

Flora, Cosmos, Salvatio: Pre-modern Academic Institutions and the Spread of Ideas Supplementary Material

David de la Croix* Rossana Scebba† Chiara Zanardello‡

October 20, 2026

1 Acknowledgements

We are grateful to Jacob Schmutz for his help in dealing with scholasticism, to Matteo Cervellati for highlighting the interpretation of our network as not requiring compliance, to Debin Ma for discussing the Chinese Malthus, to Kerstin Enflo for introducing us to Rudbeck and his view on Atlantis, to Sascha Becker, Margherita Fantoli, Violet Soen, Fabio Mariani, Cecilia Garcia Peñalosa, Yann Bramoullé, Catarina Chiopris, Nathan Nunn, Stelios Michalopoulos, Klaus Desmet, Ralf Meizenzhals, Paula Gobbi, Luca Pensieroso, Joachim Voth and to the participants to the Fresh workshop (Louvain-la-Neuve, June 2024) “Institutions, human capital, and long-term development: Lessons from pre-modern Europe”, to the XII H´eloise workshop (Warsaw, September 2024) “From East to West and Back: Circulations of Knowledge in Pre-Modern and Modern Europe - Actors, Institutions, and Spaces”, to the Guerzensee CEPR workshop, to the conference on Deep-Rooted Factors in Comparative Development (Brown, 2025), and to the Cesifo summer conference in Venice. We also thank the participants to seminars in Namur, Heidelberg, Oxford, Warwick, Lille, Belfast, Naples (Parthenope), Marseille (workshop LORDE 2025), CERGE Prague, Rotterdam, and Alice Fabre for her discussion at LORDE 2025.

2 Bipartite representation

This network is derived from an initial bipartite representation, consisting of two types of nodes: scholars and institutions. In the bipartite version, edges connect scholars to the

*IRES/LIDAM, UCLouvain & CEPR, Paris.

†University of Antwerp.

‡Institute for Advanced Study in Toulouse (IAST). Toulouse School of Economics, Universite Toulouse Capitole, Toulouse, France.

institutions they were affiliated with. Since our focus is on scholar-to-scholar interactions, we project this bipartite graph onto a single-mode network of scholars, where an edge between two nodes represents their concurrent affiliation with the same institution, as shown in Figure 1.

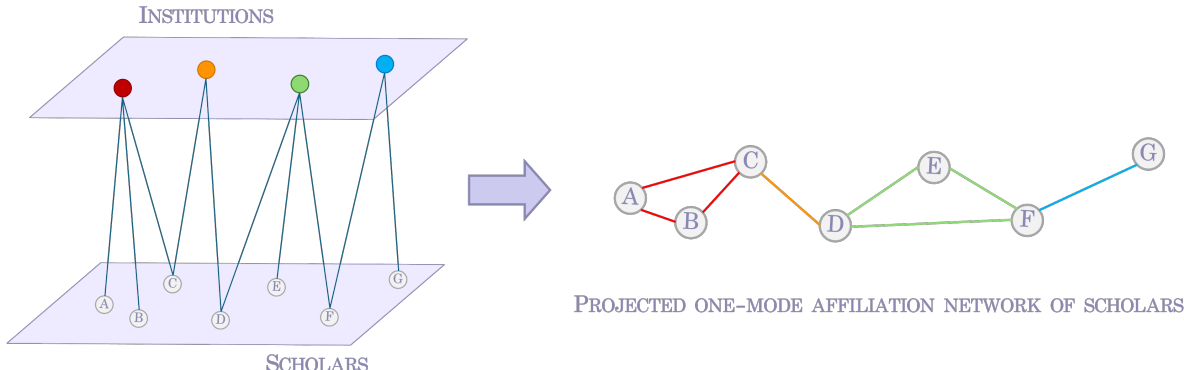


Figure 1: Intuitive representation of network projection: from a bipartite or two-mode graph to the one-mode affiliation network of scholars. Diagram inspired by Geraerts and Vasques Filho (2024).

3 Additional descriptive statistics

3.1 Universities, academies, scholar over time

Figure 2 and Figure 3 show the number of scholars over time of the top-10 universities and academies ranked by size in 1793, respectively. By the end of the period, Cambridge is the most populated university and the Royal Society the most populated academy. Tables 1 and 2 report detailed descriptive statistics for each institution.

