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

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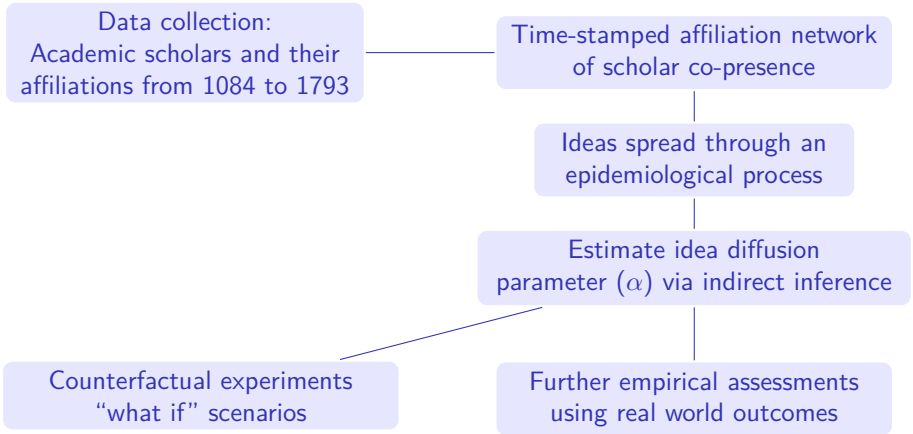
Europe, 1000–1800 CE: A Hub of Academic Innovation

- Over **350 academic institutions** hosted more than 100,000 *eruditi* across Europe between 1000 and 1800
- Many of these scholars contributed **at least a few innovative ideas** during their lifetimes
  - Some of these ideas left a lasting **legacy**, shaping Europe's long-term development
- Scholars did not work in isolation—they were part of a **vast academic community** connected through **universities and academies.**
- Together, they formed an infrastructure for knowledge dissemination

This paper

How academic institutions shaped the spread of ideas



Assumption

Key Assumption: Ideas spread by contact within institutions (Becker et al. 2024).

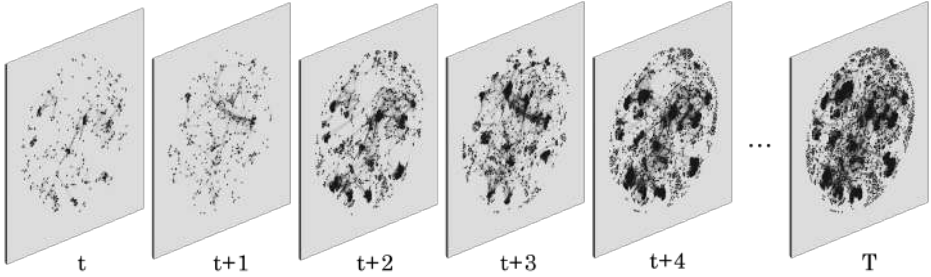
- Institutional affiliations as potential channels for diffusion among scholars
- Other complementary knowledge spread channels Alternative Channels
  - E.g. epistolary exchanges, books, student-teacher interactions
    Cervellati et al. (2025), Chiopris (2024), Becker et al. (2020), Koschnick (2025)
- Main advantage: lower bound on total diffusion & does not rely on compliance (exposure $\not\Rightarrow$ endorsment)
- Main challenge: we cannot track how ideas spread in pre-modern academia, but we can *simulate* it

Data collection: UTHC-RETE data

- Scholars with a documented affiliation to higher education institutions from their inception to the eve of the Industrial Revolution - around 600 secondary sources
  1. **Universities**
     - Hired scholars physically located there
     - Teaching and researching theology, law, humanities, medicine, and sciences
     - Since 1088
  2. **Academies** Paintings
     - Scholars elected as members. Interactions were both local and international
     - Start during the Renaissance, expansion after 1650
     - Focus on humanities (arts), sciences, applied sciences
- Individual human capital proxied by library footprint PCA
- Example: Emmanuel Tremellius

Time-evolving affiliation network

- Scholars are connected through an evolving affiliation network
- Criteria for connection:
  1. Being at the same time in the same academic institutions
  2. Working in the same field, broadly defined (e.g. theology, sciences)
- Time dimension: year-by-year basis Scholars over time Giant component



