

CATHOLIC CENSORSHIP AND THE DEMISE OF KNOWLEDGE PRODUCTION IN EARLY MODERN ITALY*

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Censorship makes new ideas less available to others, but also reduces the number of people choosing to develop non-compliant ideas. We propose a new method to measure the effect of censorship on knowledge growth, accounting for the agents' choice between compliant and non-compliant occupations. We apply our method to the Catholic Church's censorship of books written by members of Italian universities and academies over the period 1400–750. We highlight new facts: once censorship was introduced, censored authors were of better quality than the non-censored authors, but this gap shrank over time and the intensity of censorship decreased over time. We use these facts to identify the deep parameters of a novel endogenous growth model that links censorship to knowledge diffusion and occupational choice. We conclude that the average log publication per scholar in Italy would have been 43% higher if censorship had not been present, while the effect of adverse macroeconomic processes is almost four times smaller. The induced reallocation of talents towards compliant activities explains half the effect of censorship.

Italy's primacy in knowledge creation was undisputed in the fifteenth and sixteenth centuries. However, Northern and Western Europe overtook Italy in the following two centuries, a period in which scholars and the knowledge they produced are believed to have played an essential role in the rise of the West (Mokyr, 2016). The first explanation proposed for such a reversal of fortune is the fight, led by the Catholic Church, against novel ideas (Landes, 1999). The innovations that were targeted for suppression included heliocentrism (Gingerich, 1973), infinitesimal calculus (Alexander, 2014) and atomism (Beretta, 2007).¹ These novel ideas were at the root of the Scientific Revolution in Europe.

In this paper we focus on the role of one weapon in the Church's arsenal, the power to censor books published by scholars. The list of prohibited books is called the *Index Librorum Prohibitorum*. We ask whether this censorship was key to altering the growth path of the generation of new knowledge in the Italian peninsula.

In answering this question we make three contributions. First, we construct a large sample of scholars active in Italy from 1400 to 1750 and we document how the intensity of censorship and the (relative) notability of authors whose books were censored changed over time. Second, we

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The data and codes for this paper are available on the Journal repository. They were checked for their ability to reproduce the results presented in the paper. The replication package for this paper is available at the following address: <https://doi.org/10.5281/zenodo.8095574>.

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¹ Probably Newton would have had issues developing his particle theory of light in a country averse to atomism.

use these data to identify the deep parameters of a novel model linking censorship to knowledge diffusion, accounting explicitly for agents' endogenous selection into compliant versus non-compliant activities. Third, we perform a counterfactual experiment to assess quantitatively the contribution of censorship to the decline in total publications per scholar in Italy.

In the first part of the paper, we present a database of Italian scholars active in the academies and universities from 1400 to 1750. For each scholar, we identify whether their work was censored by the Church. We also measure the 'quality' of each scholar by their quantity of written output registered in today's library catalogues. Using this new database, we document the drop in publications per person over the period 1400–750. Comparing the distribution of the publications per person, we highlight that, in the sixteenth century, the censored authors were of much better quality, on average, than the non-censored authors. Moreover, this difference shrunk over time. The intensity of censorship decreased as well, after it was first introduced in the sixteenth century. This pattern may reflect either a deliberate choice by the best authors to switch from non-compliant to compliant publications, or a change in the Church's policy, or both.

In the second part of the paper, we introduce a structural model linking censorship to knowledge diffusion and productivity growth over the long run. The model explicitly includes the two mechanisms described in the first part. In the model, knowledge is codified in books and can be of two types: conformist and non-conformist. Following the literature on endogenous growth and knowledge diffusion (Kremer, 1993; Jones, 2001; Lucas, 2009; Lucas and Moll, 2014; De la Croix *et al.*, 2018), we assume that authors randomly draw ideas from the stock of knowledge left by the previous generation, retaining the best one. We introduce a novel occupational choice made by printers between printing compliant/conformist books or revolutionary/non-conformist books.² Revolutionary books are less likely to be printed if they are of lower quality than compliant books. We show that, by censoring revolutionary books, the Church can not only reduce the share of people who are pursuing revolutionary ideas, but, more importantly, it can alter drastically the path of knowledge development. Setting up a (costly) censorship apparatus reduces the spread of revolutionary ideas and forces society to converge towards a compliant steady state.

By developing and estimating a structural model we introduce a new methodology to measure the effect of censorship on knowledge growth. We account for the effect of censorship on the availability of books already written, and for its repercussions for the sector and the quality of future knowledge. We do this by modelling the endogenous selection of agents into the compliant versus non-compliant sectors, which depends on past knowledge and censorship. The Church's decision to introduce censorship is also endogenised. Overall, the structure and estimation of the model allow us to build a counterfactual path of knowledge dynamics characterised by the absence of censorship.

In the third and last part of the paper, we use the facts highlighted in the first part to identify the deep parameters of the structural model. The most important parameter, namely the rate of censorship, is intuitively identified by the share of censored authors. The dynamics of the overall quality of authors identify some key technological parameters. The productivity of censored and non-censored authors is implied by the share of censored authors and overall quality. Without targeting these moments in particular, the model matches them well, which gives credence to the model's mechanisms. The fixed cost of imposing censorship is picked to match the timing of the creation of the first index of forbidden books. Simulations show that imposing a

² In a robustness exercise, we also consider the possibility that authors and printers self-censor out of fear of being persecuted under the Inquisition.

censorship rate of 18% on the non-conformist books was sufficient to reduce the share of non-conformist authors from 52% in 1470–550 to 29% in 1680–750. We conclude that the average log publication per scholar in Italy would have been 43% higher if censorship had not been present. Interestingly, half of this effect stems from the induced reallocation of talents towards compliant activities, while the other half arises from the direct effect of censorship on book availability.³ The results are robust to several sensitivity checks, including a model extension that accounts for the imperfect enforcement of censorship on the Italian peninsula (Putnam, 1906). The parameter that governs imperfect censorship is calibrated such that it matches the causal estimates of censorship enforcement in Becker *et al.* (2021).

The effect of censorship on knowledge growth can be contrasted with the impact of adverse macroeconomic shocks that struck the Italian economy over the same period. To model such shocks, we assume that the number of books people can buy is proportional to income per capita. If real GDP per capita had remained constant after 1470 instead of dropping by about 20% (Malanima, 2011), the average log publication per scholar would have been 12% higher. The effect of adverse macroeconomic conditions on knowledge production is one-fourth of the effect of censorship.

Our paper relates to three strands of the literature. First, we add to the existing literature on the effects of censorship. Motivated by the fact that a large share of the world population is currently subject to censorship,⁴ previous research studied how autocratic governments strategically impose censorship (King *et al.*, 2013; Zhuang, 2022) and its effectiveness in stopping the spread of non-compliant ideas (Roberts, 2014). This paper contributes to this literature by proposing a novel method for studying censorship, which accounts for the endogenous selection of agents into compliant versus non-compliant knowledge. On the theory side, Shadmehr and Bernhardt (2015) proposed a model where the ruler can censor media reports to avoid revolts, while citizens might update negatively about a regime when they see no news. Guriev and Treisman (2020) studied the trade-offs between various tools of authoritarian politics such as censorship, propaganda and repression. We contribute to this literature by making endogenous the creation and quality of non-compliant content.

Another strand of the literature explores how government and religious institutions fought against novel ideas in early modern Spain (Vidal-Robert, 2011; Drelichman *et al.*, 2021), Europe (Anderson, 2015; DeWitte *et al.*, 2022; Cabello, 2023), Imperial China (Koyama and Xue, 2015) and the Islamic world (Iyigun, 2015; Chaney, 2016; Rubin, 2017). We differ from these works by distinguishing the effect of censorship from that of the Inquisition. Censorship affects knowledge production by making some ideas unavailable to future generations, while the Inquisition is the enforcement arm of the Church, responsible for punishing heretics. Censorship can be effective even if heretic authors do not risk their lives. This paper is also one of the first works in economics about the effect of Catholic censorship, alongside Becker *et al.* (2021) and Comino *et al.* (2021). Becker *et al.* (2021) studied the effect of censorship on the number of printed books, while Comino *et al.* (2021) focused on the effect of censorship on publishing firms in Venice. Both unravel a causal effect of censorship on publication levels. Both also observe long-lasting dynamic effects of censorship on knowledge accumulation. Instead of taking books or printers as the unit of observation, we focus on scholars and on the decision to comply with the Church's ideology.

³ The effect of censorship is also due to the interaction between (i) its direct effect and (ii) the induced reallocation of talents. We reported the sizes of (i) and (ii), assuming that the effect of the interaction is shared between (i) and (ii) proportionally, according to their relative 'pure' effects.

⁴ According to Freedom House (2017), only 13% of the world population enjoys a free press.

Focusing on authors allows us to weight them by quality, and to study the dynamic effects of censorship on quality via the diffusion of knowledge to future generations in a structural growth model.

Second, our paper contributes to the literature on changes and persistence in institutions and development (Acemoglu *et al.*, 2005b; Johnson and Koyama, 2019; Henriques and Palma, 2023). Closely related to our work, Bénabou *et al.* (2022) focused on the persistence of religiosity in a framework where belief-eroding innovations can be censored, and religious institutions can adapt the doctrine to the new knowledge. Ekelund *et al.* (2002; 2004) studied the behaviour of the Catholic Church before and after the rise of Protestantism by interpreting the Church as an incumbent monopolistic firm. Ours is a dynamic approach to understanding the persistence of the Catholic Church's reach, where decisions to impose censorship depend on the current and future (endogenous) distributions of authors' quality by sector. Our framework allows us to rationalise both the Church's late reaction to the rise of Protestantism and that several books censored in the sixteenth century had circulated freely in the previous centuries.