4 Contextual information

4.1 Botanical Realism and botanic gardens

In Europe, natural history traces its roots back to ancient Greek philosophers such as Aristotle, Theophrastus, and Dioscorides. During the Scientific Revolution, botany underwent major advancements, transitioning from a primarily descriptive field into a more systematic and experimental science. By the 16th and 17th centuries, botany started encompassing not only the identification and classification of plants species, but also the growing field of plant physiology, investigating the properties and functions of plants life. This marked a shift in botanical practices, expanding beyond the descriptive and illustrative focus of ancient authors (Applebaum 2003), towards a more empirical approach that we will refer to as

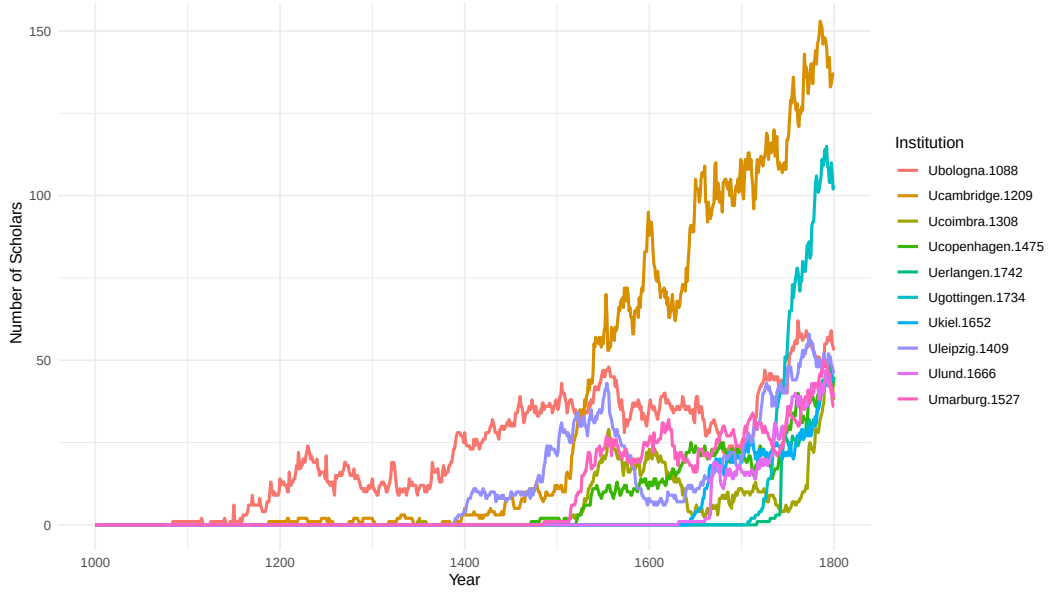


Figure 2: Number of university professors between 1000 and 1800 of the top 10 universities considering the number of scholars in 1793. In the legend, the name of the institution with the foundation date.

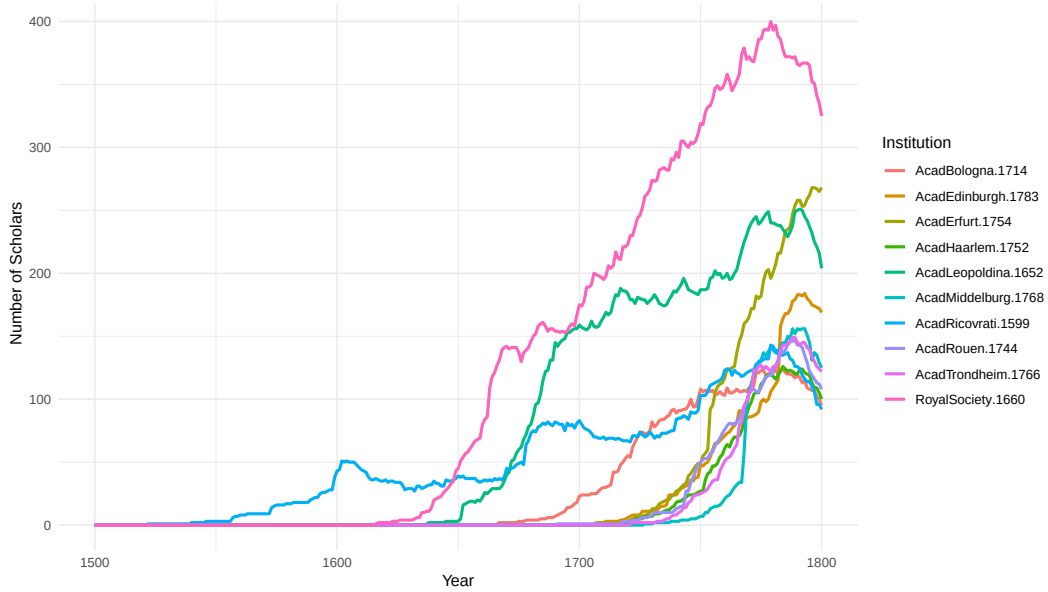


Figure 3: Number of academicians between 1500 and 1800 of the top 10 academies considering the number of scholars in 1793. In the legend, the name of the institution with the foundation date.