The network over time

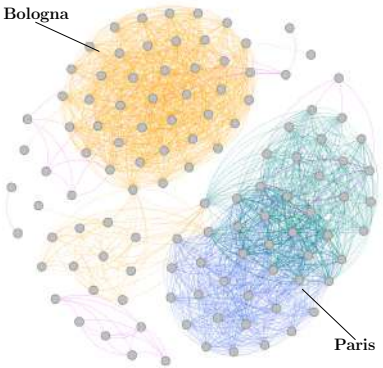


Figure: Year 1200

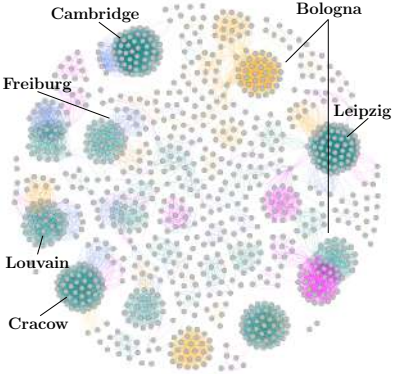


Figure: Year 1508

Legend: Theology, Law, Humanities, Sciences

Notes: Isolates not represented. Edges signify concurrent affiliation

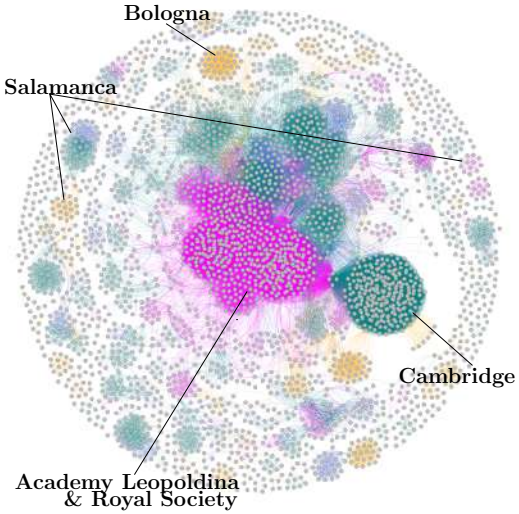
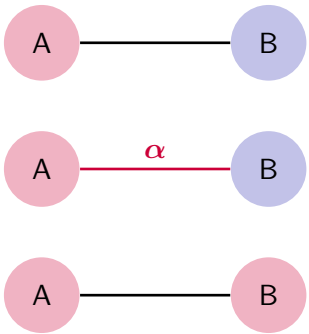


Figure: Year 1730

This network w/out academies | Giant Component

Simulating exposure to ideas

- Inspired by epidemiological models (Koher et al. 2016, Fogli and Veldkamp 2021)
- Ideas as infections without recovery



1. Suppose scholar A was previously exposed to an idea
2. She may expose B through their shared institutional tie with a certain α
3. B, in turn, may expose her own peers in the next time step

Formal Model

Three metrics of (simulated) exposure to ideas

1. **Expected scholar** s **exposure** averaging $[i_s^d]_t$ over D simulations

2. **Institution** k **exposure** S_t^k: average over individuals s belonging to set of members $V(k,t)$, weighting individual exposure by quality q_s:

$$S_t^k = \sum_s \underbrace{q_s}_{\text{quality}} \left(\underbrace{I(s \in V(k,t))}_{\text{membership}} \underbrace{[\bar{i}_s]_{t'}}_{\text{exposure}} \right) \tag{1}$$

3. **City** c **exposure** S_t^c: averaging over institutions k, weighting by inverse distance w_{ck}:

$$S_t^c = \sum_k w_{ck} \tilde{S}_t^k \tag{2}$$

Methodology

- The speed of idea diffusion crucially depends on the link activation probability α
- But actual exposure is **unobserved** $\Rightarrow$ use related historical events as **indirect validation**
- For each α in a grid over $[0, 1]$ at intervals of 0.05:
  - Simulate the spread of two ideas, one at a time: $idea_1$ and $idea_2$
  - Estimate two Cox models relating exposure to historical outcomes, and compute the combined log-likelihood: $\ell(\alpha) = \ell_1(\alpha) + \ell_2(\alpha)$
- Maximize $\ell(\alpha)$ to recover the best-fitting diffusion parameter: $\hat{\alpha} = \arg\max_\alpha \ell(\alpha)$.
- Construct a confidence interval via likelihood ratio: $2[\ell(\hat{\alpha}) - \ell(\alpha)] \leq \chi^2_{1,0.95} \approx 3.84$
- Use the lower bound α_{low} for conservative analysis

Two ideas as case studies

During the Scientific Revolution, scholars began to challenge ancient authorities, seeking reliable knowledge through empirical and mathematical reasoning

Flora: Botanical Realism

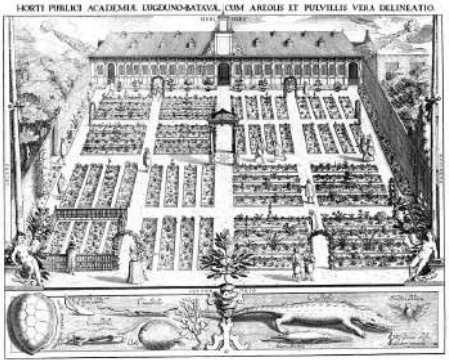
- In 1542, botanist Leonhart **Fuchs** (b. 1501 - d. 1566) publishes *De historia stirpium commentarii insignes*
- Featuring over 500 visual representations of plant species, with descriptions of their uses and characteristics, and highlighting differences from ancient texts
- Professor in Ingolstadt (1522-1533) and Tübingen (1535-1566)

