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 **100,000 academic scholars** across Europe during this period.
- Sometimes, scholars contributed **at least a few innovative ideas** in their lifetimes.
- Some ideas left a **lasting legacy**, shaping European development:
  - *Frisius*: Triangulation $\rightarrow$ Modern GPS
  - *Clavius*: Gregorian calendar $\rightarrow$ Global standard
  - *Montesquieu*: Separation of power $\rightarrow$ Democracies today

Academic Networks and Institutions

- Scholars did not work in isolation—they were part of a **vast academic community** connected through **universities and academies.**
- By 1800:
  - **200 universities** established (1000–1800).
  - **150 notable academies** (1500–1800).

This paper

How individual ideas gained significance when channelled by institutions.

Data collection:
Academic scholars and their
affiliations from 1084 to 1793

Affiliation network as a sequence
of adjacency matrices
representing contact at time t

Ideas spread through an
epidemiological model

Counterfactual experiments
"what if" scenarii

Empirical assessment
using real world outcomes

Assumption

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

- Proximity drives diffusion, not necessarily intentional communication: Serendipitous nature of knowledge diffusion.
- Institutional environments provide structured yet informal opportunities for exchange.
- Ideas "infect" scholars like diseases without recovery.

Alternative (complementary) channels

- **Networks of Written Communication:**
  - **Epistolary network:** Based on letter exchanges (Roller 2023).
  - **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).

Advantages of the Affiliation Network

Main Advantages:

- Offers a lower bound on total diffusion.
- Highlights the role of each institution in knowledge dissemination.
  - Example: Identifying "hubs" versus "peripheral" institutions.
- Does not rely on compliance (unlike citation or coauthorship networks).
  - $\approx$ *intention-to-treat analysis.*
- Data gaps are identifiable (unlike epistolary networks).
  - Institutions provide structured records for tracking affiliations.

Data collection: UTHC-RETE data

- Scholars with a documented affiliation to higher education institutions between the 11th and 18th century
  1. **Universities**
     - Scholars physically located there
     - teaching and researching theology, law, humanities, medicine, and sciences
     - Since 1088
  2. **Academies**
     - Scholars as ordinary, foreign and corresponding members. Interactions were both local and global
     - Start during the Renaissance, expansion after 1650
     - Focus on humanities (arts), sciences, applied sciences
- Individual human capital proxied by library footprint

Example of secondary source

Series professorum qui in academia rheno-traiectina publice aut docuerunt aut etiamnunc docent (1861)

(The series of professors who have either taught or are currently teaching at the University of Utrecht)

Matheseos: of Mathematics
Iuris: law

55. Hermannus Alexander Roëll, *Marco-Westphalus*, nat. a. 1653. Ex academia Franequerana evocatus, Prof. *Theologiae* d. 22 Sept. 1704. Ob. d. 12 Iulii 1718. *

56. Iosephus Serrurier, *Amstelaedamensis*, Prof. *Philosophiae et Matheseos* d. 3 Febr. 1706, *Medicinae et Botanices* d. 18 Maii 1716, *Institutionum Medicarum* d. 7 Iunii 1723. Ob. d. 15 April. 1742. *

57. Iohannes Iacobus Vitriarius, *Genevensis*, nat. a. 1679. Ex academia Heidelbergensi huc evocatus, *Iuris civilis et publici* Prof. d. 17 Sept. 1708. In academiam Lugduno-Batavam profectus exeunte a. 1719. Obiit d. 11 Dec. 1745. *

58. Hieronymus van Alphen, *Hanoviensis*, nat. d. 12 Maii 1665. In ecclesia Amstelaedamensi Euangelii interpres, huc evocatus, Prof. *Theologiae* d. 26 Febr. 1715. Ob. d. 7 Nov. 1742. *

59. Franciscus Burmannus, Franc. F. *Rheno-Traiectinus*, nat. d. 15 Maii 1671. In ecclesia Amstelaedamensi Euangelii interpres, huc evocatus, Prof. *Theologiae* d. 26 Febr. 1715. Ob. d. 22 Sept. 1719. *

60. Arnoldus Drakenborch, *Rheno-Traiectinus*, nat. d. 31 Dec. 1684. *Historiarum et Eloquentiae* Prof. d. 25 Maii 1716. Ob. d. 16 Ian. 1748. *

Affiliation network of scholars

The database is like a large Affiliation Matrix (aka, Incidence Matrix, or individual-by-group matrix)