Finally, this paper relates to the literature on the root causes of the relative decline of Italy. Among the hypotheses regarding the demise of Italy are excessive control by the guilds (Cipolla, 1994), the inability of Italy to seize the new, profitable transatlantic trade routes (Braudel, 1994; Landes, 1999), war and plagues (Alfani, 2013a,b) and the fight of the Catholic Church against novel ideas (Gusdorf, 1969; Landes, 1999). We focus on the latter argument by examining the role of the Catholic Church's censorship on knowledge diffusion. Compared to the literature on knowledge diffusion in the Malthusian epoch (De la Croix *et al.*, 2018), in which craftsmen carry and share knowledge, we model a complementary vector of idea transmissions by focusing on codified/written knowledge. We do not seek to make a direct link between censorship and economic growth, even though recent research highlights the importance of upper-tail human capital for pre-industrial Europe's take-off (Mokyr, 2011; 2016; Cantoni and Yuchtman, 2014; Squicciarini and Voigtländer, 2015).

The remainder of this paper is organised as follows. In Section 1, we present the data sources, and we highlight two novel facts about censorship and scholar quality. In Section 2, we develop a model linking censorship to knowledge diffusion. In Section 3, we estimate the structural model and present its implications for the role of censorship in Italy's accumulation of knowledge.

1. Data

1.1. Academies, Scholars, Publications and Censorship

Our unit of observation is a scholar active in Italy, to whom we will attach publications and, possibly, censorship. The database is built in three steps.

First, we collect information on all scholars who were appointed to an Italian university or were nominated to an Italian academy over the period 1450–750. For universities, the main sources are as follows. An extensive coverage of the University of Bologna is provided by Mazzetti (1847). The University of Padova is covered by Facciolati (1757): we complete its information with the works of Pesenti (1984) and Casellato and Rea (2002). Professors at the university in Rome, Sapienza, were found in Renazzi (1803). Professors at the University of Naples are covered by Origlia Paolino (1754). Pavia is another well-documented university: Raggi (1879) lists all of its professors. Pisa is covered in Fabroni (1791). The smaller University of Macerata also benefits from full coverage by Serangeli (2010). For academies, we use the database 'Italian

Table 1. *Total Number of Scholars and Publications by Period.*

Period	Total number of published scholars					Median number of publications per person				
	1	2	3	4	5	1	2	3	4	5
Europe	421	1,320	3,000	3,863	5,602	27	53	61	59	51
Italy	210	401	773	778	782	72	93	73	40	27
France	54	212	490	731	964	20	83	87	61	62
Germany & Austria	90	489	1,015	1,005	2,069	8	47	59	120	97
Great Britain & Ireland	15	57	174	372	958	15	77	146	210	137
Denmark & Sweden	1	13	56	152	348	5	25	63	57	81
Spain & Portugal	25	99	280	220	201	32	47	33	15	6

Note: Period 1 spans the years 1400–69, period 2 the years 1470–539, period 3 the years 1540–609, period 4 the years 1610–79, period 5 the years 1680–749.

Academies 1525–700, the first intellectual networks of early modern Europe’ made available by the British Library in 2013. Among the academies covered, the Gelati and the Ricovrati are two important ones. We complete these data with Parodi (1983) for the language academy ‘La Crusca’ and with Maggiolo (1983) for full coverage of the biggest academy, the Ricovrati. In [Online Appendices A.3 and A.4](#) we discuss how representative the data are, and how much of the Italian university/academy population is covered. [Figure A.2 in Online Appendix A.2](#) shows an example. Tommaso Dempstero is in the list compiled by Mazzetti (1847) of professors at the University of Bologna. We also find him, under his Latin name, Thomas Dempsterus, in the history of the University of Pisa by Fabroni (1791). Checking the Italian encyclopedia from the Istituto dell’Enciclopedia Italiana (1929), we corroborate the information on Bologna.

Second, we use the Worldcat search engine, which provides references to the collections of thousands of libraries around the world, to assign to each scholar all the written output he/she generated, including post mortem editions. We count the number of ‘publications’, including different editions of the same work. We only record publications by the author, and exclude publications about the author. Worldcat provides a good approximation of the population of known European authors. Chaney (2020) compared the Universal Short Title Catalogue (USTC, 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. [Online Appendix Figure A.2](#) shows the Worldcat page for Thomas Dempster, with the total count of publications (by or about). We can identify the two types of publications by scraping the page. From the graph on the webpage, we can see that all publications are by him. In a third step, we look at the list of forbidden books from De Bujanda *et al.* (1996) and De Bujanda and Richter (2002). We find an entry for Thomas Dempster with a short biography and the list of books that were forbidden, with the date of the corresponding decrees.

We now show some statistics on the number of scholars and on their publications. In [Table 1](#) the period 1400–750 has been divided into five periods of 70 years each. The first line covers all of Europe, from the database built by De la Croix (2021), and includes both universities and academies. The full database can be consulted at <https://shiny-lidam.sipr.ucl.ac.be/scholars/>. Columns (1) to (5) contain the number of ‘published’ scholars per period, i.e., those having some work referenced in Worldcat. Columns (6) to (10) show the median number of publications per person. The second line covers the subset of scholars affiliated to an Italian institution.

The number of publications per person charts the decline of Italy. It is both a relative decline (relative to the rest of Europe), and an absolute decline. Until period 2 (1470–539), published

scholars in Italy produced an output higher than the average European scholar. Then, a reversal appears in period 3 (1540–609) and the gap becomes wide in period 5 (1680–749). The appearance of the gap coincides with the formalisation of censorship, via the first index published by the University of Paris in 1544, and the first Roman Index, also known as the *Pauline Index*, promulgated by Pope Paul IV in 1559 (De Bujanda and Richter, 2002). Note that the Catholic Church also censored scholars who never visited Italy, but the Church struggled to enforce censorship outside Italy (Putnam, 1906).⁵ In [Online Appendix A.6](#), we show that the decline of Italy we highlighted is robust to the way it is measured. The same pattern is observed using the number of scholars per inhabitant, other measures of publications and Wikipedia pages.

Table 1 also shows statistics for individual countries. For countries like France, Germany and Austria, we observe that up to period 2 (1470–540) published scholars produced a similar or lower output than Italy, while a gap appears in the following periods. Note that eventually these countries reach a level of output well beyond that of Italy. A similar pattern can be observed for Great Britain, Ireland, Denmark and Sweden, with the caveat that we have very few observations for these countries in the first two periods. Spain and Portugal are different, as these countries do not overtake Italy. This is not surprising given the intensity of the Spanish Inquisition (Vidal-Robert, 2011).

Table A.1 in [Online Appendix A.5](#) disaggregates the Italian numbers by (important) institutions. The decline from period 3 to period 5 is present in the universities of Bologna, Padua, Pavia, Pisa, Torino, in the two Roman universities and in the Florentine Studium. The academies do better, in particular the Ricovrati, but this is not enough to compensate for the overall decline at the Italian level.

One can argue that the decline in knowledge production in Italy might be because the standard for recognition as a professional scholar declined. If published scholars are positively selected and the barriers to entry weaken, the median quality of scholars goes down. One way to control for this problem is to look at the dynamics of top scholars, who are less affected by changes in the barriers to entry. Hence, in [Table A.6 in the Online Appendix](#), we show that Italy still loses to Europe in terms of knowledge production if we consider only scholars whose longest Wikipedia page (across all languages) is longer than 5,000 characters. Moreover, in [Online Appendix A.8](#) we show that Italy is overtaken by Europe across all the fields of scholarship that we are able to identify, ruling out the possibility that this observation was driven by a composition effect across fields.

1.1.1. *Two features of author censorship*

On May 23, 1555 a new Pope was elected and Cardinal Caraffa became Paul IV. This election heralded the return of the conservatives. In 1559, Paul IV ordered the publication of the first long list of prohibited books, the Index. The concept was refined further by the Council of Trent, which established in 1564 the *Index Librorum Prohibitorum*. The Index comprised three parts. The first part contained the name of the heretical authors whose entire output, past and future, was condemned (*opera omnia*, all the works). The second part contained a list of censored

⁵ Putnam (1906) noted that the other European States also created and enforced their indexes and controlled the press. He also noted that these restrictions were generally less well enforced than the Roman indexes and bore less serious consequences for the production of knowledge, except in Spain, where censorship was carried out with consistency and thoroughness. There were some difficulties enforcing Roman censorship in Italy outside the Papal State, but recent estimates by Becker *et al.* (2021) suggest that it has been applied more widely than previously thought.

publications by authors who still belonged to the Church. The third part dealt with anonymous publications.

The Catholic Church's attempt to control publications is probably the biggest experiment in the history of censorship.⁶ The entirety of ideas accessible to citizens had to be controlled to maintain the predominance of the Church. The Inquisition was responsible for the enforcement of censorship: the punishments for reading and keeping censored books included excommunication, eternal damnation and confiscation of assets, which helped finance the inquisitory apparatus (Maifreda, 2014). Censorship lasted four centuries: the last version of the Index was published in 1948.

The Index was established following a change in the attitude of the Church towards novel ideas, including scientific ones. The Copernicus case best illustrates the reversal of attitude. His concept of a heliocentric system was developed around 1505, and first documented in an unpublished book intended for his friends. The Pope Clement VII learned about these ideas in 1533 and liked them. Several highly ranked clerics asked Copernicus to publish his treaty. One advantage of Copernicus's system was to provide more accurate computations for astronomical events. Then, after the conservative revolution, Copernicus's writings were blacklisted. What appeared to be a legitimate hypothesis in 1543 became in 1616 a foolish thesis, absurd in philosophy, and formally heretic. The Church took more than three centuries to accept heliocentrism and removed Copernicus's works from the Index in 1846.