Cosmos: Mathematical Astronomy

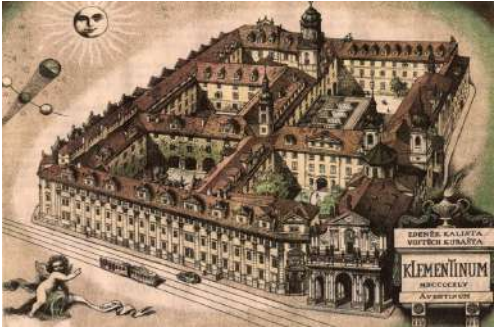
- In 1454, German mathematician Johannes **Regiomontanus** (b. 1436 – d. 1476) begins his *Theoricae novae planetarum* with Georg Peurbach + *Epitoma in Almagestum Ptolemaei, c. 1463*, which clarified, corrected, and expanded Ptolemaic astronomy
- Application of mathematics, highly useful for practitioners in engineering, astronomy, and calendar studies (incl. Copernicus)
- Professor in Vienna (1457-1461), Padua (1463-1466) and Pozsony (1467-1471)

Two related outcomes

Botanic gardens & astronomical observatories



The Hortus botanicus of Leiden
was opened in 1590
Source: Montreal Botanic Garden (1886)



Prague, tower built 1722,
instruments installed there 1751
Source: Howse (1986)

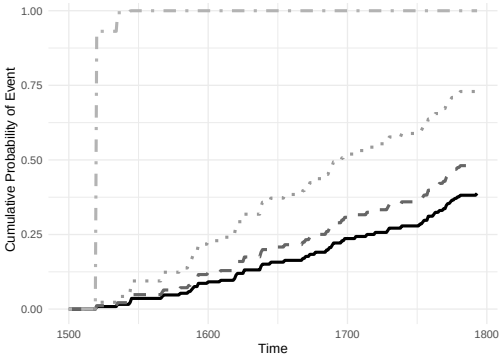
Results for Botanical Realism Cox

Dep. var.: Hazard rate of botanic garden founding						
α	**0**	**0.1**	**0.3**	**0.5**	**0.7**	**1**
(ihs) Exposure to Bot. Real. S_t^k		0.079 (0.287)	0.225** (0.090)	0.223*** (0.073)	0.222*** (0.069)	0.224*** (0.068)
(ihs) Non exposure to Bot. Real. $\check{S}_t^k$	0.397*** (0.070)	0.505*** (0.074)	0.529*** (0.077)	0.545*** (0.078)	0.551*** (0.079)	0.554*** (0.079)
(ihs) Distance to Tübingen	-0.138** (0.054)	-0.237*** (0.060)	-0.205*** (0.058)	-0.192*** (0.057)	-0.187*** (0.057)	-0.184*** (0.057)
Log Likelihood	-295.234	-295.529	-293.516	-292.034	-291.396	-291.037
(ihs) Pop in 1500	YES	YES	YES	YES	YES	YES
Observations	54390	54390	54390	54390	54390	54390

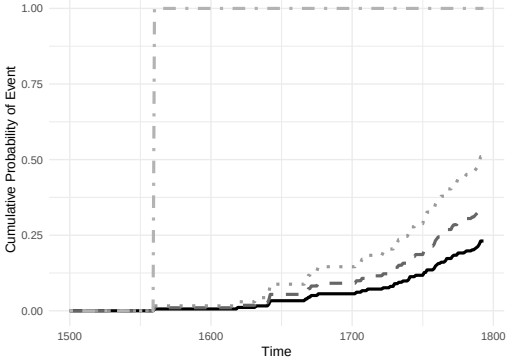
Results for Mathematical Astronomy

	Dep. var.: Hazard rate of astronomical observatory creation					
α	**0**	**0.1**	**0.3**	**0.5**	**0.7**	**1**
(ihs) Exposure to Math. Astr. S_t^k		0.314***	0.293***	0.281***	0.281***	0.288***
		(0.068)	(0.057)	(0.056)	(0.054)	(0.053)
(ihs) Non exposure to Math. Astr. $\check{S}_t^k$	0.374***	0.546***	0.562***	0.540***	0.543***	0.546***
	(0.063)	(0.094)	(0.093)	(0.097)	(0.096)	(0.096)
(ihs) Distance to Vienna	-0.151***	-0.169***	-0.158***	-0.153***	-0.152***	-0.151***
	(0.044)	(0.044)	(0.043)	(0.043)	(0.043)	(0.043)
Log Likelihood	-250.707	-250.243	-248.470	-249.257	-248.944	-248.379
(ihs) Pop in 1500	YES	YES	YES	YES	YES	YES
Observations	54390	54390	54390	54390	54390	54390

$\alpha_{\text{low}} = 0.25$



(a) Probability of Botanic Garden for different exposure to Botanical Realism



(b) Probability of observatory for different exposure to Mathematical Astronomy

Hazard functions under varying levels of constant exposure: the dot-dashed line assumes maximum exposure (resp., 5.75 and 7.32), the dotted line assumes a constant exposure of 1, the dashed line a constant mean exposure, and the solid line no exposure.

Further empirical assessments

- Using $\alpha = \alpha_{\text{low}}$, we simulate the spread of several other "ideas", beyond the context of the Scientific revolution (theses, paradigm, and methodologies)
- We investigate the correlation between exposure to "ideas" and outcomes
  $\Rightarrow$ Constraint: data availability of city-level, pan-European outcomes.