Institution	Mean	Median	SD	Min	Q1	Q3	Max
Ubologna.1088	34.14	37	13.02	14	26.5	41	53
Ucambridge.1209	69.57	105	60.38	1	8.5	113.5	137
Ucoimbra.1308	8.29	4	13.70	0	0	8	38
Uerlangen.1742	9.71	0	17.38	0	0	12.5	43
Ugottingen.1734	22.86	0	41.23	0	0	28.5	103
Ukiel.1652	12.71	4	16.66	0	0	20.5	44
Ucopenhagen.1475	17.57	22	17.45	0	1	27	45
Uleipzig.1409	21.29	20	19.17	0	7	33.5	48
Ulund.1666	13.14	1	17.67	0	0	25.5	40
Umarburg.1527	16.43	18	16.35	0	0.5	30	36

Table 1: Descriptive statistics for the top 10 universities, considering the number of scholars in 1793. In the first column, the name of the institution with the foundation date. “SD” stands for Standard Deviation, “Min” for minimum, “Q1” for first quartiles, “Q3” for third quartiles, and “Max” for maximum.

Institution	Mean	Median	SD	Min	Q1	Q3	Max
AcadBologna.1714	32.29	0	48.17	0	0	59	108
AcadEdinburgh.1783	31	0	63.43	0	0	24	169
AcadErfurt.1754	45.29	0	99.89	0	0	24.5	268
AcadHaarlem.1752	18.14	0	37.47	0	0	13.5	100
AcadLeopoldina.1652	79	3	98.48	0	0	173	204
RoyalSociety.1660	123.43	45	149.10	0	0	247	325
AcadRicovrati.1599	45.29	39	46.78	0	0	87.5	103
AcadRouen.1744	22.71	0	41.94	0	0	25.5	108
AcadTrondheim.1766	21	0	45.50	0	0	12.5	122
AcadMiddelburg.1768	18.86	0	46.88	0	0	3.5	125

Table 2: Descriptive statistics for the top 10 academies, considering the number of scholars in 1793. In the first column, the name of the institution with the foundation date. “SD” stands for Standard Deviation, “Min” for minimum, “Q1” for first quartiles, “Q3” for third quartiles, and “Max” for maximum.

“Botanical Realism”. Before 1650, botany was considered merely a complement to medical studies, but it became an independent field of study during the Scientific Revolution. Universities renowned for their medical faculties began offering innovative botany lectures, where students were taken directly to gardens to observe plant species first-hand. These universities were also the first to establish their own botanic gardens to support further research and development in botany. Following this trend, private citizens and local lords also recognized the importance of botanical studies and funded the creation of such gardens (Applebaum 2003).

One key figure in this transformation was Leonhart Fuchs, a German physician and botanist. He is best known for his book *De historia stirpium commentarii insignes*, which translates to “Notable commentaries on the history of plants”. First printed in Basel in 1542, one year before Nicolaus Copernicus’ *De revolutionibus orbium coelestium* and Andreas Vesalius’ *De humani corporis fabrica*, this work laid the foundation for modern botany. Fuchs not only provided ideal visual representations of 511 plant species, but he also included his own critical observations on their uses and characteristics, highlighting differences from ancient texts (Applebaum 2003). Figure 4 shows a page of this book, emphasizing the realistic description of a plant.



Figure 4: A page of *De historia stirpium commentarii insignes*

Furthermore, we gathered information on the existence and founding dates of European botanic gardens. Our starting point was the first annual report of the Montreal Botanic Garden (1886), which lists the botanic gardens open worldwide in 1885. From this, we selected only European gardens and determined their founding dates using AI-assisted tools, which were then manually verified through sample checks. We then matched this sample of botanic gardens with our university cities, assuming that a city without a botanic garden was not listed in the first annual report by Montreal Botanic Garden (1886). To fix ideas, Figure 5 shows the *Hortus botanicus* (botanic garden) of the University of Leiden, which was opened in 1590. This is a case of a large garden with a dedicated building, but some other gardens were much smaller.

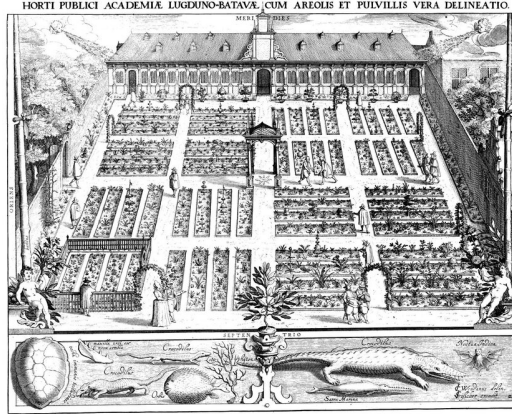


Figure 5: The Hortus botanicus of Leiden

4.2 Mathematical Astronomy and astronomical observatories

The 15th and 16th centuries witnessed a growing interest in experimental science and increasing dissatisfaction with the explanations offered by ancient astronomical authorities, such as Claudius Ptolemy (c. 100–c.170, Alexandria). Similar to the approach seen in Botanical Realism, this paradigm shift led mathematicians and astronomers to question the accuracy of Ptolemy’s models and refine them through observation and mathematical analysis. This era marked the beginning of a mathematical reform in astronomy, characterized by advances in trigonometry, new geometric formulas, and the adoption of decimal calculations. The focus shifted from simply explaining celestial motions to understanding the physical mechanisms behind them.