$B_{79555 \times 374}$

$$B = \begin{array}{cccc} & \textit{Leiden} & \textit{Cambridge} & \textit{Louvain} \\ \textit{Erasmus} & 0 & 1 & 1 \\ \textit{Lipsius} & 1 & 0 & 1 \\ \textit{Clusius} & 1 & 0 & 0 \\ \textit{Bucer} & 0 & 1 & 0 \end{array}$$

allows to build two classes of networks

Two types of network (1)

Network of universities: adjacency matrix $A = B'B$, how Leiden, Cambridge and Louvain are connected through the mobility of professors. (de la Croix and Morault, 2024)

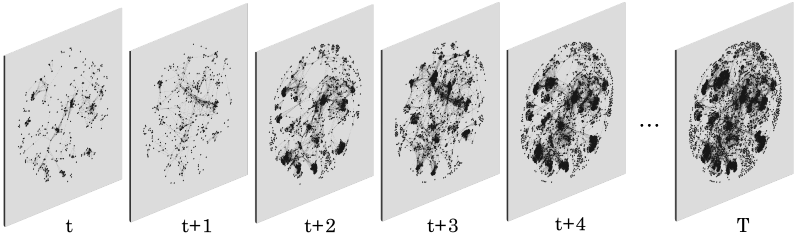
Network of scholars: adjacency matrix $A = BB'$, how professors are connected by sharing a common affiliation. Using Bolean arithmetic, we get

$$A = \begin{array}{lcccc} & \textit{Erasmus} & \textit{Lipsius} & \textit{Clusius} & \textit{Bucer} \\ \textit{Erasmus} & 1 & 1 & 0 & 1 \\ \textit{Lipsius} & 1 & 1 & 1 & 0 \\ \textit{Clusius} & 0 & 1 & 1 & 0 \\ \textit{Bucer} & 1 & 0 & 0 & 1 \end{array}$$

Issues: time dimension, field dimension

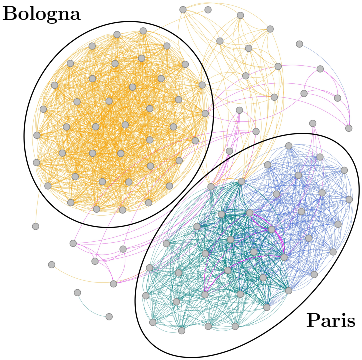
Temporal network of scholars

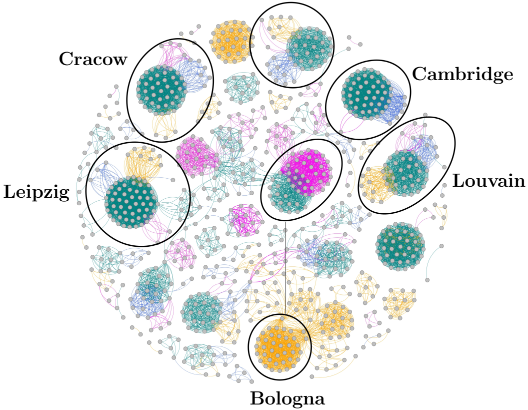
- We study the period 1084 to 1793
- Scholars are connected though an evolving affiliation network (time index to A_t)



- Criteria for connection: being at the same time in the same institution,
- and working in the same field

The network over time: 1200 and 1508

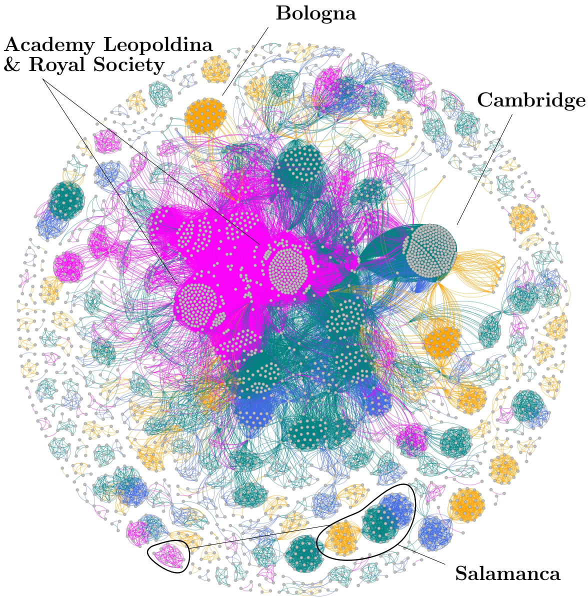




Legend: Theology, Law, Humanities, Sciences

Note: Isolates not represented

Archipelago of small "islands" connected through the mobility of scholars



1730

Rise of multiple simultaneous affiliations, partly due to the breakthrough of academies

