborch G
Pilatus L
Marsili L
Bateman W
de Padova M
Bedersi J
de Bury R
Del Virgilio G
of Heytesbury W
Vargas y Toledo A
Carusi B
Bandalo A
Oliver B
da Vigevano G
de Alnwick G
Buckingham T
Di Negro A
da Parma T
de Villemaria (the young) H
of Ware W
de Berceo G
Garlande J
de Cantimpré T
de Fournival R
de Bourbon E
d'Andeli H
Bononiensis T
Fava G
de Trilia B
Riniero
Marsch A
de Saint-Quentin G
de Cingoli G
d'Auxerre G
Gallego P
de Dinant J
de Lille A
ben Judah ibn Tibbon S
Ibn Daud A
de Montboissier P
Hispalensis J
Silvestre B
de Cluny B
de Béthune E
Boncompagno
Uguccione N
Helias P
Papiensis B
Hungarus D
Enrico
de Chartres T
de Corbeil P
de Chériton E
Primat H
Ardizzoni G
de Wilton S
d'Orchelles G
di Orléans A
da Salerno M
Bene N
Universalis G
of Cricklade R
de Dinant D
d'Amiens N
de Kent H
Samaritanus A
de Mortagne G
Ottone
de Sully E
de Sèchelle J
of York T
Matarellus N
Glaber R
de Mayence G
il Peripatetico A
de Compiègne R
Bernard
of St Gallen E
de Liège F
de Liège E
de Liège A
of Zell U


Cluster 7
Years
No. Titles (asinh)
1000
1200
1400
1600
1800
2
4
6
8
10


Cluster 8
No. Titles (asinh)
Years
2
4
6
8
10
1000
1200
1400
1600
1800
Linnaeus C
Bernardin de Saint−Pierre J
Trew C
Thunberg C
de Lamarck J
Sprengel K
Duhamel du Monceau H
Banks J
Miller P
Bradley R
Scheuchzer J
Ray J
Ruysch F
Celsius O
Camerarius J
Estienne C
Clusius C
Fuchs L
Aldrovandi U
Bauhin G
Mizauld A
Alpini P
von Franckenau G
Major J
Grew N
Belon P
Lauremberg P
Rondelet G
Toxites M
Camers J
d'Orta G
de l'Obel M
Lonicerus A
Vesling J
Cordius E
Bauhin J
Nuñez de Toledo y Guzman H
Cesalpino A
du Ruel J
Costeo G
Wolf K
Brettschneider J
Vorstius A
Ursinus L
Sebiz M
Braun N
Morison R
Montagnana B
Wieland M
Vorstius A
Alcyonio P
Bauhin J
d'Auvergne P
Cesi F
de la Brosse G
Kyber D
Burser J
Castelli P
Contarini N
Vallot A
da Veiga T
Franckenius J
Zaluzanius de Zaluzan A
Bobart the Elder J
Aldini T
Dodonaeus R
Tilli M
Gluntius Dorstenius T
Alpini A
Faber J
de Sareshel A
Ghini L
Mayer H
Walther M
Atrocianus J
Geoffroy C
Arduino L
Frivaldszky J
de Plantade F
van Breda J
Lorkin T
Robin J
Siccus J
Karamyschew A
d'Estrées J
Cleghorn H
Pomar J
Checcaccius A
von Hugo A
Garden A
Noailles L
Brohon J
Gmelin the Elder J
Bjelke S
Willemet P
Christophersson A
Coltellini L
Richardson R
Huber de Risenpach A
Robert N
Robin V
Plazza M
Tineo G
Colbjørnsen J
Merlet de la Boulaye G
Schreiber H


Cluster 9
Years
No. Titles (asinh)
1000
1200
1400
1600
1800
2
4
6
8
10
Arouet de Voltaire F
von Humboldt A
Robertson W
Malthus T
Piranesi G
Homann J
Bellin J
d'Aulnoy M
Sturm L
Boyle R
Kircher A
Digby K
Heinsius N
Gracián B
Meursius J
Puteanus E
Barlaeus C
Gualdo G
Pontanus J
Clüver P
Scaliger J
Schott A
Botero G
Lazius W
Sansovino F
Benito Arias M
Peretti F
Simmler J
Giraldi L
Ramusio G
Münster S
Barlandus A
Mousouros M
Quintin J
Manuzio A
Sanuto L
de Teive D
Wissenburg W
Irenicus F
Ziegler J
Calenus C
Mendes A
Turler H
Mariani A
Besson J
Kirwitzer V
Faenzi V
Stein B
Sfondratus F
Pimenta E
de Cabrera Morales F
Litta A
Halley A
Friese H
Schipano M
Vignal P
Winston T
Reifenberg J
Falconieri A
Sibthorp H
Festari G
Bacchetti A
Kéralio L
Kalmeter H
Molyneux S
Areskine R
Bassetti A
Chetwynd W
Pryss A
Wynde W
Mattioli E
de Carcavi P
Guillimann F
Bianchi V
Afonso G
Agocchi G
Civalli H
de Zanti G
de Margallo P
Bydzovinus a Florentino M
Pasinus L
Guidelli T
Guidetti F
Martire d'Anghiera P
Boece H
Sanudo M
Krantz A
Mariano L
Naldi N
Münzer H
de Ferraris A
Ricci M
Biondo F
Carmeliano P
Colonna C
Panteo G
Gelous S
Textoris W
Ehinger G
Tifernate G
Biglia A
Bracciolini P
Veronese G
Trepezunzio G
Crisolara E
Dati L
Marcanova G
Rambaldi B
de Mandeville J
de Wodeham A
de Marignolli G
Helory Y
of Sherwood W
de Chateauroux E
de Paderborn O
of Wales G
Alcadin N
Picaud A