A key figure in this revolution was Regiomontanus, pseudonym of Johannes Müller. His mastery of Greek and mathematics enabled him to study the original works of Ptolemy and other ancient thinkers. At the University of Vienna, around 1454, he and his mentor, Georg Peurbach (1423–1461), began collaborating on *Theoricæ novæ planetarum*. This seminal work introduced new methods for solving plane and spherical trigonometry problems, including the use of sine and tangent functions. Regiomontanus also created extensive trigonometric tables with values calculated to decimal units, which remained influential for centuries. As such, he can be considered a pioneer of Mathematical Astronomy. While trigonometry had been used in astronomy and other sciences, Regiomontanus’s contributions greatly enhanced its application. His work, alongside Peurbach’s, laid the groundwork for later revolutionary astronomers such as Copernicus, Kepler, and Galileo (Applebaum 2003).

After Peurbach’s death, Regiomontanus moved to Northern Italy, then to Hungary in 1467. Later, he settled in Nuremberg, drawn by its status as a free city and central location. There, he established a workshop and printing press, dedicating himself to the dissemination

of scientific knowledge. In 1463, he published *Epitoma in Almagestum Ptolemaei*, which clarified, corrected, and expanded Ptolemaic astronomy. Two pages of *Epitoma* are shown in Figure 6. In 1472, he published *Theoricæ novæ planetarum*, his collaboration with Peurbach. In 1475, Pope Sixtus IV invited him to Rome to work on calendar reform, but Regiomontanus died shortly after, at age 41.

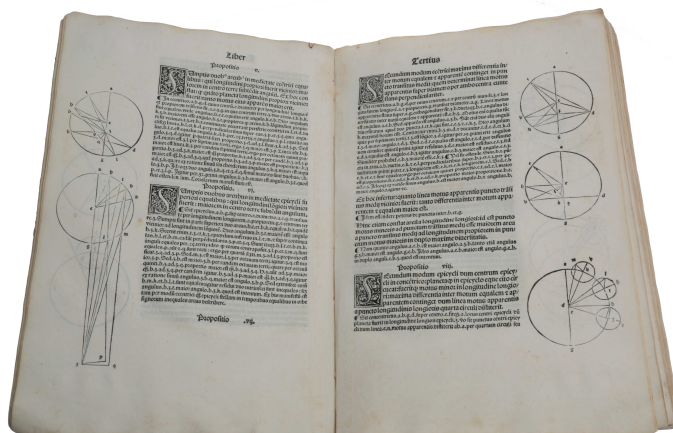


Figure 6: Two pages of *Epitoma in Almagestum Ptolemaei*

We examine the creation of observatories in the same 185 university cities defined in Section 3.2. We collected the names and foundation dates of observatories from *The Greenwich List of Observatories* compiled by Howse (1986). As with the botanic gardens, we only considered observatories in continental Europe, assuming that a location lacked one if it was not listed in our source. To fix ideas, Figure 7 shows the main building of the University of Prague, the Clementinum. There, a tower was built in 1722. Later, in 1751, instruments were installed, and the tower became an astronomical observatory.

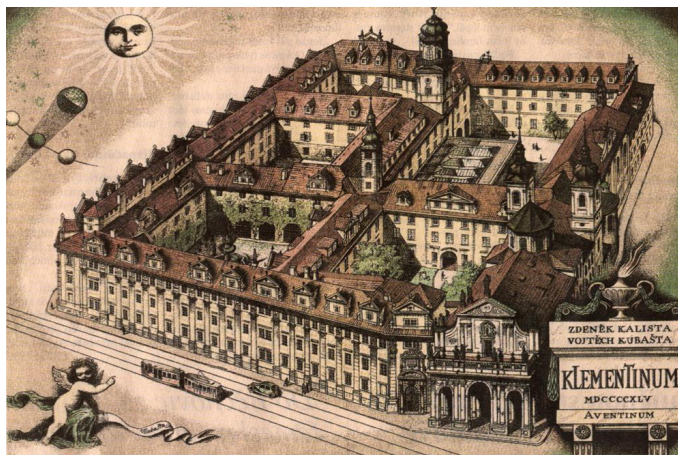


Figure 7: The *Clementinum* in Prague with its observatory

5 Additional applications

This section reports two additional applications of the estimated diffusion model as in Section 4 in the main text. They are not used to estimate the link activation probability; instead, they illustrate how the same framework relates to other historical outcomes and how exposure need not imply adoption or agreement.