3. *Backlash*: Scholasticism & adoption of Protestantism
   Rubin (2014)
4. *Good and bad ideas*: Antisemitism, Philosemitism & Pogroms
   Anderson, Johnson, and Koyama (2017) & Jedwab, Johnson, and Koyama (2019)
5. A *wrong idea*: the claim that Swedes are descendants of the lost civilization of Atlantis (credits to Kerstin Enflo)

Counterfactual experiments

Aim: to assess how important or necessary these components are

Placebo inventors What if Botanical Realism was not invented by Fuchs but by other scholars based somewhere else? +

- look into diffusion speed and survival of ideas
- assess importance of initial conditions

Alternative networks What if some parts of the networks were missing?

- Academies +
- Geographical regions: France, British Isles, Holy Roman Empire, Iberic Peninsula +
- Religious orders: the Jesuits +

Conclusions

- European scholars were part of an academic network shaped by institutional ties
- We investigate its role by combining an affiliation network derived from original microdata with an epidemiological model
- **Main result:** The network was dense enough to – alone – foster the spread and preservation of ideas across time and space
  - Interpersonal ties within institutions matter for diffusion
  - Mechanisms: mobility and academies amplify intellectual exchange
  - The institutional network also served as a safeguard, helping preserve ideas even during shocks such as university closures (e.g Thirty Years War and *Flora*)
- *Broader question:* Could this resilience and density be part of the explanation for Europe's early intellectual lead?

Model

- A temporal network $\mathbb{G}$ as a sequence of adjacency matrices $A_t = [a_{sv}]_t$

  Each element $a_{sv} = 1$ if scholars s and v are connected at time t, and 0 otherwise

- State vector $I_t = [i_s]_t$ of length N;

  $i_s = \{0, 1\}$ indicates if scholar s was exposed to an idea

- Initial "inventor": there is some date t_0 st. $[i_s]_t = 0$ for all $t < t_0$

  At t_0, $[i_{s^\star}]_{t_0} = 1$ exogenously. $s^\star$ is the inventor (patient zero)

- Deterministic version: $I_{t+1} = \underbrace{A_t I_t}_{\text{new expositions}} + I_t$

Back

Stochastic spread of ideas

- Link activation probability α and stochastic operator $\Omega^d(A_t)$, the dynamics are represented by:

$$I^d_{t+1} = \Omega^d(A_t) I^d_t + I^d_t \tag{3}$$

where the superscript d indicates a particular simulation

- The stochastic operator $\Omega^d(a_{sv})$ is defined as:

$$\Omega^d(a_{sv}) = \begin{cases} 1 & \text{with probability } \alpha \text{ if } a_{sv} = 1,\ s \text{ and } v \textbf{ met} \text{ and } \textbf{discussed} \text{ the idea} \\ 0 & \text{with probability } 1-\alpha \text{ if } a_{sv} = 1,\ s \text{ and } v \textbf{ met} \text{ but the idea did } \textbf{not spread} \\ 0 & \text{if } a_{sv} = 0,\ s \text{ and } v \text{ never met} \end{cases}$$

Back

First principal component of q_i Back to Data

Table: First principal component of the human capital of scholars

q_i **indicators**	**Weights**
N. characters of Wikipedia page	0.358
N. languages Wikipedia	0.367
N. of alternative names in VIAF	0.413
N. of countries in VIAF	0.438
N. of publishers in VIAF	0.425
N. of titles in VIAF	0.440
No. Eigenvalues > 1	1
% variance explained by 1st PC	70.6%

Source: Curtis, de la Croix (2023)

Alternative (complementary) channels Back

- **Networks of Written Communication:**
  - **Epistolary network:** Based on letter exchanges (Roller 2023, Cervellati et al. 2025).
  - **Citation network:** Based on referenced scholarly works (Zhao & Strotmann 2015).
  - **Coauthorship network:** Based on library data (Scebba & Fantoli, 2024).
  - **Book translations:** Intellectual dissemination through translations (Abramitzky and Sin, 2014).
- **Direct Interpersonal Influence:**
  - **Student-teacher interaction:** How students are influenced by teachers, primarily in universities (Koschnick, 2024).

Royal Academy of Sciences in Paris, 1666

Back to Data

Royal Society, 1748

Back to Data

ANNALES

DES

PROFESSEURS

DES

ACADÉMIES ET UNIVERSITÉS ALSACIENNES

1523-1871 (Strasburg)

PAR

OSCAR BERGER-LEVRAULT

NANCY

IMPRIMERIE BERGER-LEVRAULT ET Cie

1892

Tremellius, Emmanuel, Ferrariensis.
Natus 1510.
Denatus (Sedan.) 9 Octobr. 1580.

Hebrææ linguæ Professor, Lucæ, 1541.
Hebrææ linguæ Professor, 1542-1547.
Hebrææ linguæ Professor, Cambridge, 1549-1553.
Hebrææ linguæ Professor in Universitate Heidelbergensi.
Hebrææ linguæ Professor in Academia Sedanensi.

Dagmar Drüll

HEIDELBERGER GELEHRTENLEXIKON

1386–1651

Springer

Tremellius (Tremmel), Immanuel

1561 – 1577 Theol. Fak.