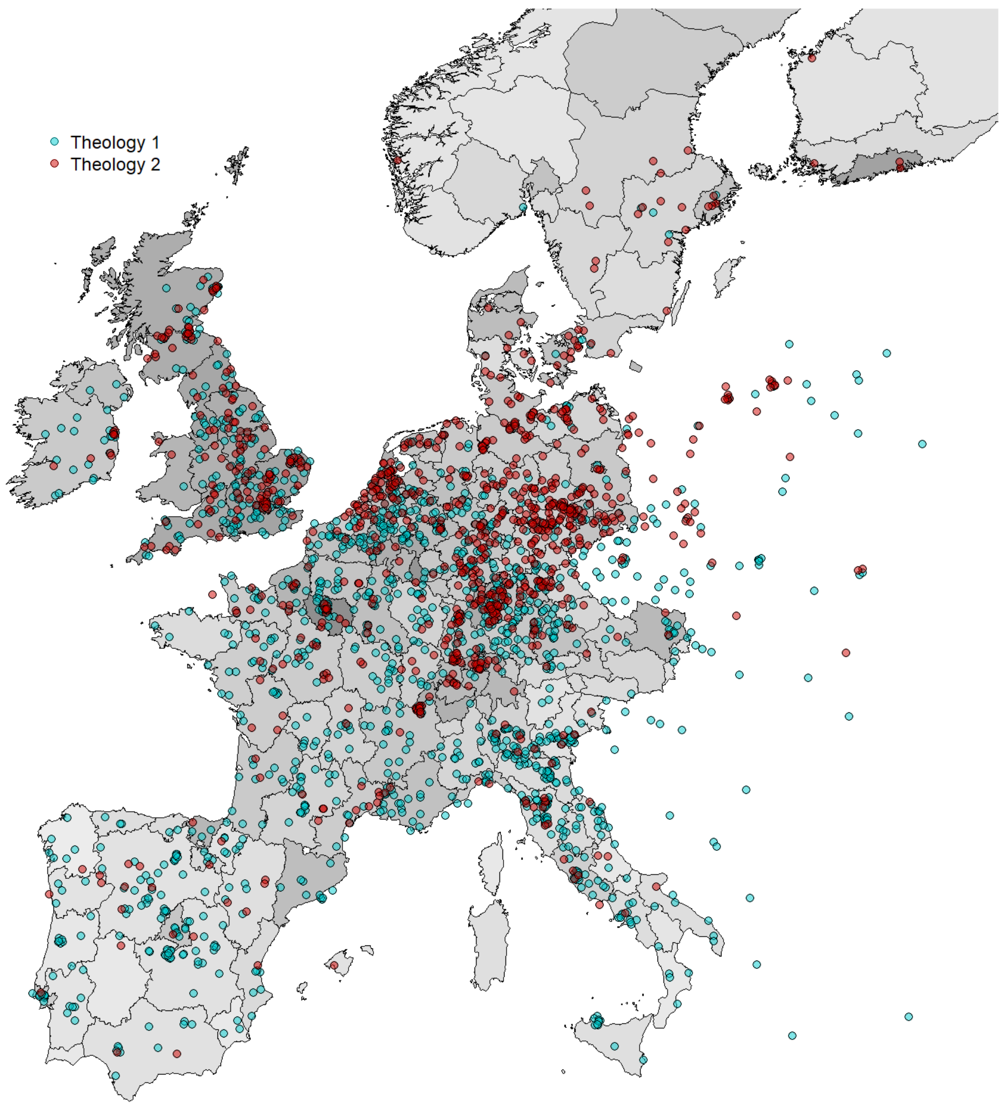


Cluster 10
No. Titles (asinh)
Years
1000
1200
1400
1600
1800
2
4
6
8
de Salerno G
Marbode N
de Ruggiero T
Africanus C
Platearius M
Salernitanus N
Hierosolymitanus B
Frugardi R
Plateario G
da Calabria U
Guglielmo
of Toledo M
de Corbeil G
de'Borgognoni T
de Maricourt P
Alderotto T
da Parma R
Rebello P
de Villeneuve A
da Saliceto G
Gordonius B
Blezin A
de Milan L
Luzzi M
da Abano P
de Chauliac G
de Saxonia A
da Foligno G
de Mondeville H
Silvatico M
Deoprepio N
Dal Garbo D
of Gaddesden J
de Solo G
Dondi dell'Orologio J
Santasofia M
Longoburgensis B
Ben samuel H
Piedimonte F
del Garbo T
Arderne J
Tournemire J
de Tassignano P
Leoniceno N
Savonarola M
Benzi U
de Tarente V
Despars J
Della Torre G
Guaineri A
Argellata P
Curialti P
Ferrari de Gradi G
Arcolano G
degli Onesti G
Nursi B
Cermisone A
Negri S
de Kerkem J
Concoregio G
de Cordoba F
Bertapaglia L
Barzizza C
Albicus S
Polcastro S
Baviera M
Veronese G
da Lendinara B
Boldiero G
Linacre T
Fracastoro G
Negri F
Marzi G
Garzoni G
Zerbi G
Lippius L
Saracenus J
Elisio G
Bagallardo P
Rustico P
Cara P
Foroli S
Landolfi C
Bassini G
de Tarrega G
Roccabonella P
Valori F
Grocyn W
von Hohenheim T
Rabelais F
Gessner C
Cardano G
Oporin J
Cornarius J
Hessus H
Vesalius A
Sylvius J
Sprenger J
Della Porta G
Sennert D
Mercuriale G
Ruscelli G
Liceti F
Cappel G
Calani P
Astari B
Fracanziani A
Schuff A
Suter J
Durastantes I
Morsing C
de Ruggiero G
Curtius N
Pfeil J
Neefe K
Mairola B
Vigius C
von Dienheim J
Bartholin T
Volckamer J
Rolfink W
Harvey W
Willis T
Bartholin C
Redi F
Sydenham T
Cheyne G
Alberti M
Wedel G
Stahl G
Boerhaave H
Hoffmann F
Heister L
Mead R
Hill J
von Haller A
Tissot S
von Büchner A
Duncan A
Baird G
Rush B
Hufeland C
Kühn K
Hastaeus C
Cornacchini O
Bontius G
Roberton J
Selvatico B
Heckius J
Sack E
Palperia G
Nervius V
Blackwood H
Albertini I
Artico G
Canaveri F
Raymann J