The Church's fight did not spare the most notable scientists and philosophers who were spreading new ideas all over Italy and Europe. Galileo Galilei was condemned, and his books were censored not only for his astronomical views, but also for his support of atomism. According to atomism, the physical world comprises fundamental, indivisible components known as atoms, violating the Aristotelian view of continuous matter. Atomism and its proponents, such as the French philosopher Descartes, were censored by the Church until at least the beginning of the eighteenth century. In a world where religion and philosophy were intertwined with natural sciences, the aversion towards atomism is likely to have affected scientific knowledge. Perhaps it is not a coincidence that the particle theory of light, which relies on an atomist view of the matter, was developed by Newton and not by an Italian.

The Church's fight had some consequences for thinking about the continuum, indivisibles and the actual infinite. The Jesuits were particularly active in these mathematical controversies, fighting against the idea that a continuous line is composed of distinct and infinitely tiny parts (Alexander, 2014). In his book, Alexander (2014) considered what the world would have been like without infinitesimals. 'If the Jesuits and their allies had had their way, there would be no calculus, no analysis, nor any of the scientific and technological innovations that flowed from these powerful mathematical techniques' (p. 291). Now, this is perhaps exaggerated, and Alexander claims more than he is able to prove. Grabiner (2014) defended the view that seventeenth-century mathematics had far too much momentum and too many demonstrable successes to be stopped by philosophical arguments about the nature of the continuum.

Another landmark of the reversal in the attitude of the Church is the censorship of all the works by, and the burning at the stake of, Giordano Bruno. Bruno had accumulated many reasons to be condemned to death, but one point of his theory that did not fit at all with the Church's view was the theoretical possibility of an infinite universe and a plurality of worlds. Bruno has become the

⁶ Earlier prohibitions were limited in scope and only affected the immediate locality in which the prohibition was issued (Putnam, 1906).

symbol of the scientist persecuted by religious authorities. In other times authors were punished with imprisonment: a notable example is Galilei.

The data in the *Index Librorum Prohibitorum* show that censorship did not always mean that the author faced personal danger. While sometimes, as for Bruno and Galilei, censorship went together with severe consequences for the author, in other cases, the consequences were mild. For example, the poet John Barclay, whose works contained satirical descriptions of the Jesuit school, was listed in the Index in 1608. At the invitation of the Pope himself, he went to Rome in 1616 and resided there until he died in 1621. Moving to Rome was a way to signal that he was a good Catholic and avoid further consequences. Not all of his writings were blacklisted, and he was able to publish again after he was first censored. In other cases, there were no consequences for the author simply because the heresy was identified after her/his death. This is the case of Bernardino Ciaffoni, who died in 1684, but was censored in 1701 because his works contained insulting claims against the Jesuits. Scholars developed different strategies to avoid negative repercussions from their writings. In sum, censorship did not always bring negative consequences for the authors, while posterity paid a premium for complicated access to the revolutionaries' wisdom, at least that embodied in forbidden books.

Being a clergyman did not confer protection against censorship. One particularly striking case is Serry Jacobus Hyacinthus. A professor in Padova, he contributed to the Dominicans-Jesuits controversy on grace, and several of his works appeared in the Index. He was not only a Dominican, but also a member of the *Congregation of the Index*, the body responsible for the creation and management of the Index. Censorship did not spare even the members of the company of Jesus, who had a primary role in the Counter-Reformation. In our database, 10 out of 173 published scholars belonging to the Jesuit university Gregoriana were censored.

We now describe censorship quantitatively. Figure 1 shows how authors belonging to our dataset are distributed according to how many publications they authored. We mark authors who were censored at least once in red, and non-censored authors in green. We provide five histograms, one for each period. Censorship started at the end of the second period, but also affected works that were published in the past. The five histograms show clearly that censorship was concentrated on top scholars for the first two to three periods, and then became more uniformly distributed over the quality of scholars. Or, as we wrote earlier, once censorship was introduced, censored authors were of better quality than the non-censored authors, but this gap shrank over time. For an alternative visualisation of the changing gap in quality between censored and non-censored authors, see Figure A.5 in Online Appendix A.10.

This shift in the identity of who was impacted by censorship reflects behavioural changes. The top scholars who had the potential to publish non-compliant ideas and become famous (as in the first three periods) decided to be more compliant, and published conventional material instead. Bruno, Copernicus and Galilei were at the top of the distribution and were all censored. Their similarly talented successors in the last two periods might have been published as canon law experts⁷ or poets.

We show in Table 2 the key moments of these distributions. It confirms what we expected from the figures: the gap in median publications between censored authors and all authors shrank from about 3.46 to 1.86 (the numbers should be interpreted as the log of the number of publications). The table shows two additional features. First, after the second period, the percentage of censored authors is shrinking over time. Second, overall quality, measured by median publications per

⁷ For example, Michelangelo Ricci (1619–82), initially a competent Roman mathematician, abandoned the study of mathematics for that of canon law, on which he became an authority. See Middleton (1975).

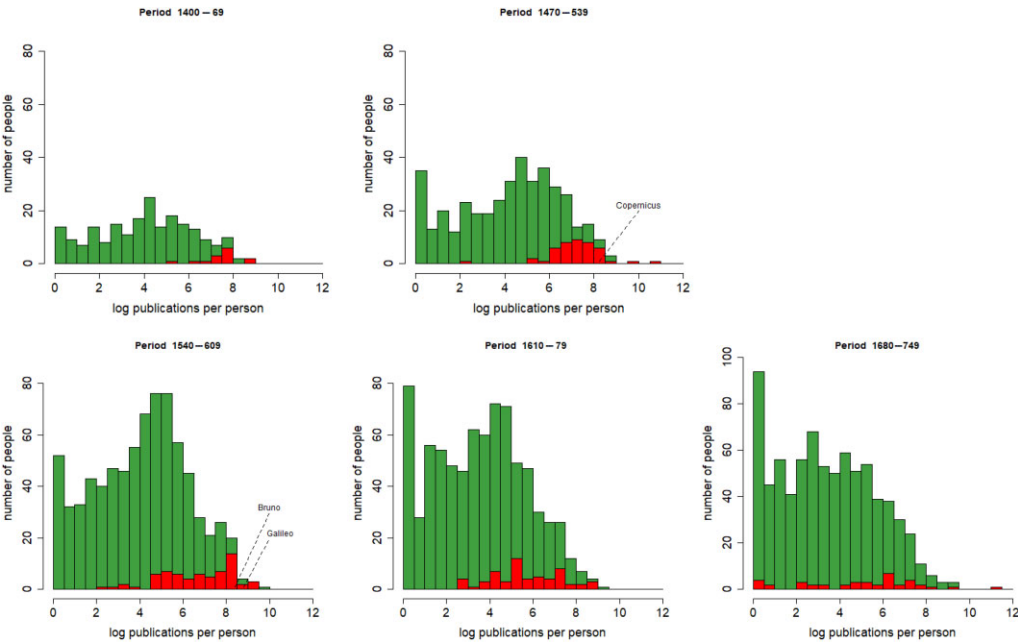


Fig. 1. *Distribution of Published Authors by Quality. Red: Censored. Green: Non-Censored.*

Table 2. *Moments to Fit.*

Moment description	Period				
	1400–69	1470–539	1540–609	1610–79	1680–749
Number of published scholars (all)	210	401	773	778	782
% censored scholars	0.07	0.11	0.08	0.07	0.05
Log publications per scholar (all), median (1)	4.27	4.53	4.29	3.69	3.3
Log publications per scholar (censored), median (2)	7.73	7.07	6.78	5.47	5.16
Gap in median publications (2) – (1)	–3.46	–2.54	–2.49	–1.78	–1.86
Log publications per scholar (all), 75th percentile	5.73	5.98	5.57	5.05	5.15
Log publications per scholar (censored), 75th percentile	7.89	7.91	8.04	7.08	6.75

person, is declining over time as well. This also holds for the top of the distribution, as the 75th percentile also diminishes over the last four periods. Those two trends are very much compatible with the idea of the top innovators’ books becoming progressively compliant and of lower quality over time.

Our data also reveal possible geographical patterns in censorship. Figure 2 shows the place of birth of the scholars in the database, distinguishing the censored (red) from the not censored (green) ones. Geographical coordinates have been slightly randomised, so that people born in cities still appear as distinct points in the diagram. From the map of Italy, we can observe that our data cover the whole peninsula and its islands. Moreover, censorship affects all regions fairly uniformly.