≈ "small world" property

Scholars over time

Giant component

Epidemiological Model

- Inspired by epidemiological models (Koher et al. 2016, Fogli and Veldkamp 2021)
- T periods, N scholars
- 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 $I_t = [i_s]_t$; $i_s = \{0, 1\}$ indicates scholar s exposure to an idea
- Initial "inventor" (patient zero): there is some date t_0 where $[i_s]_t = 0$ for all $t < t_0$
  at t_0, $[i_{s^\star}]_{t_0} = 1$ exogenously. $s^\star$ is the inventor

Spread of ideas - Deterministic version

- State vector updated following (using Boolean arithmetic):

$$I_{t+1} = \underbrace{A_t I_t}_{\text{new expositions}} + I_t \tag{1}$$

- once exposed to, ideas cannot be forgotten (no "recovery" status)

Spread of ideas - Stochastic version

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

$$I^d_{t+1} = \Omega^d(A_t) I^d_t + I^d_t \tag{2}$$

where the superscript d indicates a particular simulation.

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

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

- $\mathbb{E}[\Omega^d(A_t)] = \alpha A_t$.

Three levels of exposure to ideas

Scholar s expected exposure: averaging $[i_s^d]_t$ over D simulations

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:

$$S_t^k = \sum_s \underbrace{q_s}_{\text{quality}} \left(\underbrace{I(s \in V(k,t))}_{\text{membership}} \quad \underbrace{[\bar{i}_s]_{t'}}_{\text{expected exposure}} \right) \tag{3}$$

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

$$S_t^c = \sum_k w_{ck} \tilde{S}_t^k \tag{4}$$

Empirical assessment

- We feed into the model several key ideas
  (choice driven by importance and availability of outcomes)
- Caveat: "idea" as an umbrella term for new theses, paradigm, and methodologies
- We set $\alpha = 0.3$ & $D = 1,000$
- We investigate the correlation of the exposure of "ideas" and outcomes:
  1. Botanical Realism & botanic gardens
  2. Mathematical Astronomy & astronomical observatories
  3. Scholasticism & adoption of Protestantism
- 1& 2 are straightforward implications, 3 is a counter-reaction/backlash
- Underlying assumption: a significant correlation gives support to our model

1. Botanical Realism, Fuchs, and botanic gardens

- A paradigm shift in botany during the Scientific Revolution: Botanical Realism
  - Scholars began questioning ancient authorities and sought reliable knowledge through direct observation and experimentation
- In 1542, German botanist Leonhart Fuchs (b. 1501 – d. 1566), professor in Tübingen, 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
- Using a Cox Proportional Hazard model, we relate the likelihood for a university city to see the creation of a botanic garden with the exposure to Botanical Realism Building Data on Botanic Gardens

Vulgaris rubra L.

BETA
NIGRA.
Roter Mangolt.

rum, exigua eſt alimonia. Iecoris obſtructionibus, quam Malua, aptius
datur, magis autem ubi cum Sinapi eſtur, aut aceto. Lienoſos item ſimiliter man-
ducata, mirificè iuuat.

EX PLINIO.

B Nec Beta ſine remedio eſt utraq;. Siue candidæ, ſiue nigræ radix recens & ma-
defacta, ſuſpenſa funiculo, contra ſerpentiũ morſus efficax eſſe dicitur. Candida Be
ta cocta, & cum Allio crudo ſumpta, contra tineas. Nigræ radices ita in aqua coctę,
pruriginẽ tollunt, atq; in totum efficacior eſſe traditur nigra. Succus eius capitis do
lores ueteres & uertigines, item ſonitum aurium ſedat, infuſus ijs. Ciet urinã. Me-
detur dyſentericis iniecta, & morbo regio. Dolores quoque dentium ſedat illitus
ſuccus. Et contra ſerpentium ictus ualet, ſed huius radici duntaxat expreſſus. Ipſa
uerò decocta, pernionibus occurrit. Albę ſuccus epiphoras ſedat, fronte illita. Alu-
minis pauco admixto, ignem ſacrum. Sine oleo trita licet, aduſtis medetur. Et con-
tra eruptiones papularum cocta. Eadem contra ulcera quæ ſerpunt. Illinitur & alo-
pecijs cruda. Et ulceribus quæ in capite manant. Succus eius cum melle naribus in-
ditus, caput purgat. Coquitur & cum lenticula addito aceto, ut uentrem molliat.
Validius cocta, fluctuationes ſtomachi ſiſtit & uentris.