Jadelot J
Aretin L
Riviera T
Palazzi F
Frey J
Borda D
Schmidt J

Appendix A.4 The Two Theology Clusters

As shown in Figure A2, the Theology 2 cluster is strongly concentrated in historically Protestant areas, whereas the Theology 1 cluster is less geographically clustered. Theology 2 contains notable Protestant Reformers; the top 3 scholars by publication are Luther, Melanchton, and Wesley. However, the correlation between the clusters and denomination is not perfect. For example, Theology 2 contains scholars born back to 1039, centuries before the Reformation.

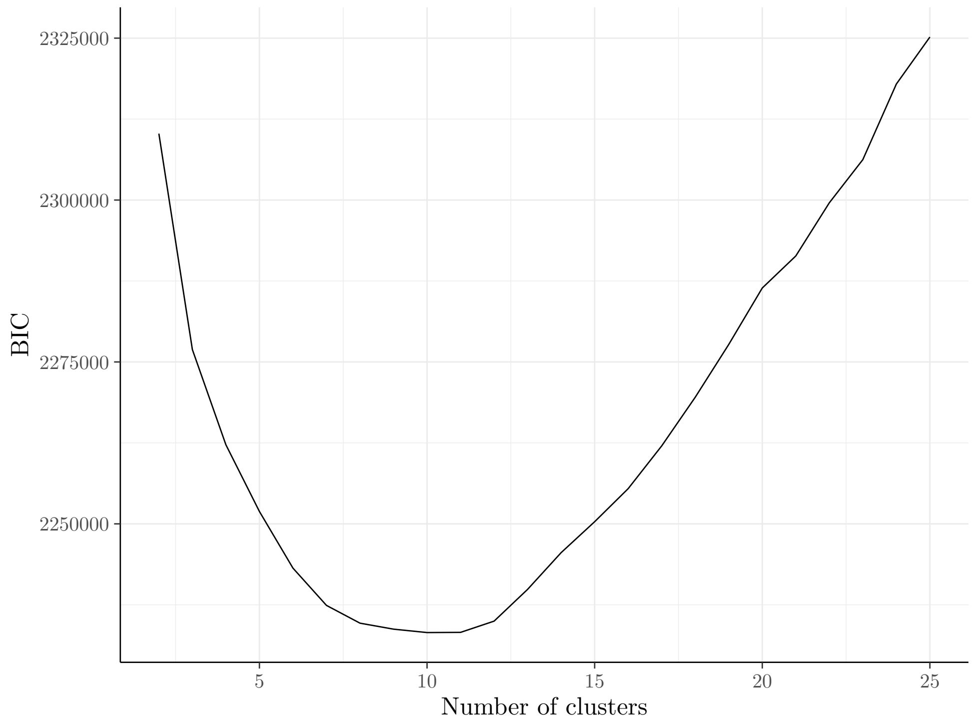
Figure A2: Birthplace of Theologians by Cluster



Appendix A.5 k-means algorithm

Figure A3 displays the BIC for the k-means algorithm estimated at different values of k. $BIC_k = TWSS_k + \log(I)Jk$, where $I = 16,149$ and $J = 1,360$. This is minimized at $k = 10$.

Figure A3: Bayesian Information Criterion for Different Values of k



Note: k-means estimated using the default R package which implements the Hartigan-Wong algorithm (Hartigan and Wong 1979). We initiate the k-means algorithm with 500 random guesses.

Appendix B Robustness

Appendix B.1 Share regressions

In Table 3, we weight each scholar by a function of the number of his publications. Here, we show that our results are robust to two alternative measures. The first is the number of works reported by WorldCat. The difference here is that the number of publications includes reprints and translations as seperate publications, whereas the number of works does not. The second is the number of titles reported by VIAF based on the data in Curtis and De la Croix (2023), which typically do not include reprints and translations. Here, we lose a few scholars whose details were revised in the more recent versions of RETE. As shown in Tables B1 and B2, we find similar results with both measures.