Some members of Italian universities and academies were born outside Italy (as with Thomas Dempster in our example above), so we also constructed a map of Europe. Figure A.6 in Online Appendix A.6 provides a European view of the places of birth of our scholars. Some

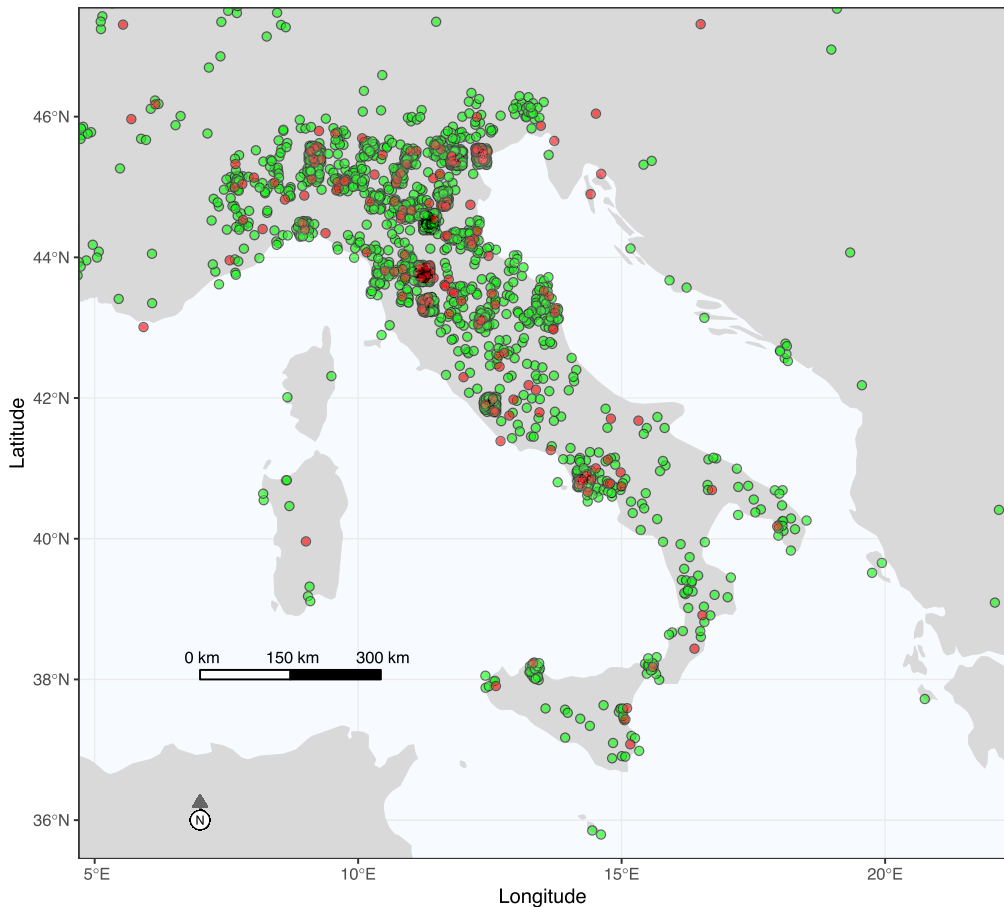


Fig. 2. *Place of Birth of Censored (Red) and Non-Censored (Green) Members of Italian Universities and Academies—Italy.*

of them are foreign or corresponding members of some academies, such as the Ricovrati. They might have never visited Italy, so we use a specific robustness test that excludes those foreigners.

2. Occupational Choice and Knowledge Diffusion

In this section, we build on the theory of accumulation and dissemination of knowledge through the combination of ideas (Kortum, 1997; Lucas, 2009; Lucas and Moll, 2014). We add to this theory a new occupational choice, which can be biased by the presence of censorship. Authors, building on the knowledge created by the previous generation, write books that can be compliant with the Catholic Church's ideology or revolutionary (in the sense of the Humanistic and Scientific Revolutions). Printers decide whether to be active in the revolutionary or compliant sector. They make this choice according to the quality of the books of each type that they encounter. The Catholic Church dislikes revolutionary ideas and might decide to censor them. This would

decrease the share of revolutionary books, and hence their quality, redirecting printers towards compliant books. This distortion alters the accumulation of the total stock of knowledge in the economy.

2.1. Knowledge Diffusion

Time is discrete. At each date t one generation of S persons is alive. Knowledge is embodied in books and books transmit knowledge from one generation to the next. At the beginning of each period, the individuals first learn from μ_t books. Here μ_t is a parameter representing the number of books one can buy during one's lifetime. We let it depend on time to allow changes in μ_t , for example when income or length of life changes. Books include content that is more or less relevant to producing goods and services. A book i has a characteristic h_i drawn from an exponential distribution. Characteristic h_i should be seen as a negative feature, for example the irrelevance of the book. The quality of a book is a decreasing function of its irrelevance, with elasticity θ :

$$q_i = h_i^{-\theta}, \quad \theta \in (0, 1). \quad (1)$$

Books are of two types, which define different distributions from which their relevance is drawn. *Compliant* books, indicated by the superscript C , contain knowledge that is compliant with the ideology of the Catholic Church. *Revolutionary* books, denoted by the superscript R , contain knowledge that is considered heretical by the Catholic Church. Taking examples from Alexander (2014), geometry books would be compliant while books using infinitesimal calculus would be revolutionary. Both of them are of variable quality, which we call relevance. At the beginning of time t , the irrelevance of book i of type j follows an exponential distribution

$$h_i^j \sim \exp(k_t^j) \quad \text{with } j \in \{C, R\}.$$

Note that the scale parameter k_t^j depends on the book type. As the expected value of h_i^j equals the inverse of k_t^j , k_t^j measures the average usefulness of knowledge in sector j .

Since the irrelevance of books is exponentially distributed and given (1), the distribution of book quality follows a Fréchet distribution; see [Online Appendix C.1](#). The distribution of book quality represents the technology frontier. The median ($Q_2(q^j)$) and third quartile ($Q_3(q^j)$) of book quality, used in the estimation, are

$$Q_2(q^j) = (k^j)^\theta [\log(2)]^{-\theta}, \quad Q_3(q^j) = (k^j)^\theta [\log(4/3)]^{-\theta}, \quad \text{with } j \in \{C, R\}.$$

The number of revolutionary books that each agent will read in $t + 1$ depends on their availability in bookshops. The share of printers that produced revolutionary books in the previous generation is denoted by m_t . Therefore, an individual will read $\lfloor \mu_{t+1} m_t \rfloor$ revolutionary books and $\lfloor \mu_{t+1} (1 - m_t) \rfloor$ compliant books, drawn from their respective distribution. Each individual s retains the best book coming from each of the two distributions. Formally, the process of retaining the best books by sector is described as

$$\hat{h}_s^C = \min\{h_1^C, \dots, h_{\lfloor (1-m_t)\mu_{t+1} \rfloor}^C\}, \quad \hat{h}_s^R = \min\{h_1^R, \dots, h_{\lfloor m_t\mu_{t+1} \rfloor}^R\}.$$

For the sake of simplicity, from now on we will approximate $\lfloor (1 - m_t)\mu_{t+1} \rfloor$ and $\lfloor m_t\mu_{t+1} \rfloor$ to $(1 - m_t)\mu_{t+1}$ and $m_t\mu_{t+1}$, respectively, so that we can proceed with our analysis treating the number of books read as a continuous variable. As the exponential distribution satisfies the

minimum stability postulate, we have

$$\begin{aligned} \min\{h_1^C, \dots, h_{(1-m_t)\mu_{t+1}}^C\} &\sim \exp(k_t^C(1-m_t)\mu_{t+1}) \\ \text{and } \min\{h_1^R, \dots, h_{m_t\mu_{t+1}}^R\} &\sim \exp(k_t^R m_t \mu_{t+1}). \end{aligned}$$

Hence, the distribution of the actual relevance of the best book read by person s follows

$$\hat{h}_s^j \sim \exp(b_{t+1}^j) \quad \text{with } j \in \{C, R\},$$

where b_{t+1}^C and b_{t+1}^R are defined as

$$b_{t+1}^C = k_t^C(1-m_t)\mu_{t+1}, \quad b_{t+1}^R = k_t^R m_t \mu_{t+1}.$$

Later in life, generation $t+1$ writes new books, combining their inherited knowledge with a new idea. This new idea is drawn from a distribution whose scale parameter depends on the average quality of the books they have read:

$$h_{sN}^j \sim \exp(\nu b_{t+1}^j) \quad \text{with } j \in \{C, R\}.$$

Taking the best of their acquired and new knowledge leads to a book with irrelevance distributed as

$$\tilde{h}_s^j = \min(h_{sN}^j, \hat{h}_s^j) \sim \exp((1+\nu)b_{t+1}^j).$$

We can now summarise the dynamics of the two types of knowledge by the dynamics of the scale of their distribution:

$$k_{t+1}^C = (1+\nu)k_t^C(1-m_t)\mu_{t+1}, \quad (2)$$

$$k_{t+1}^R = (1+\nu)k_t^R m_t \mu_{t+1}. \quad (3)$$

2.1.1. Occupational choice

We now define how the share of printers producing revolutionary books evolves over time. We suppose that printers have to decide whether to be active in the compliant sector or in the revolutionary sector at the beginning of their activity.⁸ Once they have chosen a sector, they would print any author they meet randomly. They will thus determine their sector of activity based on the first author s they meet. This author has written two book projects of relevance $\tilde{h}_s^C$ and $\tilde{h}_s^R$. Only one of these two book projects will be printed: the printed book will have quality q_i^C or q_i^R , according to which book project was chosen. There are $2S$ book projects, which reduces to S books actually printed. Printers decide their sector, taking into account the relative relevance of the two books. Printers also take into account the fact that customers of the bookshop might value differently two books with the same quality that belong to two different sectors. This might happen because of consumer preferences or because of the way in which book quality translates into consumption goods. We summarise these two effects assuming that the relative price at which revolutionary books are sold is represented by p . Using the properties of the exponential distribution (see [Online Appendix C.3](#)), we can write a closed-form expression for the probability that the revolutionary book is best:

$$\text{Prob}\{q_i^C < p q_i^R\} = \text{Prob}\{\tilde{h}_s^C > p^{-1/\theta} \tilde{h}_s^R\} = \frac{b_{t+1}^R}{b_{t+1}^R + b_{t+1}^C p^{-1/\theta}} = m_{t+1}. \quad (4)$$

⁸ Suggestive evidence of this choice by Venetian printers is offered by Comino *et al.* (2021).