1561 – 1577 Altes Testament; 1561 – 1575 Hebräische Sprache

* 1510 Ferrara (im Ghetto)

† 9. Okt. 1580 Sedan

mosaisch, seit 1540 kath., seit 1541 ref.

⚭ Okt. 1544 Elisabeth N.N., Witwe

K 1 T, 1 Stief-T, 1 S: Immanuel T., s. Toepke 2 (1886) S. 26, Hundsnurscher (1996) S. 45

LA FRANCE

PROTESTANTE

PARIS

ALUMNI CANTABRIGIENSES

CAMBRIDGE

TREMILL or TREMYLL, —— (*senior*). Pens. at PETERHOUSE, in 1581. Probably Richard, s. and h. of Richard, of Bedfordshire. Of Wrawby, Lincs. Married Helen, dau. of William Thorley, of Northamptonshire. Probably brother of Henry (1580) and of James (above). (*Essex Pedigrees*, 608.)

TREMELLIUS, JOHN EMMANUEL. Hebrew lecturer, 1550-3. A Jew. B. at Ferrara, 1510. Studied at Padua between 1530 and 1540. Converted to Christianity by Cardinal Pole, his godfather, 1540. Teacher of Hebrew at Lucca, where he imbibed the opinions of the reformers chiefly through the influence of Peter Martyr. Came to England; resided with Archbishop Cranmer at Lambeth Palace, 1547. Preb. of Carlisle, 1552. Left England on the accession of Queen Mary, 1553. Head of the gymnasium at Hornbach, 1559. Imprisoned for his Calvinistic views; released, 1560. Professor of Old Testament studies at Heidelberg, 1561. D.D. (Heidelberg), 1561. Sent to England as Envoy of the Elector; resided with Archbishop Parker, *c.* 1565. Expelled from Heidelberg, 1576. Appointed teacher of Hebrew at Sedan. Translated the Bible from Hebrew and Syriac into Latin. Author, miscellaneous. Died at Sedan, Oct. 9, 1580. (*Cooper*, I. 425; *D.N.B.*)

TREMLETT, GEORGE. Adm. sizar (age 17) at SIDNEY, Dec. 21,

TRÉMELLIUS (Emmanuel), né à Ferrare, vers 1510, et mort à Sedan, le 9 oct. 1580.

Trémellius quitta la religion juive dans laquelle il était né, pour embrasser la religion catholique, et celle-ci pour se faire protestant. Après sa conversion, il se retira à Lucques, où il enseigna quelque temps la langue hébraïque, mais la crainte de l'Inquisition finit par le chasser d'Italie, ainsi que Pierre Martyr et d'autres italiens, partisans secrets de la Réforme. Il s'établit d'abord à Strasbourg, où il donna des leçons d'hébreu. Plus tard, il passa en Angleterre et y resta jusqu'à la mort d'Edouard. Chassé de nouveau par Marie la sanguinaire, il retourna en Allemagne en 1553, et fut placé comme professeur d'hébreu dans l'école de Hornbach. Quelque temps après, l'électeur palatin Frédéric III l'appela à Heidelberg. En 1560, nous le trouvons à Metz, où il s'était marié pendant un premier séjour qu'il avait fait dans cette ville avant de se rendre à Strasbourg. S'il est vrai qu'il y fut arrêté par ordre du maréchal de Vieilleville sous le règne de François II, sa détention fut de courte durée, puisqu'il fut un des députés (1) que les Protestants de Metz envoyèrent en Cour aussitôt après la mort de ce prince, pour demander à la reine régente la liberté du culte, le rappel des bannis et la délivrance de *Guillaume Paluseau*, prisonnier à Auxerre. Les deux dernières demandes furent accordées; quant à la première, il fut répondu que les prétendus Réformés n'auraient ni temple ni lieu d'exercice quelconque à Metz, qu'ils n'y tiendraient aucune assemblée sous peine de mort, mais que Sennecterre leur assignerait un lieu hors de la ville pour y faire leurs prêches. Il est probable que Trémellius ne tarda pas à retourner à Heidelberg, d'où, quelques années plus tard, il fut appelé à Sedan par le duc de Bouillon pour y remplir une chaire d'hébreu qu'il occupa jusqu'