In Table B3, we look to see if the associations appear to be non-linear. We focus on the two clusters' whose shares are statistically significant at the 5% level when including fixed effects: Science and Botany. It does seem to be the case that the first scholar in either cluster matters more than the total share. However, given that the mean region has 2.08 scientists and 1.77 botanists (with standard deviations of 4.17 and 3.34), only one scientist or botanist is not a trivial number.

In Table B5, we extend the analysis from Table 5 to the shares by field. We are still confident that the most informative level of aggregation is by birthplace for the reasons described in the main text.

While the choice to focus on locations of birth was data-driven, we also here include some anecdotes the highest share in the science cluster for birth, activity, and death places.

Nordmark, Sweden, has the highest share in the Science cluster of science by birthplace, with the two most notable of the 8 notable scholars born in the region, Zacharias Nordmark (1751–1828) and Jöns Svanberg (1771–1851), classified as in the science cluster. Both were active at the Academy of Stockholm and the University of Uppsala, and Nordmark was also active at the University of Greifswald. The third most notable scholar in the region, Daniel Solander (1733–1782), was in the botany cluster and was a full member of the Academy of Birmingham and the (British) Royal Society. Nordmark produced several scientists, despite hosting no academy or university.

The region with the highest share in the Science cluster by activity place is Castile-La Mancha, Spain. Of the 26 notable scholars, 5 are classified as in the science cluster, with a weighted share of 0.25. Four were active at the Toledo School of Translators in Toledo during the 12th century: Michael Scotus (1175–1232), born in Durham, England; Gerardus Cremonensis (1114–1187), born in Cremona, Italy; Plato Tiburtinus (?–?), born in Tivoli, Italy; and Daniel de Morley (1140–1210), born in Morely, England. Only one was born in Spain. Pedro Ciruelo (1470–1548) who was active at the University of Siguenza, was born in Daroca, Spain. Despite its ability to attract foreign scientists, while Castile-La Mancha was the birthplace for 69 scholars, none ended up in the Science cluster. The most common cluster was Theology 1, with 30 scholars. While this example does not guide us in our choice between the two, it illustrates that a region can look very different if we focus on activity or birthplaces.

Basque Country, Spain, has the highest share in the Science cluster by death place, with one of the two notable scholars dying there, Charles Malapert (1580), classified as in the science cluster. Malapert was born in Mons, Belgium and was a member of the faculty at the University of Pont-à-Mousson, the Univeristy of Douai, and the Colegio Imperial de Madrid (coded as a weak link). He died in Vitoria-Gasteiz on his journey to Madrid. The other scholar who died in the region was Michael de Elizalde (?–1678) who was active at the University of Roma Gregoriana and is classified in the Theology 1 Cluster.Malapert had no connection to the region other than his death mid-journey, which seems unlikely to have much effect on the region.

In Table B4, we drop all regions with a university or academy during our period of study. The overall pattern is very similar, with some changes in statistical signifiance. Given that the sample size is much smaller, this is not surprsing. The share in Science is not significant without country fixed effects, and the share in Botany is not significant with country fixed effects, but the magnitudes are similar.

Table B1: Robustness, number of WorldCat works

	log GDP per capita in 1900				in 2015
	(1)	(2)	(3)	(4)	(5)
Local scholarship	0.197*	0.146**	0.182*	0.139*	0.180***
	(0.094)	(0.067)	(0.089)	(0.074)	(0.053)
Share Theology 1			0.210	0.006	0.137
			(0.234)	(0.180)	(0.177)
Share Theology 2			1.419**	0.414	0.177
			(0.597)	(0.507)	(0.229)
Share Politics			0.380	0.006	-0.095
			(0.426)	(0.132)	(0.213)
Share Law			-0.857**	-0.428*	-0.077
			(0.338)	(0.209)	(0.150)
Share Science			1.465***	1.228***	0.659*
			(0.449)	(0.325)	(0.320)
Share Philosophy			-0.027	-0.111	0.214*
			(0.096)	(0.121)	(0.113)
Share Botany			0.813**	0.585***	0.626***
			(0.336)	(0.171)	(0.134)
Share Culture			0.094	-0.129	-0.172
			(0.385)	(0.369)	(0.201)
Share Medicine			0.107	-0.430	-0.065
			(0.477)	(0.536)	(0.260)
N	172	172	172	172	165
Adj. R Squared	0.325	0.629	0.449	0.654	0.707
Controls:					
Country FEs	No	Yes	No	Yes	Yes
Regional	Yes	Yes	Yes	Yes	Yes

Note: $^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$. Standard errors clustered by country in parentheses. The unit of observation is a NUTS2 region. GDP per capita from the Rosés-Wolf database on regional GDP (Rosés and Wolf 2021) and from Eurostat. For comparison, regions with GDP in 2015 but not in 1900 are omitted. $n_{r,s}$ is the weighted total of scholars. Shares are the weighted share of the total scholars who are assigned to a given field. GDP per capita from the Rosés-Wolf database on regional GDP (Rosés and Wolf 2021). All regressions include regional controls: log ruggedness from Nunn and Puga (2012), log post-1500 calorie suitability index from Galor and Özak (2016), and the log of the region's area.