EX SYMEONE SETHI.

Eius ſuccus mediocriter abſtergit. Hic etiam uentrem ad effluxũ proritat, & ſto-
machum aliquando uellicat, eorum præſertim qui hunc ualde ſenſilem obtinent.
Quapropter edulium eſt ſtomacho infeſtum, ſi plurimũ comedatur. Exiguum eſt
eius alimentũ, ſicut cæterorũ olerum. Vtilis uerò eſt ad iecoris obſtructiones cum
aceto comeſta. Pari modo ſi edatur, & lienis obſtructionib. bonum fit medicamen-
tum. Conſtat autem Beta ex contrarijs facultatibus. Succus enim eius calidus eſt,
uentrem conſtringit, & ſitim affert. Eius uerò corpus craſſarum partium,
flatuoſum, concoctu difficilè & frigidum, uentremq; ſiſtit,
maximè ſi aqua in qua coctum eſt, ſubin-
de abijciatur.

DE TINCTO-

Cox Proportional Hazards Model

Hazard rate at time t (risk of event at time t): $h(t) = h_0(t)\exp\left(\Sigma_i \beta_i x_i(t)\right)$

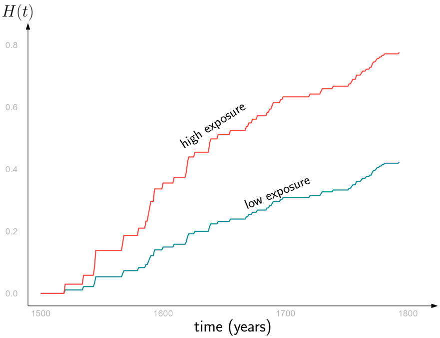
- Baseline hazard $h_0(t)$ is shifted proportionally by factors x_i. Some of which might be time-varying.

Cumulative hazard:

$$H(t) = \int_0^t h(x)\,dx$$

$x_i(t)$: **Exposure to $\rightarrow$ Event**
Botanical Realism $\rightarrow$ Have a botanic garden
Mathematical Astronomy $\rightarrow$ Have an observatory

$\Rightarrow$ estimate β_i by maximum likelihood



Cox Proportional Hazards Model - Botanic gardens

Size

	Risk of creating a Botanic Garden		
	(1)	(2)	(3)
(ihs) Exposure Botanical Realism S_t^k	0.363***	0.292***	0.249**
	(0.077)	(0.092)	(0.098)
(ihs) City population in 1500		0.256***	0.308***
		(0.081)	(0.088)
(ihs) Distance to Tübingen (gravity model)			-0.226***
			(0.062)
Log Likelihood	-297.050	-294.296	-292.307

Note: *p<0.1; **p< 0.05; ***p<0.01. 54,390 observations

All the variables are transformed in inverse hyperbolic sine.

A one-unit increase in exposure $\Rightarrow$ +43.7%, +33.9%, +28.3%.

2. Cosmos: Regiomontanus

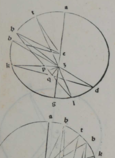
- In 1454, German mathematician Johannes Regiomontanus (b. 1436 – d. 1476) begun his *Theoricae novae planetarum* with Georg Peurbach + *Epitoma in Almagestum Ptolemaei, c. 1463*, which clarified, corrected, and expanded Ptolemaic astronomy, influencing Copernicus.

- Advanced application of mathematics, highly useful for practitioners in engineering, astronomy and related calendar studies.

- Professor at the university of Vienna (1457-1461), Padua (1463-1466) and Pozsony (1467-1471)

⇒ Were institutions with high exposure to Regiomontanus' work more likely to build an astronomical observatory?

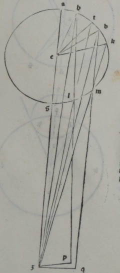
Propositio v.



Sumptis duob⁹ arcub⁹ in medietate ecētrici equalibus: qui longitudini propiori fuerit vicinior: maiorem in centro terre subtēdit angulū. Ex hoc constat: q̄ quāto planeta longitudini propiori vicinior fuerit: tanto motus eius apparēs maior erit.