5.1 Anti-Judaism and the Persecution of Jews

Our model can propagate not only good ideas, but also bad or even false ones. One such idea is anti-Judaism. The availability of data on Jewish persecutions from Anderson, Johnson, and Koyama (2017) and Jedwab, Johnson, and Koyama (2019) allows us to apply the same approach as in Section 4 in the main text. The roots of anti-Judaism run deep and are widely discussed in the literature. Scholasticism, once again, played a role in rationalizing prejudice against Jews. Thomas Aquinas (1225–1274), one of the most influential scholars at the University of Paris and the intellectual heir of Lombardus, endorsed many prevailing medieval Christian views about Jews. He supported the idea that Jews should live in subjugation as a reminder of their supposed rejection of Christ. In the *Summa Theologiae*, he also discusses Jews in ways that reinforce their marginalization.

The next generation of scholastic theologians, such as John Duns Scotus (c. 1266–1308) and William of Ockham (c. 1287–1347), contributed to the broader scholastic discourse that pathologized Judaism as a theological error (see Abulafia (2011), which provides a substantial discussion of how scholastic theology and legal reasoning shaped Christian–Jewish relations between 1000 and 1300). While these theological ideas do not explicitly advocate persecution, they may have interacted with the mechanisms identified by Anderson, Johnson, and Koyama (2017) and Jedwab, Johnson, and Koyama (2019). In Anderson, Johnson, and Koyama (2017), cold temperatures are shown to increase the probability of persecution of Jewish communities. Jedwab, Johnson, and Koyama (2019) extend this insight, showing that negative shocks more broadly, particularly plagues, raise the likelihood of minority persecution.

To study if there is an association between yearly exposure to scholasticism S_t^c and the probability of violent acts against Jews, we use data from Anderson, Johnson, and Koyama (2017) and Jedwab, Johnson, and Koyama (2019).¹ Building on this literature, we hypothesize that the association between negative shocks and the likelihood of Jewish persecutions is stronger in cities with greater exposure to scholasticism S_t^c . One possible interpretation of this pattern is that, in cities where local priests were more exposed to scholastic teachings and disseminated anti-Judaic arguments, the local intellectual and religious climate was more

1. We thank the authors for sharing the most recent (and still unpublished) version of the pogroms and persecutions data.

receptive to scapegoating Jews in times of crisis. To test this hypothesis, we augment the empirical framework of Anderson, Johnson, and Koyama (2017) by including an interaction term between our measure of scholastic exposure and the incidence of plague outbreaks.

Table 3: Linear Probability Model - Yearly Exposure to scholasticism and cities' probability of persecution of Jews

	Persecutions	
	Replication (1)	S_{ct} x Plague (2)
Temperature $_{c,t-1}$	-0.467*** (0.125)	-0.473*** (0.124)
Plague	5.100* (2.149)	-1.437 (0.984)
Exposure to scholasticism S_{ct}		0.155* (0.064)
Exp. to scholasticism S_{ct} x Plague		5.084*** (1.490)
Controls	✓	✓
City Fixed Effects	✓	✓
Observations	273,878	273,878
R ²	0.013	0.018

Note: *p<0.1; **p< 0.05; ***p<0.01. Standard errors clustered at the climate grid level in parentheses. City fixed effects are always included.

Column (1) replicates Anderson, Johnson, and Koyama (2017) specification (2) Table 3, p.940. Coefficients are multiplied by 100 to represent percentage points.

Controls include a slope variable for the 10 years surrounding the Black Death and a measure of population density as in Anderson, Johnson, and Koyama (2017).

Table 3 presents the results of this panel regression. The dependent variable, Persecutions, takes the value 1 when either an expulsion or another violent act against Jews occurred in a given year, following the definition in Jedwab, Johnson, and Koyama (2019). As in both Anderson, Johnson, and Koyama (2017) and Jedwab, Johnson, and Koyama (2019), we restrict the analysis to cities with a documented Jewish presence.

Column (1) replicates specification (2) of Table 3 in Anderson, Johnson, and Koyama (2017, p. 940). The estimated coefficient on lagged temperature is nearly identical: we find that a one-degree decrease in temperature increases the probability of Jewish persecutions in the following year by 0.467 percentage points, compared to 0.464 percentage points in Anderson, Johnson, and Koyama (2017). Despite this similarity, our sample differs slightly for two main reasons: (i) our dependent variable is drawn from a more recent version of the dataset used by Anderson, Johnson, and Koyama (2017), and (ii) we eliminate duplicate city entries prior to estimation.

Column (2) introduces an interaction between yearly exposure to scholasticism S_t^c at the city level and a dummy variable indicating the presence of a plague, following Anderson,

Johnson, and Koyama (2017). Interestingly, the plague dummy is not statistically significant on its own anymore, while exposure to scholasticism S_t^c is only slightly significant at 10% level. However, their interaction is both statistically and substantively significant. This suggests that the coexistence of a theoretical framework portraying Jews as a threat and a plague outbreak is associated with a significantly higher likelihood of violence against Jews. The coefficient on the interaction term is also sizable: during a plague, a one-unit increase in exposure to scholasticism is associated with a 5.1 percentage point higher likelihood of Jewish persecutions.