Table B2: Robustness, number of VIAF titles

	log GDP per capita in 1900				in 2015
	(1)	(2)	(3)	(4)	(5)
Local scholarship	0.334*	0.267**	0.298*	0.257**	0.319***
	(0.160)	(0.105)	(0.151)	(0.117)	(0.079)
Share Theology 1			0.228	0.069	0.147
			(0.246)	(0.162)	(0.185)
Share Theology 2			1.321**	0.210	0.112
			(0.575)	(0.463)	(0.223)
Share Politics			0.405	0.106	-0.041
			(0.397)	(0.115)	(0.196)
Share Law			-0.783**	-0.326*	-0.029
			(0.317)	(0.181)	(0.134)
Share Science			1.346**	1.084***	0.588*
			(0.454)	(0.343)	(0.291)
Share Philosophy			-0.020	-0.135	0.231**
			(0.108)	(0.125)	(0.103)
Share Botany			0.814**	0.577***	0.612***
			(0.338)	(0.178)	(0.143)
Share Culture			0.214	0.010	-0.121
			(0.373)	(0.320)	(0.197)
Share Medicine			0.211	-0.295	-0.025
			(0.548)	(0.567)	(0.250)
N	172	172	171	171	164
Adj. R Squared	0.323	0.634	0.441	0.655	0.713
Controls:					
Country FEs	No	Yes	No	Yes	Yes
Regional	Yes	Yes	Yes	Yes	Yes

Note: $^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$. Standard errors clustered by country in parentheses. The unit of observation is a NUTS2 region. GDP per capita from the Rosés-Wolf database on regional GDP (Rosés and Wolf 2021) and from Eurostat. For comparison, regions with GDP in 2015 but not in 1900 are omitted. $n_{r,s}$ is the weighted total of scholars. Shares are the weighted share of the total scholars who are assigned to a given field. GDP per capita from the Rosés-Wolf database on regional GDP (Rosés and Wolf 2021). All regressions include regional controls: log ruggedness from Nunn and Puga (2012), log post-1500 calorie suitability index from Galor and Özak (2016), and the log of the region's area.

Table B3: Robustness, nonlinear associations

	log GDP per capita, 1900					
	(1)	(2)	(3)	(4)	(5)	(6)
Local scholarship	0.100	0.104*	0.098	0.102	0.078	0.085
	(0.059)	(0.058)	(0.058)	(0.059)	(0.057)	(0.056)
Share Science		0.501				0.712*
		(0.462)				(0.394)
Any scientist	0.163***	0.128**			0.132***	0.092**
	(0.040)	(0.054)			(0.039)	(0.042)
Any botanist			0.158**	0.137**	0.125**	0.098*
			(0.056)	(0.053)	(0.055)	(0.046)
Share botany				0.259		0.446**
				(0.181)		(0.161)
N	172	172	172	172	172	172
Controls:						
Country FEs	Yes	Yes	Yes	Yes	Yes	Yes
Regional	Yes	Yes	Yes	Yes	Yes	Yes

Note: $^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$. Standard errors clustered by country in parentheses. The unit of observation is a NUTS2 region. GDP per capita from the Rosés-Wolf database on regional GDP (Rosés and Wolf 2021) and from Eurostat. For comparison, regions with GDP in 2015 but not in 1900 are omitted. $n_{r,s}$ is the weighted total output of scholars. Shares are the weighted share of the total scholars who are assigned to a given field. GDP per capita from the Rosés-Wolf database on regional GDP (Rosés and Wolf 2021). All regressions include regional controls: log ruggedness from Nunn and Puga (2012), log post-1500 calorie suitability index from Galor and Özak (2016), and the log of the region's area.

Table B4: Robustness, regions with no university or academy

	log GDP per capita in 1900				in 2015
	(1)	(2)	(3)	(4)	(5)
Local scholarship	0.628***	0.337**	0.471**	0.192	0.462**
	(0.175)	(0.147)	(0.189)	(0.138)	(0.169)
Share Theology 1			-0.287	-0.516**	-0.017
			(0.221)	(0.179)	(0.223)
Share Theology 2			0.871	0.686	0.438
			(0.710)	(0.748)	(0.248)
Share Politics			0.212	0.007	-0.223
			(0.525)	(0.225)	(0.246)
Share Law			-0.782**	-0.265	-0.037
			(0.275)	(0.198)	(0.183)
Share Science			0.814	1.200**	0.582**
			(0.632)	(0.520)	(0.259)
Share Philosophy			-0.025	-0.093	0.438***
			(0.183)	(0.184)	(0.121)
Share Botany			0.782*	0.557	0.793***
			(0.401)	(0.342)	(0.162)
Share Culture			-0.112	-0.323	-0.166
			(0.515)	(0.457)	(0.199)
Share Medicine			0.453	0.207	-0.364
			(0.779)	(0.649)	(0.208)
N	63	63	63	63	61
Adj. R Squared	0.313	0.549	0.412	0.565	0.834
Controls:					
Country FEs	No	Yes	No	Yes	Yes
Regional	Yes	Yes	Yes	Yes	Yes

Note: $^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$. Standard errors clustered by country in parentheses. The unit of observation is a NUTS2 region. GDP per capita from the Rosés-Wolf database on regional GDP (Rosés and Wolf 2021) and from Eurostat. For comparison, regions with GDP in 2015 but not in 1900 are omitted. $n_{r,s}$ is the weighted total of scholars. Shares are the weighted share of the total scholars who are assigned to a given field. GDP per capita from the Rosés-Wolf database on regional GDP (Rosés and Wolf 2021). All regressions include regional controls: log ruggedness from Nunn and Puga (2012), log post-1500 calorie suitability index from Galor and Özak (2016), and the log of the region's area.