Using the law of large numbers, this probability also defines the share of printers active in the revolutionary sector m_{t+1} . From now on we refer to $\hat{p}$ as $\hat{p} = p^{-1/\theta}$.

Since $k_{t+1}^j = (1 + \nu)b_{t+1}^j$, (4) can be written as

$$m_{t+1} = \frac{k_{t+1}^R}{k_{t+1}^R + \hat{p}k_{t+1}^C}. \quad (5)$$

The dynamics of knowledge quality (2) and (3), together with the occupation choice (5) and initial conditions k_1^C and k_1^R , determine m_1 and the equilibrium path $\{m_t, k_t^C, k_t^R\}_{t \geq 1}$.

2.1.2. *Censorship*

So far, the Church did not play any role in the model. We now let the Church interfere with the process of occupational choice by imposing a rate of censorship on revolutionary books. More precisely, the Church can limit the number of revolutionary titles that an author can read, making unavailable a fraction β of the volumes that she would have read without censorship. Formally, the process of censorship limits the number of revolutionary books that individuals in $t + 1$ encounter during their life to $\mu_{t+1}m_t(1 - \beta)$ and therefore alters the process of accumulation of revolutionary knowledge, which now follows

$$k_{t+1}^R = (1 + \nu)(1 - \beta)k_t^R m_t \mu_{t+1} \quad \text{with } \beta \in [0, 1]. \quad (6)$$

Note that in this way the Church can decrease the current share of revolutionary books m and also make it less likely that revolutionary works will be written in the future. This is because the accumulation of revolutionary knowledge slows down. The law of motion of k_{t+1}^C (see (3)) does not change when the Church imposes censorship on revolutionary books.

The Church could also limit the spread of revolutionary books by persecuting authors and printers accused of heresy. This fact matters for the accumulation of knowledge as authors and printers might decide to self-censor their works to keep themselves safe. The baseline model does not feature self-censorship, but we include this mechanism in a robustness check in [Online Appendix F.3](#).

2.1.3. *The dynamics under an exogenous church's behaviour*

So far, we mentioned that the Church can limit the share of revolutionary books through censorship, but we did not mention how the Church is choosing β . Clearly, the choice of β over time will depend on the behaviour of agents described in the previous section and on the objective of the Catholic Church. On the one hand, the Church wanted to have the smallest possible number of heretical books circulating, to maintain its power. On the other hand, we do not know what prevented the Church from imposing the highest level of censorship in any period. The Church was probably trading off censorship with other motivations. It could have been because the Church was directing attention elsewhere, or because overly harsh censorship could damage the Church itself,⁹ or something else.

Here we treat β as if it were exogenous, and we study the dynamics under this assumption. We start by defining $z = k^R/k^C$: note that the share of revolutionary ideas m can assume one

⁹ As an example, we can think that if the censorship is overly harsh, the Catholic Church might lose status or influence relative to the Protestant Church. This reasoning is plausible if devotees dislike censorship that is too harsh. While rulers had the final say about the religion of their territory, their decision was not completely independent from the common people's beliefs. Protestantism could spread thanks to the invention of the printing press, which aroused popular support by distributing pamphlets (Eisenstein, 1980; Rubin, 2014). Probably it would not be the best choice for a ruler to impose Catholicism if a large majority of the population had already converted to Protestantism.

and only one value given z , which means that once we know the dynamics of either of the two variables, we also know the dynamics of the other. From (5) we get

$$m_t = \frac{z_t}{\hat{p} + z_t}. \quad (7)$$

We decided to make m_t rather than z_t our main variable for describing the model dynamics because its domain is a bounded set. The equilibrium can be summarised in a single equation by the law that governs the dynamics of m . Dividing (6) by (2) side by side, and substituting the resulting z_{t+1} into (7) at time $t + 1$, we get the equation that governs the equilibrium dynamics of m :

$$m_{t+1} = \frac{(1 - \beta)m_t^2}{1 - m_t((\beta - 2)m_t + 2)} = f(m_t; \beta). \quad (8)$$

Equation (8) and an initial m_1 allow us to determine the equilibrium path $\{m_t\}_{t \geq 1}$. The initial m_1 depends on the initial conditions we have imposed on parameter $\hat{p}$ through

$$m_1 = \frac{k_1^R}{k_1^R + \hat{p}k_1^C}.$$

The equilibrium path $\{m_t\}_{t \geq 1}$ satisfies the following result.

PROPOSITION 1. *Given the initial $m_1 \in [0, 1]$, the long-run share of revolutionary authors, $m \equiv \lim_{t \rightarrow \infty} m_t$, is given by*

- (i) $m = 0$ if $m_1 < 1/(2 - \beta)$ (compliant steady state),
- (ii) $m = 1$ if $m_1 > 1/(2 - \beta)$ (revolutionary steady state),
- (iii) $m = m_1$ if $m_1 = 1/(2 - \beta)$ (unstable steady state).

PROOF. See [Online Appendix C.4](#). □

Figure 3 illustrates Proposition 1. On the left, there is no censorship. The two locally stable steady states are 0 and 1. Their basin of attraction is delimited by the unstable steady state $1/2$. On the right, there is a positive censorship rate. The dynamic function is shifted to the right, and the unstable steady state delimiting the two basins of attraction is larger and equal to $1/(2 - \beta)$. The figure depicts a situation in which, for the same initial condition m_1 , dynamics converge to the revolutionary steady state under no censorship $\beta = 0$, but to the compliant steady state with $\beta > 0$.

Note that the path of m_t does not depend on the process μ_t , but quality levels k_t^R and k_t^C do.

2.1.4. The dynamics under an optimising church's behaviour

In the previous subsection, we described the dynamics under a constant rate of censorship β_t . A simple way to go beyond this approach would be to assume a rule of thumb behaviour of the following type: the Church chooses the lowest rate of censorship that allows convergence to a world with no revolutionary ideas. We analysed this case in [Online Appendix C.5](#). This approach has two main shortcomings. Firstly, it makes strong assumptions regarding how the Church trades off the gains and losses of imposing censorship. Secondly, it leaves unexplained the timing of censorship. Here we propose a model that can endogenise the timing of censorship and, most importantly, can explain the features of authors' censorship that we illustrated in

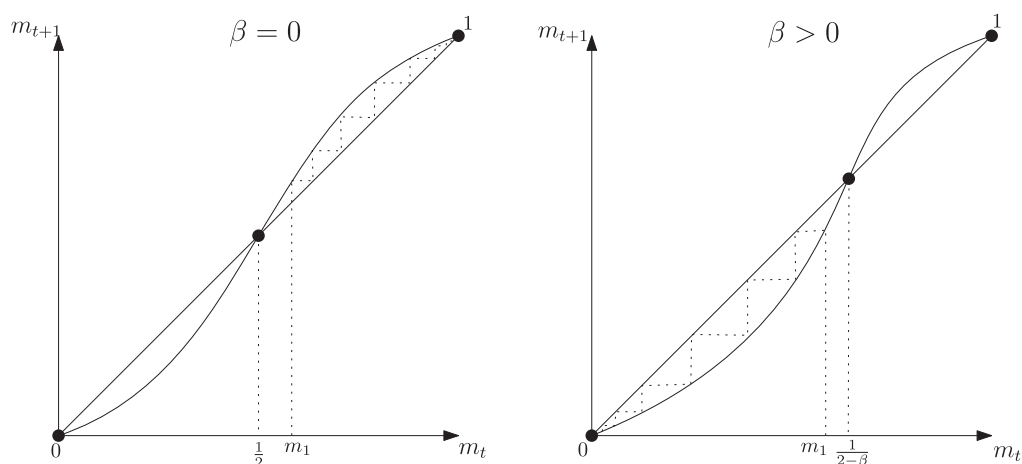


Fig. 3. Dynamics of m_t under No Censorship (Left) and Exogenous Censorship $\beta > 0$ (Right).

Section 1.1.1. We assume that setting up an apparatus capable of creating a list of forbidden books and enforcing its application represented a large fixed cost for the Church. The Church cannot enforce any censorship before having paid a fixed cost ψ . After having paid ψ , it can impose a rate of censorship up to $\bar{\beta}$.

The maximum rate of censorship $\bar{\beta} < 1$ depends on feasibility, but also on political economy considerations. Italy was not a unified state, but was divided into multiple states with their own objectives and relationships with the Church/Papal States. In the presence of a more or less unified market for books, the Church, to be effective in its censorship, had to avoid making too unhappy any of the Italian states. States had available an alternative role of heresy spreader in which they could protect local authors and publishers from persecution. This placed a constraint on the Church's capacity to censor.

The Church cares about the share of compliant books in the economy: its utility function is given by $u(\cdot)$, which is differentiable, bounded and strictly increasing in $1 - m_t$. We write this problem recursively in Online Appendix D.

In Online Appendix D we also show that, when m_1 is large or small enough, the convergence forces to the steady state are so strong that there is no benefit of imposing censorship. Thus, in these cases, setting up a (costly) censorship apparatus is not optimal. Whether it is optimal to impose censorship for intermediate m_1 depends on the model parameters, which we estimate in the next section.

3. Quantitative Results

3.1. Identification Strategy

In this section, we estimate the parameters of the model of knowledge diffusion under the optimising Church's behaviour described in Section 2, using the data and stylised facts described in Section 1. We follow a three-step estimation strategy. The first step is to set one parameter following the literature. The second step is to estimate six parameters using a minimum distance estimation procedure, under the assumption that censorship kicks in mid-sixteenth century, as

Table 3. *Model Periods.*

t	Years	Rate of censorship β	Share of censored authors	μ_t
1	1400–69	0	0	1.000
2	1470–539	0	$m_2\bar{\beta}$	0.878
3	1540–609	$\bar{\beta}$	$m_3\bar{\beta}$	0.787
4	1610–79	$\bar{\beta}$	$m_4\bar{\beta}$	0.828
5	1680–749	$\bar{\beta}$	$m_5\bar{\beta}$	0.851

in the data. The last step is to set one last parameter to match the timing of the introduction of censorship.