5.2 Finding Atlantis: A True Story of Genius and Madness

We now turn to Olaus Rudbeck’s (1630–1702) claim that Sweden was the cradle of civilization and the site of the lost city of Atlantis. It is an interesting case to simulate using our model for two reasons. First, it illustrates that ideas—whether accurate or not—can still spread through affiliation networks, which further underscores the crucial role of institutions in shaping intellectual diffusion. Second, it highlights that individuals do not necessarily need to agree with an idea in order to help propagate it.

Rudbeck, who was professor of medicine at the University of Uppsala from 1658 to 1692 (Von Bahr 1945), claimed that Sweden was in fact the mythical island of Atlantis, and thus the cradle of all ancient civilization. He supported this sweeping theory by drawing connections between the Norse mythology, the Bible, and classical sources. Rudbeck explained his thesis in the book *Atlantica* (also known as *Atland eller Manheim*), first published in four volumes between 1679 and 1702 (King 2005). It was written in Latin (vol. 1) and Swedish (vols. 2–4). *Atlantica* was not fully translated into major European languages during the 18th century. The length, complexity, and eccentricity of Rudbeck’s arguments likely discouraged publishers. His ideas were seen by many contemporaries as extravagant, although some Nordic nationalist thinkers admired them. Despite its eccentricity, *Atlantica* was referenced and critiqued by various 18th-century thinkers, including two academic scholars, Denis Diderot and Ludvig Holberg. They may have been exposed to Rudbeck’s ideas indirectly through the affiliation network, given that they are unlikely to have read his books in Swedish themselves.

Denis Diderot (1713–1784) was a member of the Prussian Academy of Sciences from 1751 (Amburger 1950). Diderot’s radical thinking, conflict with French authorities, and nonconformist personality kept him outside the fold of French academies. In the article *Étymologie* of his *Encyclopédie* (published over the period 1751–1765), Diderot used Rudbeck’s work as a cautionary example of how speculative etymology can lead to erroneous conclusions, critiquing the methodology employed in *Atlantica*. Our simulation reveals that Diderot had a 100% chance of being exposed to Rudbeck’s ideas as early as 1751—the year of his election—because he hypothetically encountered numerous members who were already exposed to the

idea.

Ludvig Holberg (1684–1754) was a prominent Danish-Norwegian writer and philosopher, and professor at the University of Copenhagen from 1717 to 1754 (Slottved 1978). He satirized Rudbeck’s theories, mocking the idea of Sweden as Atlantis and highlighting the speculative nature of Rudbeck’s claims. According to our simulation, the chance Holberg was exposed to Rudbeck’s idea is 0 until 1753, when it goes to 8.9%. It gains an additional 29.2% in the following year, before he died. This highlights two features of our approach: first, our exposure is a lower bound, and in this case Holberg might have been acquainted with Rudbeck’s work through other means. In other words, even in cases where we know from historical evidence that a scholar engaged with an idea, our model still captures eventual exposure through the network alone. Second, Holberg was never affiliated with an academy, but only with a university, which in our model means it must have taken more time for ideas to reach him. As shown in Section 5 of the paper, this institutional feature plays a key role in shaping how easily ideas circulate through the network.

6 Removing components of the network - technical discussion

As explained in the main text, we simulate the spread of ideas in a network stripped of certain components. This gives us better insight into the role of each component. Under this approach, we rewrite Equation (1) as

$$I_{t+1}^B = B_t I_t^B + I_t^B \quad (1)$$

where the new affiliation matrix $B \leq A$ in the Hadamard order (that is, every entry of B_t is less than or equal to the corresponding entry of A_t). Then it is obvious that $I_t^B \leq I_t \forall t$, assuming the same initial condition $I_0 = I_0^B$. Indeed, in the new dynamics, there will be fewer exposed persons at every time step, since reducing the number of connections reduces the opportunities for ideas to spread. This follows from the fact that matrix multiplication with a reduced adjacency matrix B_t leads to a weakly lower infection count at every step.

In the stochastic version, as $\mathbb{E}[\Omega^d(B_t)] = \alpha B_t$, we have $\mathbb{E}[\Omega^d(B_t)] < \mathbb{E}[\Omega^d(A_t)]$ in the Hadamard order, and $\mathbb{E}[I_t^B] \leq \mathbb{E}[I_t]$, $\forall t$. This means that, with an infinite number of simulations D , the world with B (fewer contacts) will still have fewer exposures than the world with A , even in the presence of stochastic transmission. But this statement is no longer strictly true in every realization. If we simulate the process many times, the law of large numbers implies that the average outcome of these simulations should converge to the expectation. The required number of simulations D may however be very large, because of strong non linear effects coming from the topology of the network.