Table B5: Robustness, shares by birth, activity, and death place

	log GDP per capita, 1900					
	Birth place		Activity place		Death place	
Local scholarship	0.171*	0.129*	0.039*	0.028	0.096***	0.080***
	(0.079)	(0.067)	(0.021)	(0.018)	(0.019)	(0.017)
Share Theology 1	0.215	0.028	0.215	0.086	0.098	-0.043
	(0.230)	(0.173)	(0.231)	(0.144)	(0.227)	(0.163)
Share Theology 2	1.440**	0.381	0.524	0.209	0.526	0.034
	(0.609)	(0.501)	(0.697)	(0.306)	(0.407)	(0.184)
Share Politics	0.417	0.049	0.215	0.110	0.349	0.029
	(0.415)	(0.131)	(0.352)	(0.230)	(0.393)	(0.143)
Share Law	-0.850**	-0.427*	-0.439	0.178	-0.577	0.159
	(0.336)	(0.208)	(0.678)	(0.262)	(0.454)	(0.240)
Share Science	1.451***	1.215***	0.584	0.849***	0.397	0.779
	(0.425)	(0.312)	(0.463)	(0.273)	(0.662)	(0.494)
Share Philosophy	-0.029	-0.107	0.789*	0.511	0.198	0.178
	(0.097)	(0.126)	(0.391)	(0.328)	(0.433)	(0.299)
Share Botany	0.856**	0.649***	1.037	0.143	0.055	-0.028
	(0.350)	(0.199)	(0.769)	(0.485)	(0.254)	(0.202)
Share Culture	0.102	-0.108	0.255	0.279	0.646	0.278
	(0.376)	(0.358)	(0.491)	(0.607)	(0.402)	(0.352)
Share Medicine	0.075	-0.425	0.137	0.067	0.703**	0.272
	(0.457)	(0.525)	(0.550)	(0.235)	(0.304)	(0.252)
N	172	172	106	106	162	162
Adj. R Squared	0.458	0.656	0.310	0.707	0.355	0.668
Controls:						
Country FEs	No	Yes	No	Yes	No	Yes
Regional	Yes	Yes	Yes	Yes	Yes	Yes

Note: $^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$. Standard errors clustered by country in parentheses. The unit of observation is a NUTS2 region. GDP per capita from the Rosés-Wolf database on regional GDP (Rosés and Wolf 2021) and from Eurostat. For comparison, regions with GDP in 2015 but not in 1900 are omitted. $n_{r,s}$ is the weighted total of scholars. Shares are the weighted share of the total scholars who are assigned to a given field. GDP per capita from the Rosés-Wolf database on regional GDP (Rosés and Wolf 2021). All regressions include regional controls: log ruggedness from Nunn and Puga (2012), log post-1500 calorie suitability index from Galor and Özak (2016), and the log of the region's area.

Appendix B.2 Robustness of IV estimate

In Table B6, we drop all regions within a country (using 1900s borders) with at least one refugee from the relevant groups. The results are similar.

In Table B7, we add a control for the total urban population within a region from Buringh 2021. We use a reference date from before the start of the specific migrant flows, 1300 for the pooled and Byzantine migrants, 1500 for the Hugenots and British Catholics. The results are robust except for the British Catholics.

Table B6: Robustness, region-restricted IV

	log GDP per capita, 1900				
Panel A: IV	(1) OLS	(2) IV	(3) IV	(4) IV	(5) IV
Local scholarship	0.135**	0.279***	0.129***	0.396***	0.449**
	(0.060)	(0.077)	(0.025)	(0.087)	(0.138)
Panel B: First-stage	Local scholarship				
		(2)	(3)	(4)	(5)
N Refugees		0.062***			
		(0.010)			
N Byzantines			0.122***		
			(0.028)		
N Huguenots				0.067*	
				(0.033)	
N British Catholics					0.061**
					(0.025)
N	172	156	121	130	123
Controls:					
Country FEs		Yes	Yes	Yes	Yes
Regional		Yes	Yes	Yes	Yes
1st stage F-stat.		49.94	36.76	10.27	7.99

Note: $^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$. Standard errors clustered by country in parentheses. The unit of observation is a NUTS2 region. GDP per capita from the Rosés-Wolf database on regional GDP (Rosés and Wolf 2021). Local scholarship is the weighted total of scholars born in the region. N refugees, N Byzantines, N Huguenots, and N British Catholics are the number of scholars of a group that was active or died in the region; see text for details. All regressions include regional controls: log ruggedness from Nunn and Puga (2012), the log post-1500 calorie suitability index from Galor and Özak (2016), and the log of the region's area.