Before going into the estimation details, we specify the relationship between model periods and their empirical counterpart; see Table 3. We consider five model periods that correspond to 1400–69, 1470–539, 1540–609, 1610–79 and 1680–749. We made this choice following four criteria. First, we want each period to correspond to an equal number of years. Second, we want to stop in 1750 as the Church might have lost the capacity to censor after this date.¹⁰ Third, we want a year close to 1544 (first edition of the Index) to be the threshold between two consecutive model periods. In this way, we can claim that censorship started in the second of these two periods. Finally, we do not want each period to be too short because the number of authors per period would be small, causing the moments' standard errors to be large. A robustness analysis with 10 periods instead of five is proposed in [Online Appendix F.3](#).

Table 3 shows in parallel the censorship rate and the share of censored authors, to stress that censorship in period 3 affects books written in period 2. The process for μ is taken from the annual GDP per capita series offered by Malanima (2011) and Bolt and van Zanden (2020). We obtain μ_t by averaging GDP per capita over the 70 calendar years corresponding to each model period t . Values are normalised to have $\mu_1 = 1$.

Preset parameter. We set the discount factor δ to 0.06, which corresponds to a quarterly discount factor of 0.99: $0.06 \approx 0.99^{280}$. This parameter's role is minimal: conditionally on censorship starting on $t = 3$, it does not affect dynamics.

Minimum distance estimation. We estimate the vector of six parameters

$$\boldsymbol{\vartheta} = [k_1^C, k_1^R, \theta, \bar{\beta}, \nu, p],$$

using a minimum distance estimation procedure. The parameters are identified by minimising the distance between 14 empirical and theoretical moments, thus implying 8 ($= 14 - 6$) over-identifying restrictions. The first moments are based on the distribution of the quality of all authors, q_{it} , obtained by drawing with probability m_t from the distribution of q_t^R (i.e., a Fréchet($(k_t^R)^\theta, 1/\theta$)) and with probability $(1 - m_t)$ from the distribution of q_t^C . Five moments are the median¹¹ of the quality of all authors $Q_2(q_t)$, and five other moments are their 75th percentile $Q_3(q_t)$. The last four moments are the share of censored authors $m_t\bar{\beta}$ for $t = 2, 3, 4, 5$.

The above estimation problem belongs to the family of the simulated method of moments (McFadden, 1989), a structural estimation technique to be applied when the theoretical moments are obtained from simulating the model. Note that we refrain from targeting separately moments based on censored versus non-censored authors. These moments will rather be used to evaluate the quality of our estimation.

¹⁰ Putnam (1906) claimed that censorship exerted the largest influence between 1550 to 1750.

¹¹ We target the median instead of the mean because it is less sensitive to outliers.

Table 4. *Identification of Parameters.*

Estimated parameters		Value	Standard errors	Target
Compliant knowledge in 1	k_1^C	13.4	1.08	$\Omega(\vartheta)$
Rev. knowledge in 1	k_1^R	102.3	7.82	$\Omega(\vartheta)$
Productivity of books	θ	0.35	0.015	$\Omega(\vartheta)$
Max censorship	$\bar{\beta}$	0.18	0.015	$\Omega(\vartheta)$
Knowledge growth	ν	1.44	0.076	$\Omega(\vartheta)$
Price of rev. books	p	0.5	0.019	$\Omega(\vartheta)$

Our six parameters are expected to influence all moments (except ν , which does not affect $m_t \bar{\beta}$). But we can still think that some moments are more important than others for identifying specific parameters. Parameters k_1^C, k_1^R are identified by moment $m_2 \bar{\beta}$ (which depends on $m_1 \bar{\beta}$ through (8)) and by the median of the distribution of q_{i1} . Parameter ν is identified by the growth rate of overall quality. Parameter p is identified by the average share of censored authors $m_t \bar{\beta}$ over time (see (7)). Parameter $\bar{\beta}$ influences the speed at which m_t converges (see (8)), and is thus identified by the dynamics of the share of censored authors. Parameter θ governs the shape of the Fréchet distribution of knowledge quality and is identified by the 75th percentile of the quality distribution.

Parameter set a posteriori. We set parameter ψ such that censorship starts in $t = 3$, as in the data. Parameter ψ has no impact on knowledge dynamics conditional on censorship starting in a defined year. See [Online Appendix F.2](#) for more details on the calibration of ψ .

3.1.1. Estimation results

We list the identified parameters and their standard errors in Table 4. The estimation delivers $k_1^R > k_1^C$: this implies that the quality of censored authors is higher than non-censored authors, which is consistent with the data even if the relative quality by sector is not among the targeted moments. The productivity of books θ equals 0.35: this is slightly lower than the value (0.5) used by Lucas (2009). Our estimate is lower because the dispersion in log publications is lower than that in earnings observed in modern US data, which is the target used in Lucas (2009). The relative price of revolutionary books p equals 0.5. This ensures that the initial share of revolutionary authors is not too large, even if they have a much higher quality than compliant scholars.¹² Parameter ν ensures that knowledge quality would have kept growing if censorship were never introduced. The rate of censorship $\bar{\beta}$ that the Church imposes equals 18%.

The model fit is reported in Figure 4, upper panels. The simulated variables rarely lie outside the 95% confidence interval of the data moments.

As a test of the theory, we compare our results to empirical observations that were not used to identify the parameters. Looking at the quality of censored q_t^R and non-censored q_t^{NC} authors (Figure 4, lower panels) is particularly interesting.¹³ This is because, from the model's theoretical restrictions, it follows that the observed share of censored authors and overall quality

¹² For example, if p was equal to 1, the share of revolutionary authors would converge to 1 very fast: as a result, the share of censored authors would converge to $\bar{\beta}$ and stay constant, unlike in the data.

¹³ The distribution of quality of censored and revolutionary authors is the same because censorship is random. The distribution of quality of non-censored authors q_t^{NC} is obtained by drawing from the distribution of q_t^R with probability p^{nc} and from the distribution of q_t^C with probability $1 - p^{nc}$, where p^{nc} is the share of *printed* books that are revolutionary.

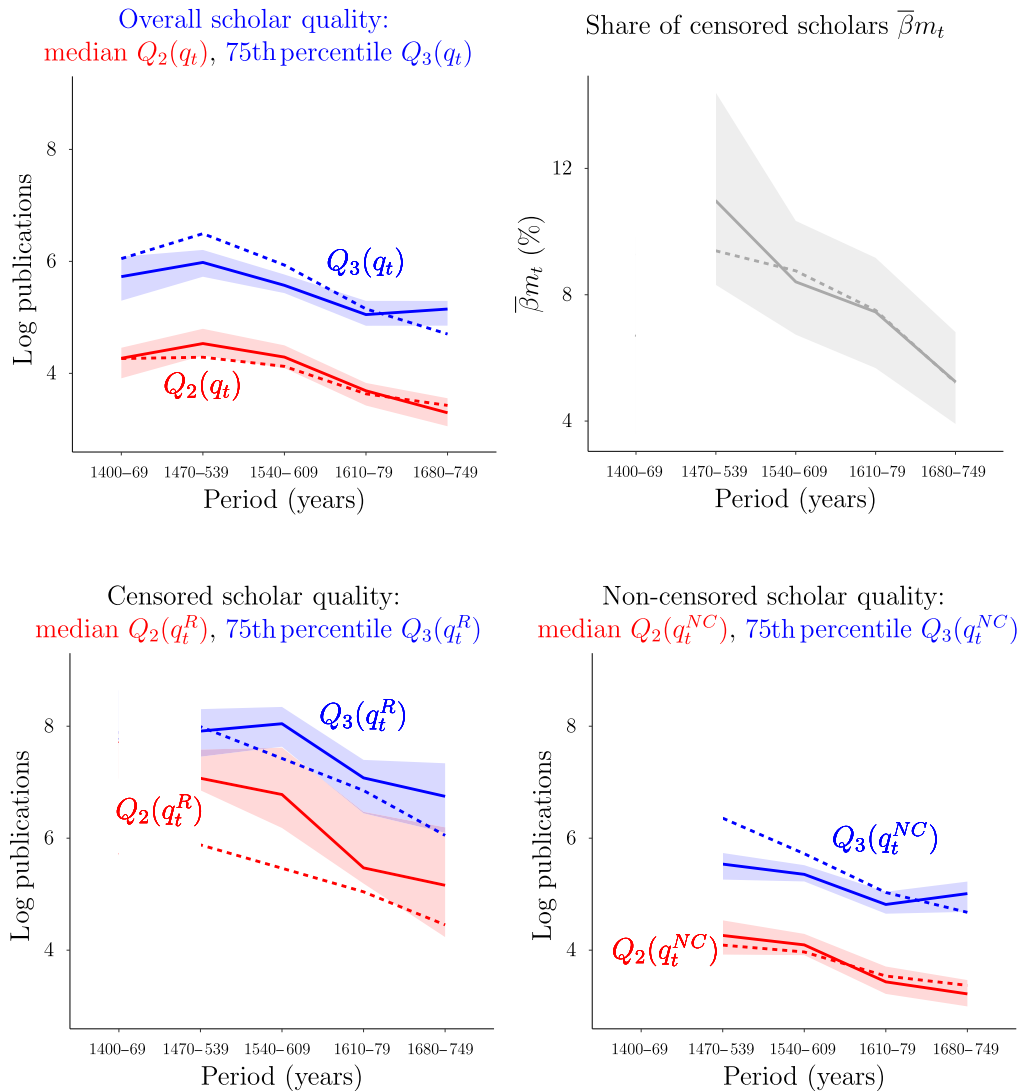


Fig. 4. *Model Fit (Upper Panels) and Over-Identification Checks (Lower Panels). Data (Solid) and Simulations (Dashed).*

imply specific distributions of q_t^R and q_t^{NC} for a given parametrisation.¹⁴ Without targeting these moments in particular, the model matches them well, which gives credence to the model's mechanisms. The model also predicts that the share of revolutionary ideas was increasing before $t = 3$. This is consistent with the fact that the share of censored books was larger in the period

¹⁴ Equation (7) implies that the share of revolutionary authors can assume one and only one value given the ratio of quality in the two sectors k_t^R and k_t^C . Since authors' quality in sector j is strictly increasing in k_t^j , a given level of overall quality and share of censored authors can only be generated by two specific values of k_t^R and k_t^C for a specific parametrisation. Finally, note that k_t^R and k_t^C are the model state variables: their values imply a specific quality of censored and non-censored authors.