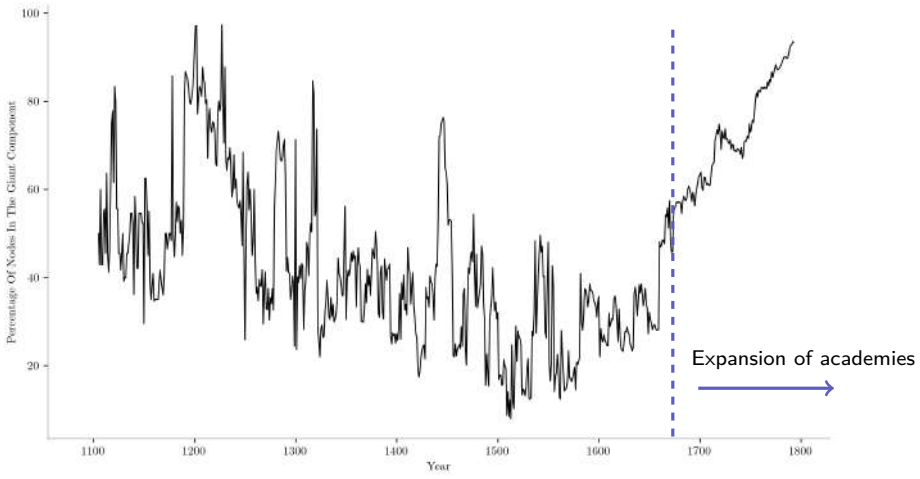
Back to Data

Number of nodes over time

Back

Percentage of nodes in the giant component

Back



Back

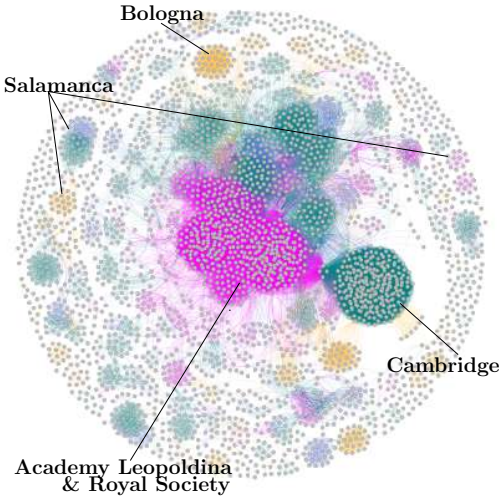


Figure: Year 1730

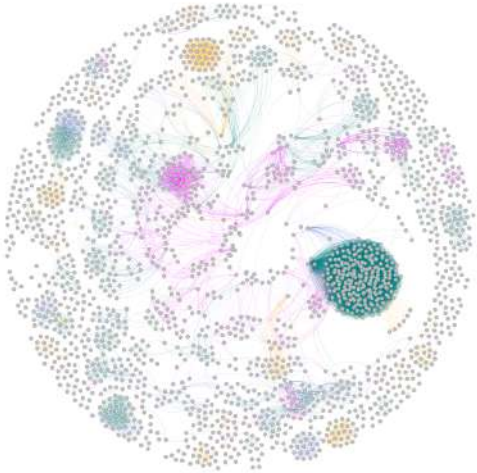
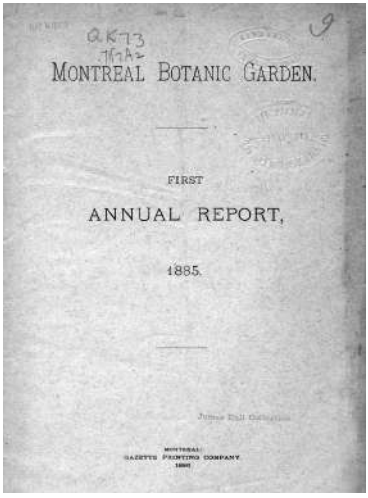


Figure: Year 1730, no academies

Building a panel of botanic gardens

- We compute institutions' exposure to Botanical Realism over time
- ... and compare with the foundation of botanic gardens (our elaboration)
- The first annual report by Montreal Botanic Garden (1886) lists botanic gardens open worldwide in 1885
- We used AI to fetch each garden's founding dates, which were then manually sample-checked



Back

Cox Proportional Hazards Model

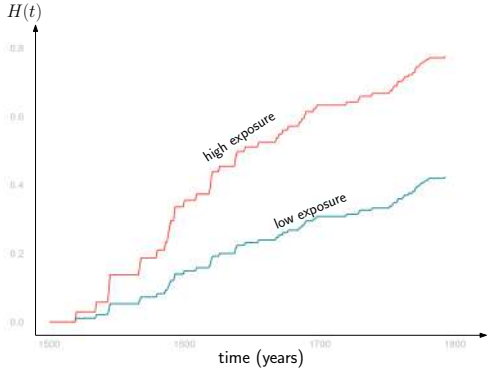
Back to Results

- Hazard rate at time t risk of event at time t:

$$h(t) = h_0(t) \exp\left(\Sigma_i \beta_i x_i(t)\right)$$

where $h_0(t)$ (baseline hazard) is shifted proportionally by factors $x_i(t)$

- Cumulative hazard: $H(t) = \int_0^t h(x)\, dx$
- In our set-up, $x_i(t)$ is the exposure to one of the two ideas and the event is the related historical outcome



Salvatio: Scholasticism, Petrus Lombardus, and his *Sentences*

Back

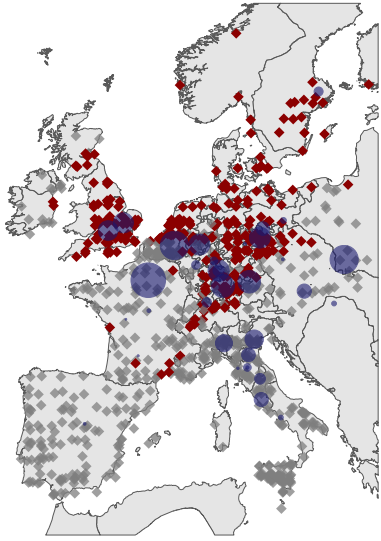
- Approaches theology using systematic reasoning, inspired by Aristotle
- Does not rely much on the Scriptures, but rather on logical argumentation
- Pioneered by Petrus Lombardus (b. 1100 – d. 1160), professor at Paris
- Main book: *Sentences* (1146)