7 Additional statistics on the role of Jesuits in the affiliation network

In the paper, we explore a counterfactual scenario examining the spread of ideas after removing Jesuit scholars from the network. Here, we present key statistics on the position and connectivity of Jesuits within the affiliation network. The network metric in Figure 8d quantifies how well-connected Jesuit-affiliated nodes are to the rest of the network. In our network structure, conductance reflects the extent to which Jesuits were integrated into mixed institutions rather than remaining isolated. The initially high conductance suggests that early Jesuits were present in diverse academic environments. Over time, the decline in conductance aligns with their increasing concentration within Jesuit institutions. Figure 9b shows the Homophily Index of Jesuits, by field between 1556 and 1767. Notably, the decreasing trend in inbreeding homophily among Jesuit scientists is likely a consequence of the rise of academies, which were largely centered on scientific disciplines and saw a relatively active participation from Jesuits.

References

- Abulafia, Anna Sapir. 2011. *Christian–Jewish relations 1000–1300: Jews in the service of medieval christendom*. Harlow: Pearson.
- Amburger, Erik. 1950. *Die mitglieder der Deutschen Akademie der Wissenschaften zu Berlin 1700–1950* [in German]. Berlin: Akademie-Verlag.
- Anderson, Robert Warren, Noel D Johnson, and Mark Koyama. 2017. Jewish persecutions and weather shocks: 1100–1800. *The Economic Journal* 127 (602): 924–958.
- Applebaum, Wilbur. 2003. *Encyclopedia of the Scientific Revolution: from Copernicus to Newton*. New York: Routledge.
- Geraerts, Jaap, and Demival Vasques Filho. 2024. Networks of confessional affiliation: religious choice and the schism of utrecht. *Journal of Historical Network Research* 10 (1).
- Howse, Derek. 1986. The Greenwich list of observatories: a world list of astronomical observatories, instruments and clocks, 1670–1850. *Journal for the History of Astronomy* 17 (4): i–89. <https://doi.org/10.1177/002182868601700401>.
- Jedwab, Remi, Noel D Johnson, and Mark Koyama. 2019. Negative shocks and mass persecutions: evidence from the black death. *Journal of Economic Growth* 24 (4): 345–395.
- King, David. 2005. *Finding atlantis: a true story of genius, madness, and an extraordinary quest for a lost world*. New York: Harmony Books.
- Montreal Botanic Garden. 1886. *First annual report 1885*. Gazette Printing Company.
- Slottved, Ejvind. 1978. *Lærestole og lærere ved københavns universitet 1537–1977* [in Danish]. Copenhagen: Samfundet for dansk Genealogi og Personalthistorie.
- Von Bahr, Gunnar. 1945. *Medicinska fakulteten i Uppsala* [in Swedish]. Stockholm: Almqvist & Wiksell International.