In Figure B1, we conduct a robustness test based on Conley, Hansen, and Rossi (2012). Assume that γ is the direct effect of local scholarship on log GDP per capita in 1900. Given a value of γ, we can estimate:

$$(y_{r,s} - \gamma\alpha_1 n_{r,s}) = \alpha_0 + \alpha_1 n_{r,s} + \phi_s + \epsilon_{r,s} \tag{8}$$

Table B7: Robustness, refugee scholar IV with urban population controls

	log GDP per capita, 1900				
Panel A: IV	(1) OLS	(2) IV	(3) IV	(4) IV	(5) IV
Local scholarship	0.137*				
	(0.068)				
Local scholarship after 1300		0.344**	0.258***		
		(0.119)	(0.042)		
Local scholarship after 1500				0.452***	0.473
				(0.143)	(0.279)
ln(total urban pop + 1), 1300	0.020	0.007	0.013		
	(0.019)	(0.020)	(0.018)		
ln(total urban pop + 1), 1500				0.005	0.003
				(0.019)	(0.028)
Panel B: First-stage		Local scholarship after 1300		Local scholarship after 1500	
		(2)	(3)	(4)	(5)
N Refugees		0.365**			
		(0.138)			
N Byzantines			0.805***		
			(0.227)		
N Huguenots				0.272**	
				(0.122)	
N British Catholics					0.283
					(0.183)
ln(total urban pop + 1), 1300		0.048*	0.048*		
		(0.026)	(0.024)		
ln(total urban pop + 1), 1500				0.070*	0.076**
				(0.034)	(0.035)
N	167	167	167	167	167
Controls:					
Country FEs	Yes	Yes	Yes	Yes	Yes
Regional	Yes	Yes	Yes	Yes	Yes
1st stage F-stat.		28.45	61.27	13.84	13.09

Note: $^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$. Standard errors clustered by country in parentheses. The unit of observation is a NUTS2 region. GDP per capita from the Rosés-Wolf database on regional GDP (Rosés and Wolf 2021). Local scholarship is the weighted total of scholars born in the region. N refugees, N Byzantines, N Huguenots, and N British Catholics are the number of scholars of a group that was active or died in the region; see text for details. The log total urban population in a NUTS2 region is using data from Buringh 2021. All regressions include regional controls: log ruggedness from Nunn and Puga (2012), the log post-1500 calorie suitability index from Galor and Özak (2016), and the log of the region's area.

where $n_{r,s}$ is the sum of the inverse hyperbolic sine of the number of publications over all scholars born in region r in country s from 1000 to 1800 (with the same normalization as before); $X_{r,s}$ is our usual vector of controls, ϕ_s is a country fixed effect, and $\varepsilon_{r,s}$ is an error term.

If we assume $\gamma \in [0, \delta]$, the confidence interval for our estimate is in the union of confidence intervals for all possible values of γ. This can be approximated by using grid points.

What is a plausible support for γ in our context? If local scholarship is narrowly interpreted as only human capital in universities or academies, one plausible value comes from Hornung (2014), which finds that "if Huguenot immigration increases by one standard deviation, productivity increases by 0.04 standard deviations." While the paper does not report the standard deviations of the regression sample, for the full sample log output in textile production in 1802 has a standard deviation of 1.826 and percent Huguenots in 1700 has a standard deviation of 0.044. An increase in one standard deviation of Huguenots should thus increase log output by 0.07304.

Assume that a one standard deviation increase in refugee Huguenot scholars increases the total Huguenot population by one standard deviation. Also assume that the estimates are externally valid in every destination country, which likely overstates the direct effect.[18] The standard deviation of our Huguenot scholar migrant instrument is 2.12, so one Huguenot scholar would increase log output by 0.03445, or increase output by $100 \times (e^{0.03445} - 1) \approx 3.505$ percent. The regressions control for inputs, so this is a measure of TFP growth in textile manufacturing.

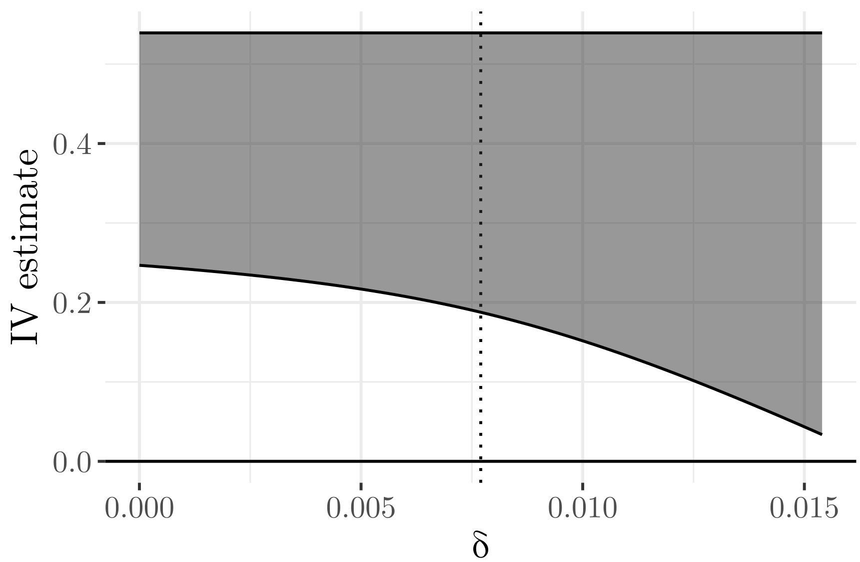
Hornung (2014) is looking at the effect of Huguenots in Prussia 1700–1800. Hornung (2014) states that "Bekmann (1751) provides a list of 46 professions introduced by Huguenots to Brandenburg, all of which were previously unknown to the country, most of them in the textile industries." So we feel it is safe to crudely approximate the total effect of Huguenots by ignoring other sectors. Textiles contributed only a share of value of 0.11 but accounted for 43% of productivity advances in England 1780–1870 (Clark 2014). England was the growth leader, and much of the productivity improvements happened after 1800, so assuming a textile share of 0.11 is an extreme upper bound. This would give an increase in overall efficiency of 0.3856% per century. If we assume a similar impact on growth 1800–1900, we would expect an increase in overall productivity by $(1.003856)^2 = 0.7726\%$, and implies a γ value of $ln(1.007726) \approx 0.0077$.