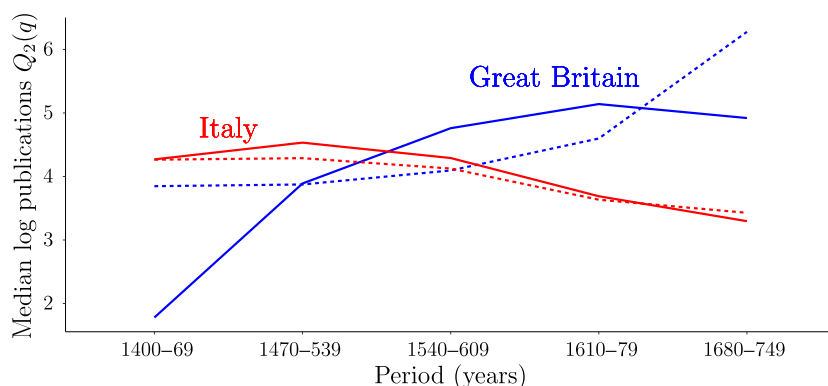


Fig. 5. Median Scholar Quality $Q_2(q_t)$. Blue: Great Britain. Red: Italy. Data (Solid) and Simulations (Dashed).

1470–539 than 1400–69. Moreover, the average difference in quality between censored and non-censored authors decreases from 1.78 in 1470–539 to 1.29 in 1680–749.

As a second out-of-sample test of our theory, we compare the dynamics of publications in Great Britain with model simulations. Data for Great Britain are in [Online Appendix G](#). We simulate the dynamics of publications by decreasing the initial conditions in the state of knowledge (k_1^R , k_1^C) used for Italy by 45% to match the median number of log publications in Great Britain in $t = 2$.¹⁵ The remaining parameters are set equal to those used for Italy, except for $\bar{\beta}$, which is set to 0 (no censorship). We also recompute the process for μ_t using GDP per capita. The results are shown in Figure 5.

Simulations of median log publications in Great Britain are relatively close to their data counterpart, even though we did not use them in the estimation procedure. The model matches the British data well when the initial conditions are set to a level lower than the Italian case. This result supports the claim that the model correctly predicts that Great Britain catches up to and then overtakes Italy through a mix of convergence forces acting in the dynamics of m_t , differences in the exogenous process of μ_t and the presence of censorship in Italy.

3.1.2. The role of censorship in knowledge formation

What is the role of the Catholic Church in the demise of knowledge production in early modern Italy? How much of this effect is driven by selection into the revolutionary/compliant sectors? In this section we answer these questions by comparing model simulations with and without censorship. This is done by setting the rate of censorship $\bar{\beta}$ to 0 in the no-censorship scenario. Figure 6 illustrates the outcomes of the experiments.

Without censorship, the share of revolutionary authors m_t would have kept increasing. It would have reached 62% in $t = 5$, instead of decreasing to 29% in $t = 5$. This fact demonstrates the effectiveness of censorship, which can change the dynamics of revolutionary ideas drastically. Moreover, censorship has the unintended effect of reducing the overall quality of scholars, which would have been 43% higher under the $\bar{\beta} = 0$ scenario.

¹⁵ We consider $t = 2$ and not $t = 1$ because we have fewer than 20 published scholars for $t = 1$.

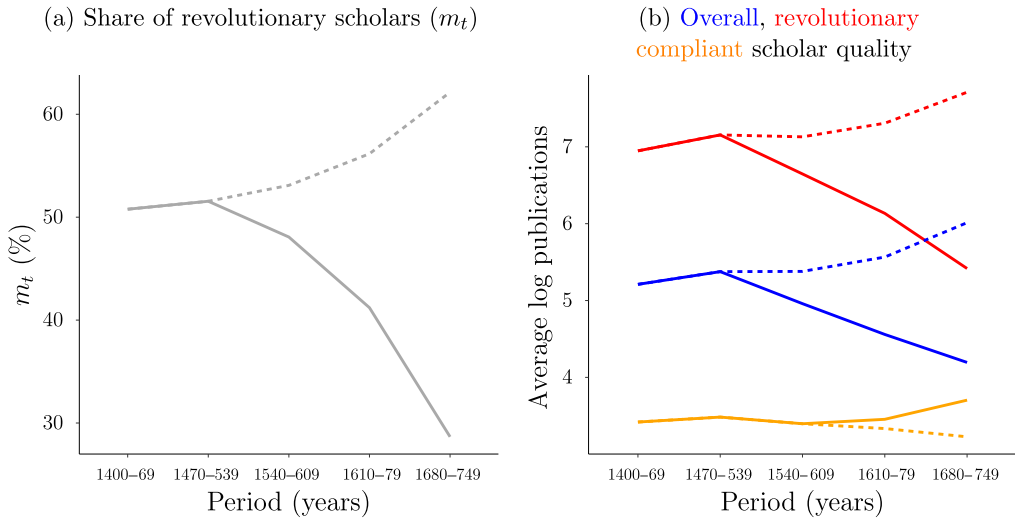


Fig. 6. *Baseline Simulations (Solid) and Simulations without Censorship (Dashed). Share of revolutionary scholars (a), dynamics of log publications (b).*

Becker *et al.* (2021) analysed the effect of censorship on knowledge growth by establishing an empirical correlation between the number of famous people born in, or migrating into, a city and the number of indexed books printed in that city. Here we look at another, complementary, dimension by considering the actual publications of the scholars. Our structural approach also allows us to quantify the effects, and to propose an interpretation of these effects, through the lens of our theory. Of course, in doing so, we impose more restrictions on the data than the reduced-form approach of Becker *et al.* (2021) does.

The loss in the overall quality is driven both by a reduction in the stock of knowledge *within each sector* and by self-selection *across sectors*. This result comes from the following decomposition:

$$\begin{aligned}
 \underbrace{q_5 - \hat{q}_5}_{=-1.82 \text{ (100\%)}} &= \underbrace{\hat{m}_5[q_5^R - \hat{q}_5^R] + (1 - \hat{m}_5)[q_5^C - \hat{q}_5^C]}_{=-1.24 \text{ (68\%); (a)}} \\
 &+ \underbrace{[m_5 - \hat{m}_5]\hat{q}_5^R + [(1 - m_5) - (1 - \hat{m}_5)]\hat{q}_5^C}_{=-1.50 \text{ (83\%); (b)}} \\
 &+ \underbrace{(m_5 - \hat{m}_5)[(q_5^R - q_5^C) - (\hat{q}_5^R - \hat{q}_5^C)]}_{=0.93 \text{ (-51\%); (c)}}. \tag{9}
 \end{aligned}$$

Variables q_5 , q_5^C , q_5^R indicate the average quality of all authors, compliant authors and revolutionary authors under the baseline scenario. The variables with a hat relate to the experiment where $\bar{\beta} = 0$. Equation (9) shows that the self-selection effect exists only if there is a quality gap between the two sectors. Indeed, if $\hat{q}_5^R = \hat{q}_5^C$, the last line is equal to zero, and the fact that printers shift their activity towards the compliant sector does not matter, as the compliant sector delivers the same quality as the revolutionary one.

The effect of censorship due to changes in quality within sectors (the direct effect) is captured by (a) in (9) and accounts for 68% of the overall drop. The self-selection effect (b) accounts for

Table 5. *Authors' Quality at Baseline, without Censorship and without Macroeconomic Shocks.*

		Period (years)				
		1400–69	1470–539	1540–609	1610–79	1680–749
Baseline	Average quality	5.2	5.4	5	4.6	4.2
No censorship	Average quality	5.2	5.4	5.4	5.6	6
($\bar{\beta} = 0$)	Gains w.r.t. baseline (%)	0.0	0.0	8.5	22.1	43.4
No macro shocks	Average quality	5.2	5.6	5.6	5.2	4.7
($\mu_t = 1 \forall t$)	Gains w.r.t. baseline (%)	0.0	4.6	12	15	11.9
Cumulative effect	Average quality	5.2	5.6	6	6.5	7.5
($\bar{\beta} = 0, \mu_t = 1 \forall t$)	Gains w.r.t. baseline (%)	0.0	4.6	21.8	43.6	77.6

83% of the overall drop. This shows that censorship is important as it pushes printers to select compliant knowledge, which has a lower quality. Finally, (c) captures the interaction between effects (a) and (b) and accounts for –51% of the total effect.