Scholasticism & the Reformation Back

- Hypothesis: it impacted the Reformation through a "disgust" effect
  Pierre Chaunu, *Le Temps des Réformes* (1975)
- Luther was trained in the scholastic method, but wrote an entire *Disputatio* against Scholasticism:

  "No syllogistic form is valid when applied to divine terms"

  "The whole Aristotle is to theology as darkness is to light"
- We compute cities' exposure to Scholasticism in the 30 years prior 1508
- ... and compare with data on Protestant cities in 1530, 1560, and 1600 from Rubin (2014)
- note: no Cox here as not enough variations is adoption of Protestantism (England)



Year 1600. Institutional exposure bubbles in **blue**. Protestant (Catholic) cities in **red** (**gray**)

Linear probability model

	Protestant in			Protestant in		
	1530	1560	1600	1530	1560	1600
	(1)	(2)	(3)	(4)	(5)	(6)
Exposure to	0.001	0.003***	0.004***	0.0005	0.005***	0.006***
Scholasticism S^c_{1508}	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Presence of university	-0.034	-0.075	-0.130**	-0.044	-0.018	-0.056
in 1500	(0.027)	(0.051)	(0.054)	(0.027)	(0.045)	(0.047)
Non exposure to				0.006	-0.034	-0.043**
Scholasticism $\check{S}^k_t$				(0.005)	(0.024)	(0.020)
Observations	867	867	867	867	867	867
Adjusted R^2	0.016	0.072	0.127	0.018	0.116	0.194
Log Likelihood	-201.02	-500.48	-515.10	-199.68	-478.98	-480.13

Notes: Robust SE clustered by territory (from Rubin 2014)

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Anti-Judaism and the Persecution of Jews

- Scholastic theologians contributed to identify Judaism as a theological error
- They did not directly advocate persecutions
- But their thesis may have interacted with negative shocks, such as plagues and cold temperatures Anderson, Johnson, and Koyama (2017); Jedwab, Johnson, and Koyama (2019)

→ LPM on the link between Scholasticism and violent acts against Jews.

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Linear Probability Model

	Persecutions	
	Replication (1)	S_{ct} x Plague (2)
$Temperature_{c,t-1}$	-0.467***	-0.496***
	(0.125)	(0.129)
Plague	5.100**	-0.719
	(2.149)	(1.274)
Exposure to Scholasticism S_{ct}		0.025
		(0.052)
Exp. to Scholasticism S_{ct} x Plague		3.621***
		(1.131)
Controls	YES	YES
City Fixed Effects	YES	YES
Observations	273,879	273,879
R^2	0.013	0.015

$\Rightarrow$ (1) replicates Anderson et al. (2017) $\rightarrow$ very similar pp despite sample differences (i.e., duplicates and updates).

$\Rightarrow$ (2) shows that only when a theoretical framework exists that picture Jews as a threat, and a plague occurs simultaneously, then the probability of violence rises significantly.

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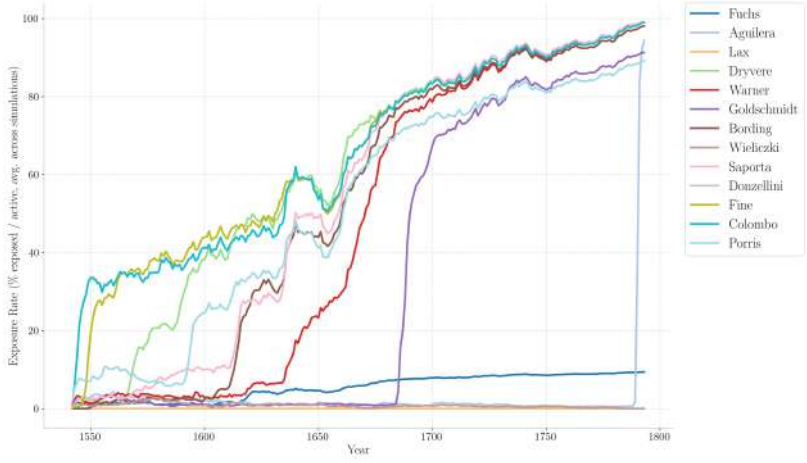
Share of exposed scholars (medicine+science) – average over simulations