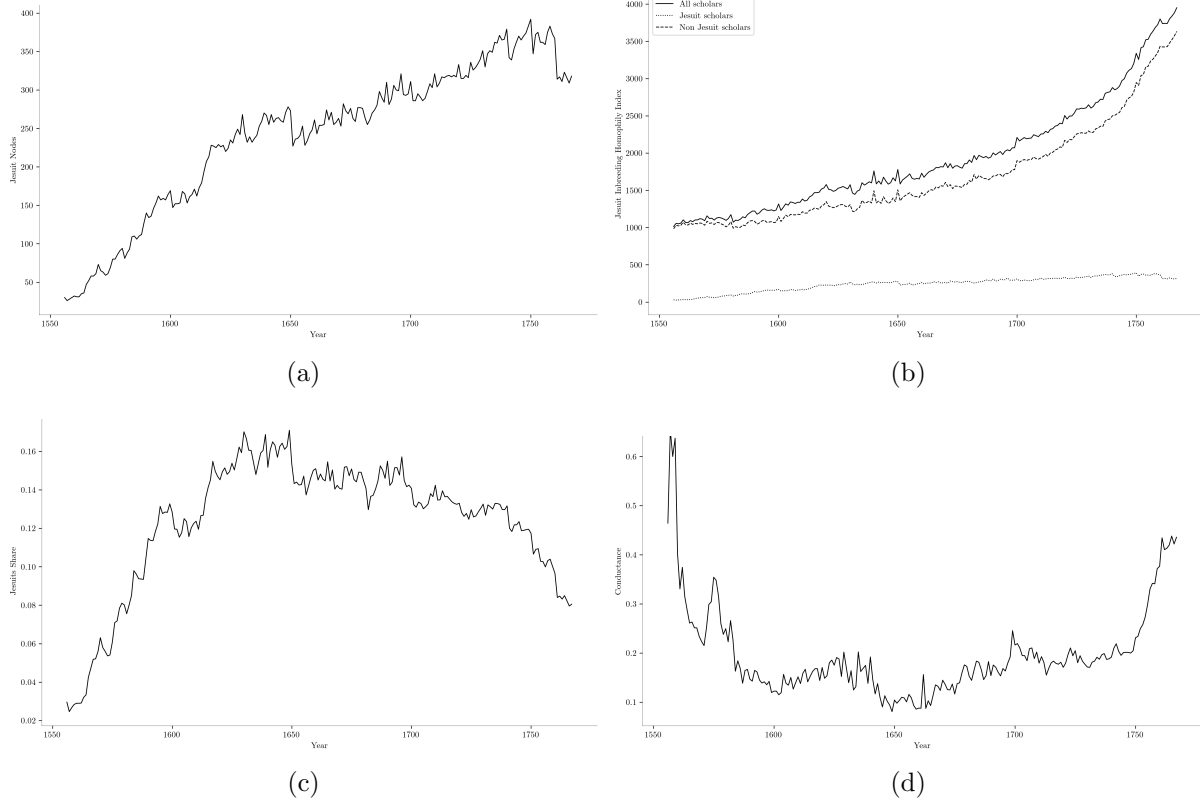


Figure 8: (a) Number of Jesuit scholars active in the network, 1556-1767. (b) Comparison of number of scholars by type: all (solid line), Jesuits (dotted line), and non Jesuit scholars (dashed line), 1556-1767. (c) Fraction of Jesuit scholars active in the network, 1556-1767. (d) Conductance of Jesuits in the affiliation network, 1556-1767.

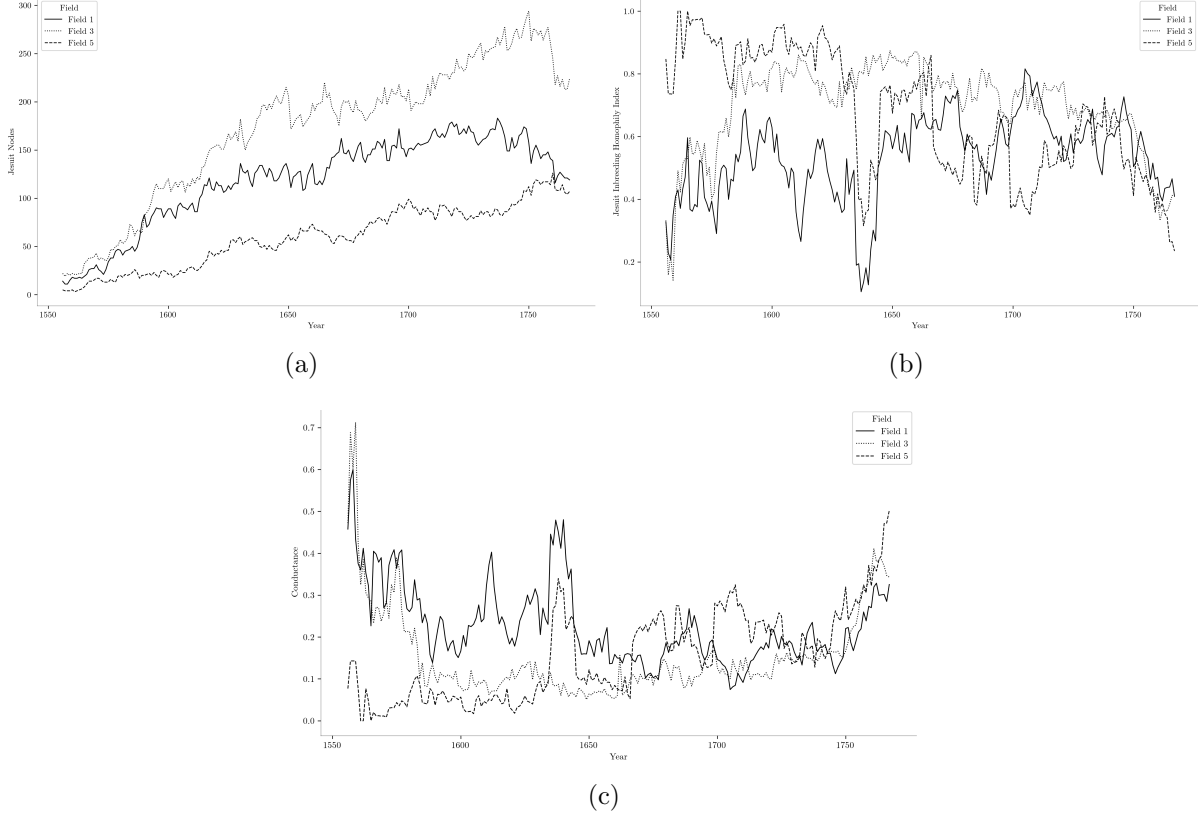


Figure 9: (a) Number of Jesuit scholars active in the network by field, 1556-1767. Field 1 stands for theology, field 3 for humanities, and field 5 for sciences. (b) Homophily Index of Jesuits, by field, 1556-1767. Field 1 stands for theology, field 3 for humanities, and field 5 for sciences. (c) Conductance of Jesuits in the affiliation network by field, 1556-1767. Field 1 stands for theology, field 3 for humanities, and field 5 for sciences.