To sum up, the effect of censorship on knowledge accumulation is not entirely due to the decline in quality within sectors. The drop in the revolutionary sector is partially compensated by the increased quality within the compliant sector. Half of the effect of censorship on knowledge growth is due to its ability to make compliant ideas relatively more available. Not only are compliant ideas of lower quality than revolutionary ones, but they would have displayed no growth in quality if there was no censorship.

Extensive robustness analysis of these results is provided in [Online Appendix F.3](#). We consider alternative ways to model censorship (imperfect enforcement of censorship, self censorship, time-varying censorship), alternative samples (only Italian born, only Southern/Northern Italian, no corresponding members of academies, universities only), alternative ways to measure scientific output (all publications, length of Wikipedia pages) and alternative model periods (10-period model). We conclude from the robustness analysis that the average log publications per scholar would have been 27%–59% higher (43% in the benchmark) if censorship had not been present.

3.1.3. *The role of macroeconomic shocks in knowledge formation*

In this section we evaluate the role played by macroeconomic factors besides censorship itself in shaping the observed decline in publications. The Italian economy declined substantially over the period under study, as reflected in the drop in GDP per capita reported in the literature. This literature on Italy's relative decline and failure to lead the transition to modern growth highlights adverse macroeconomic processes, such as the shifting trade routes in favour of Atlantic harbours (Braudel, 1979; Acemoglu *et al.*, 2005a), which would almost certainly show up in the key measure of productivity we use.

To contrast the effect of censorship on knowledge growth with the impact of adverse macroeconomic shocks hitting the Italian economy over the same period, we run a counterfactual simulation under the assumption that the process for μ_t was constant over time. Hence, instead of dropping by 20%, the number of books read (bought) by households stays constant in this counterfactual. This helps knowledge to grow as authors acquire ideas from more books. The results are shown in Table 5.

Shutting down the source of adverse macroeconomic shocks translates into moderately higher average quality as early as period 2. The gains peak at 15% in period 4, and equal 12% in period 5 (there was indeed a small recovery in μ_t from period 4 to 5). Those effects are relatively important in the first three periods, but appear small compared to the gains obtained under no censorship in

Table 6. *Different Processes for μ_t .*

t	Years	Mean age at death	μ_t (GDP per capita)	μ_t (mean age at death – 18)
1	1400–69	68.26	1.000	1.000
2	1470–539	64.03	0.878	0.916
3	1540–609	65.17	0.787	0.939
4	1610–79	64.83	0.828	0.932
5	1680–749	69.86	0.851	1.032

periods 4 and 5. Overall, the effect of censorship on knowledge production is between three to four times the effect of adverse macroeconomic conditions.

In Table 5, the final rows illustrate the combined effect of removing both censorship and adverse macroeconomic shocks. Notably, the total effect is greater than the sum of the individual partial effects. This indicates that macroeconomic shocks have amplified the negative impact of censorship, leading to an even greater reduction in the publication output of scholars.

3.1.4. *The role of demographic shocks in knowledge formation*

In the above estimation we modelled the process for μ_t as an income process, following the path of GDP per capita. Higher income makes it possible to buy more books. An alternative interpretation of μ_t is in terms of time available to read books. The total number of books one can read during one’s life should be proportional to the length of life. In that case, μ is affected by epidemiologic processes, such as the plagues of the seventeenth century, considered important for understanding the decline of Italy (Alfani, 2013a,b). To consider this hypothesis, we compute the mean age at death of our scholars by period. We assume that the time available for reading is proportional to the mean age at death minus 18 (assuming that one does not read scholarly books before the age of 18). Table 6 shows the values for the mean age at death and compares the new process for μ_t to the baseline one. Mean age at death and GDP per capita have a similar U-shaped pattern. However, the shock appears weaker when one considers life expectancy compared to when one considers GDP per capita.

Taking as baseline a simulation where μ_t takes the values in the last column, we find that the gains of keeping life expectancy constant peak at 5% in period 4 and are negligible in period 5. We conclude that the effect of censorship on knowledge production is considerably stronger than the effect of adverse longevity conditions.

Of course, the drop in per-capita GDP and the drop in longevity are not independent phenomena—adding up these effects means providing an upper-bound limit of the ‘non-censorship’ effects on book production. Using as macro shocks the product of the last two columns of Table 6, we find that the gains of keeping macro shocks constant reach 20% in $t = 4$, instead of 15% when μ_t follows GDP per capita alone. The gains equal 13% in $t = 5$ (instead of 11.9%).

The above simulation only considers the effects of longevity on the demand side of the market for books. Longevity can also affect the supply side, by reducing the time available to authors to write books. This aspect is absent from the model, but we can get an idea of its size using the data. In Online Appendix H, we quantify this channel in two steps. First, we calculate the marginal effect of living one additional year on the mean, median and 75th percentile of the log publications of European scholars. We find a highly significant effect, according to which one more year of life increases the log median publication by 0.019. Second, we adjust the baseline

Table 7. *Mean Log Publications per Scholar and the GBR-ITA Gap.*

Data			$\beta = 0$		$\beta = 0$ and $\mu_t = 1$	
GBR	ITA	ITA/GBR (%)	ITA	ITA/GBR (%)	ITA	ITA/GBR (%)
1.97	4.09	208	4.09	208	4.09	208
3.76	4.24	113	4.24	113	4.44	118
4.26	4.08	96	4.43	104	4.97	117
4.71	3.55	75	4.33	92	5.09	108
4.66	3.4	73	4.88	105	6.04	130

distributional moments by adding the marginal effects above times the deviation of aggregate longevity from its value in period 1. That is, we calculate what the scholars' publications would look like if Italy did not experience the drop in longevity. We conclude that the drop in longevity experienced by Italy over the period 1470–680 led scholars to publish less, reducing the median log publications by 2% at most. Hence, the supply side effect of the drop in longevity is there and is highly significant, but quite small.

Finally, we investigate whether the loss of population generated by wars and plagues, highlighted by Alfani (2013a), might have produced a demographic shock affecting the dynamics of knowledge production. We focus on urban population as it is more directly related to knowledge formation than the total population. We use two datasets described in Online Appendix I. In the most pessimistic case, we observe a drop in the urban population between 1600 and 1650 of 7.7%. This drop is however short lived and the population recovered and even overtook its previous level by 1750. Hence, one cannot expect stronger effects using urban population instead of longevity to measure the demographic shock.

To summarise the role of demographic shocks, it is likely that they affected knowledge production during the seventeenth century, by reducing longevity and/or the size of the urban population. However, they cannot explain why the quality of authors remained so low in our last period (1680–750), when both longevity and population had recovered. Instead, censorship removed books from libraries and depressed quality *every year* over most of the period (with diminishing enforcement in the last decades), and is therefore able to explain the dramatic cumulative effect on quality we observe in the data.

To summarise our simulation analysis, we have compiled a table (Table 7) comparing the publication output of scholars in the UK (GBR) and Italy (ITA). The first two columns display the average number of publications per scholar in each region, measured using a logarithmic scale. The third column presents the ratio between the two averages, which illustrates the trend of GBR catching up to ITA before overtaking it. To better understand this trend, we also analysed the effect of removing censorship from the data in Table 5 for the Italian region. By imputing this effect into the actual data, we recalculated the ITA/GBR ratio, which shows that Italy is not falling behind when censorship is removed. Finally, we considered the combined effect of removing censorship and shutting down macroeconomic shocks. In this scenario, the last two columns of the table show that Italy maintains a slight lead over the UK.

4. Conclusion

Censorship has a direct effect on knowledge accumulation by making censored material less available to scholars. It also discourages writers from engaging in non-compliant work, and hence

modifies the allocation of talents across different types of activities. In this paper, we developed a new method that encompasses these two channels. Then, we applied it to the Catholic Church's censorship from the Counter-Reformation to the Enlightenment. We investigated whether censorship was responsible for the demise of Italian science and evaluated the relative importance of the direct channel versus the activity choice channel.

Our analysis had three steps. First, we collected data on members of universities and academies, identifying the scholars whose books were either allowed to be printed and sold, or were put in the *Index Librorum Prohibitorum*, i.e., censored. Second, we built a theoretical model of knowledge accumulation through book production and censorship, distinguishing non-compliant knowledge (susceptible to being censored) from compliant knowledge. Third, we estimated the structural parameters of the model using facts collected from the dataset. We used the quantitative model to answer our questions by simulating a counterfactual path of knowledge dynamics characterised by the absence of censorship.

We conclude that the average log publication per scholar in Italy would have been 43% higher in 1680–749 if censorship had not been present. Renaissance Italy is regarded as the cradle of culture and science. Yet, Italy found itself in a scientific backwater during the seventeenth and eighteenth centuries, being overtaken by non-Catholic countries such as Great Britain and the Netherlands. The sizeable effect that we estimated supports a claim that the Church's censorship was one of the main drivers of Italy's decline.

Half of this drop stems from the induced reallocation of talents towards compliant activities, while the other half arises from the direct effect of censorship on book availability. This result stresses the importance of selection effects when analysing the impact of censorship on output. The top scholars at the time of the Counter-Reformation were censored (Bruno, Galilei, Copernicus), and their potential successors might have been published as compliant poets instead.

Finally, one may wonder whether the Church's censorship also had a role in the *economic* decline of Italy. This is not implausible, given that recent research highlighted the role of upper-tail human capital production in pre-industrial Europe's take-off (Mokyr, 2011; Cantoni and Yuchtman, 2014; Squicciarini and Voigtländer, 2015; Mokyr, 2016). Our analysis sets the stage for future research on this topic by directly linking the Church's censorship to upper-tail human capital production.

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Additional Supporting Information may be found in the online version of this article:

Online Appendix Replication Package

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