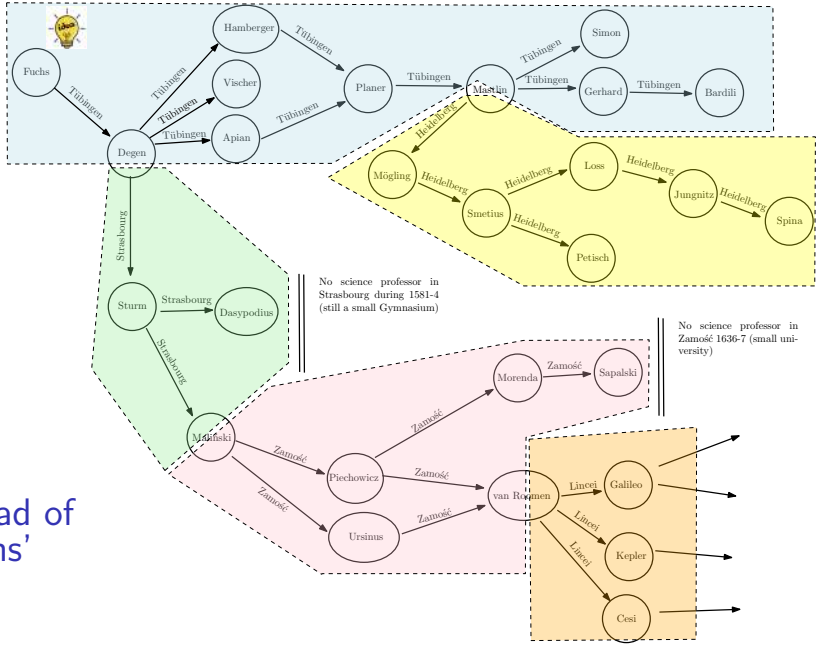
Back



Discussion Back

- In two cases (Wieliczki in Cracow and Lax in Zaragoza) the idea fails to spread due to limited scholarly mobility and weak institutional connectivity.
- In the remaining ten scenarios, the idea spreads to nearly all scholars in medicine and science by the end of the period:
  - Fastest spread: Donzellini (Padua), Colombo (Pisa), and Fine (Royal College of France)
  - Slower initial spread: Goldschmidt (Wittenberg) and Warner (Oxford), before wider diffusion after 1650
- Fuchs plateaus at 10%, meaning the idea survives in only some of the simulations, and dies out in the other cases

$\Rightarrow$ The diffusion process generated by our model is **non-ergodic**: success depends on initial conditions, particularly the inventor's network position (cf. QWERTY, David 1985)



The spread of Fuchs' idea

Counterfactual experiment 2: Absence of academies

Back

- In Fuchs' example, Lincei is necessary for the idea to survive.
- Romanus is a key player according to Zenou's definition: "the key player who is the agent that should be targeted by the planner so that, once removed, she will generate the highest level of reduction in total activity."
- What if academies were never invented ? would universities suffice ?
- Academies play a dual role:
  - Direct effect: exposing nearby cities to ideas
  - Indirect effect: helping to spread ideas (network effect)

Moments of distribution of cities' exposure relative to benchmark

Back

	Q1	Median	Q3
Botanical Realism			
With ACAD in 1600	0	5.18	12.63
No direct effect in 1600	0	5.18	12.63
No ACAD at all in 1600	0	5.16	12.58
Mathematical Astronomy			
With ACAD in 1600	0.15	8.67	22.73
No direct effect in 1600	0.14	6.66	16.97
No ACAD at all in 1600	0.14	6.45	16.41
Botanical Realism			
With ACAD in 1750	29.11	110.34	190.68
No direct effect in 1750	9.13	29.70	53.02
No ACAD at all in 1750	0	0	0
Mathematical Astronomy			
With ACAD in 1750	124.38	444.15	759.10
No direct effect in 1750	37.99	114.45	200.55
No ACAD at all in 1750	11.34	33.27	58.02

1600

- Only a few (mostly informal) academies
- They do not matter much for exposure to Botanical Realism
- Help spread of Mathematical Astronomy slightly more

1750

- Academies matter more and more directly
- Are necessary component of the network for Botanic Realism
- Important component for Mathematical Astronomy

Counterfactual 3: absence of specific regions

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	Q1	Median	Q3
Botanical Realism			
No Italian Peninsula	0	0	0
No British Isles	67.34	240.88	455.91
No France	64.40	280.03	480.19
No Iberic Peninsula	78.39	308.81	521.35
No Holy Roman Empire	0	0	0
Benchmark	78.39	308.81	521.35
Mathematical Astronomy			
No Italian Peninsula	0	0	0
No British Isles	290.39	1021.46	1911.36
No France	234.06	991.08	1668.37
No Iberic Peninsula	340.63	1348.13	2237.27
No Holy Roman Empire	339.30	1282.77	2118.87
Benchmark	358.77	1381.77	2291.75

Exposure in 1793

- Holy Roman Empire necessary only for Botanical Realism but not as much for Mathematical Astronomy
- The Italian universities of Rome and Bologna served as critical hubs, allowing scholars previously exposed to continue disseminating the ideas
- For the rest, no region of Europe was necessary for the idea to spread
- Shows the resilience of the network

Counterfactual 4: absence of Jesuits

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	Q1	Median	Q3
Botanical Realism			
Benchmark	33.29	126.13	218.01
No direct effect	32.37	121.72	212.79
No Jesuits at all	28.49	107.00	187.43
Mathematical Astronomy			
Benchmark	122.51	437.48	747.74
No direct effect	114.02	417.16	718.26
No Jesuits at all	115.86	423.61	729.94

(AI)

Exposure in 1793

- Jesuits = 10.9% of all scholars (after 1500)
- They matter surprisingly little
- Network effect is small:
  - Jesuits form a mostly self-contained sub-network
  - Limited integration with broader scholarly network