In Figure B1, we plot the confidence intervals for $\gamma \in [0, \delta]$ for various values of δ. For plausible values of γ, our IV might be biased upwards, but the confidence intervals never overlap with zero.

This analysis based only on a narrow interpretation of local scholarship. If local scholarship is a measure for local upper-tail human capital, then the effect of high-skilled Huguenot artisans on GDP is through our endogenous independent variable and there is no exclusion restriction violation. There is another potential exclusion restriction based on the endogenous selection of migration destinations. However, we hope that the event studies help mitigate this concern.

18. Hornung (2014) argues that "the technological gap that separated Brandenburg-Prussia from France was large compared to that experienced by other host countries such as England and the Netherlands," slowing the diffusion of technology in Prussia. This implies that the final impact in Prussia was higher.

Figure B1: 95% Confidence interval estimates assuming a support of $[0, \delta]$



Note: The dashed vertical line marks the upper bound estimate of γ we assume based on the Hornung (2014). See text for details on construction.

Appendix C Solving the maximization problem

The region maximizes the discounted flow of utility. Utility is defined over consumption according to $u(C)$. The future is discounted at rate ρ. The maximization program of the region can be expressed with the following present-value Hamiltonian:

$$J = u(C)\exp(-\rho t) + \nu(I_K - \delta_K K) + \mu(I_H - \bar{\delta}_H H) + \omega(AK^\alpha H^{1-\alpha} - C - I_K - I_H)$$

The variable ω is the shadow price of income, while ν and μ are the shadow prices of physical and human capital. The optimal for the controls C, I_K and I_H should satisfy:

$$\frac{\partial J}{\partial C} = u'(C)\exp(-\rho t) - \omega = 0 \tag{9}$$

$$\frac{\partial J}{\partial I_K} = \nu - \omega = 0 \tag{10}$$

$$\frac{\partial J}{\partial I_H} = \mu - \omega = 0 \tag{11}$$

The differential equations for the shadow values of the state variables K and H are:

$$\frac{\partial J}{\partial K} = \dot{\nu} = \omega\alpha AK^{\alpha-1}H^{1-\alpha} - \nu\delta_K \tag{12}$$

$$\frac{\partial J}{\partial H} = \dot{\mu} = \omega(1-\alpha)AK^\alpha H^{-\alpha} - \nu\bar{\delta}_H \tag{13}$$

The transversality conditions are

$$\lim_{t\to\infty} K(t)\nu(t) = 0 \quad \text{and} \quad \lim_{t\to\infty} H(t)\mu(t) = 0$$

From Equations (10) and (11) $\nu = \mu = \omega$. Differentiating Equation (9) with respect to time and substitute for ω from (12) we get the standard condition for choosing consumption over time. Moreover, from (12) and (13) we find that the net marginal product of physical capital should equal the net marginal product of human capital:

$$\alpha AK^{\alpha-1}H^{1-\alpha} - \delta_K = (1-\alpha)AK^\alpha H^{-\alpha} - \bar{\delta}_H$$

This relation defines an implicit function $g(\cdot)$ relating $\frac{H}{K}$ to $\frac{S}{H}$:

$$\frac{H}{K} = g\left(\frac{S}{H}\right) \quad \Leftrightarrow \quad \alpha A\left(\frac{H}{K}\right)^{1-\alpha} - (1-\alpha)A\left(\frac{H}{K}\right)^{-\alpha} = \delta_K - \delta_H\left(\frac{S}{H}\right)^{-\eta}.$$

The function $g(\cdot)$ is unambiguously increasing in its argument. We can now rewrite output at time t as:

$$Y = AK^\alpha\left(K\,g\left(\frac{S}{H}\right)\right)^{1-\alpha} = AK\left(g\left(\frac{S}{H}\right)\right)^{1-\alpha}$$

Output thus obeys an AK production function with an additional factor depending on the stock of inspirations per unit of human capital. Two regions with identical TFP and stock capital can thus differ in output: the one with the highest stock of inspirations will produce more.

In the long-run, however, this relation does not hold anymore. A balanced growth path is characterized by $\dot{C} = \dot{Y} = \dot{K} = \dot{H} = \dot{S}$. $\dot{H} = \dot{S}$ implies that $\bar{\delta}_H H = \delta_S S$, which leads to the long run stock of inspirations per unit of human capital

$$\frac{S}{H} = \left(\frac{\delta_H}{\delta_S}\right)^{\frac{1}{1+\eta}}$$

and

$$\frac{H}{K} = \frac{\delta_H}{\delta_K}\left(\frac{\delta_H}{\delta_S}\right)^{\frac{\eta}{1+\eta}}\frac{1-\alpha}{\alpha}.$$

Analyzing the stability properties of the balanced growth path would involve linearizing a system of equations including the dynamics of inspirations (6). Under the condition $\eta = 0$ (no inspirations), the growth rates of all variables immediately reach their balanced growth path values, and there is no transitory dynamics. In that case, the model behaves like a standard AK model. Using a continuity argument, the dynamics converge to the balanced growth path provided that η is small enough.