¶ In eccentrico.a.b.g.d.cuius centrū.e.diameter per longitudinē longiorē et propiorem trāsiens sit.a.e.z.g.in qua centrum terre.z.duo arcus.t.h.h.k. sint equales.vnde angulus.h.e.t.equalis erit angulo.k.e.h.Dico angulum k.z.h.maiorem esse angulo.h.z.t.propterea q̄ arcus.k.h.lōgitudini propiori sit vicinior.t.z.et.h.z.continuate occurrant periferie eccentrici in.l.et.d.ductisq̄ lineis.h.l.et.k.d.perpendicularibus super eas.z.p.et.z.q.quia angulus.h.l.t.est equalis angulo.k.d.h.per.25.tertij.ergo.z.q.maior est.z.p.Linea aūt.h.z.gulo.z.q.d.igitur p quartā sexti proportio.z.d.ad.z.l.sicut.z.k.ad.z.p. Sed z.d.maior est.z.l.per septimam tertij.ergo.z.q.maior est.z.p.Linea aūt.h.z. maior est linea.k.z.per eandem septimā tertij.ergo per octauam quinti proportio.h.z.ad.z.k.maior est q̄z proportio.k.z.ad.z.q.⁊ per eandē.h.z.ad.z.p maior est q̄z.h.z.ad.z.q.igif proportio.h.z.ad.z.p.maior est proportione.k.z ad.z.k.quare ex ratione sinuū seu chordarum angulus.z.k.q.maior est angulo.z.h.p. Ideoq̄z duo anguli.z.k.q.et.z.d.q.simul maiores sunt duobus.z.h. p.et.z.l.p. Igitur per.32.primi angulus.k.z.h.maior est angulo.h.z.t.quod fuit ostendendum. Correlarium manifestum est.

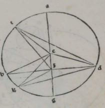
Propositio. vj.



Sumptis duobus arcubus in medietate epicycli superiori equalibus: qui longitudini lōgiori vicinior fuerit: maiorem in centro terre subtēdit angulum.

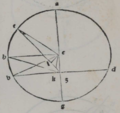
¶ Sit epicyclus.a.b.g.sup centro.e.diametro.a.e.g.transeunte per longitudinem longiorem.a.propiorem.g.⁊ centrum terre.z.Sumpti sint in parte superiori duo arcus.h.t.et.h.k.equales.h.t.quidē vicinior ad longitudinem lōgiorē. Dico angulum.h.z.t.maiorē esse angulo h.z.k. Secent enim.t.z.et.k.z.epicyclum inferius in.l.⁊.m.⁊ super continuatas.h.l.et.h.m.cadāt perpēdiculares.z.p.et.z.q. Sunt itaq̄z.h.l.t.et.h.m.k. anguli equales per.25.tertij:ideo q̄ eorum contrapositi.z.l.p.et.z.m.q.sunt equales.p.aūt ⁊.q.sunt recti: ergo per quartā sexti.m.z.ad.l.z.proportio est sicut.z.q.ad.z.p.Sed.m.z.est maior.l.z.per octauam tertij.igitur.z.q.est maior.z.p.Sed.z.h.est maior.z.h.per eandem octauam tertij.quare per octauā quinti.h.z.ad.z.q.proportio maior est q̄z.h.z.ad.z.q.h.z.aūt ad.z.p.maior q̄z.h.z.ad.z.q.per eandem igitur.h.z.ad.z.p.maior est q̄z.h.z.ad.z.q.igitur ex ratione sinuū angulus.z.h.q.maior est angulo.z.h.p. Sed extrinseci eorū b.m.k.et.h.l.t.sunt equales:igitur residui duo intrinseci sunt inequales: sciz angulus.h.z.t.maior angulo.h.z.k.quod est intentum. Ex his manifestū est tam per modū eccentrici q̄z epicycli stellam in temporibus equalibus in orbe signorum inequales arcus describere.

Propositio .vij.



Secundum modum ecētrici maxima differentia inter motum equalem ⁊ apparentē continget in puncto transitus medij: quem determinat linea motus apparentis super diametro per ambo centra euntē stans perpendiculariter.

¶ Sit eccentricus.a.b.g.d.per cuius centrum.e.⁊ per centrū mundi.z.⁊ longitudinem longiorē.a.⁊ propiorem.g.transeat diameter.a.g. Linea motus apparentis stans super.a.g.orthogonaliter sit.z.b.ductaq̄z.b.e.angulus diuersitatis inter motū equalem ⁊ apparentē est.e.b.z. Motus eni equalis tūc est angulus.a.e.b.Sed apparēs est angulus.a.z.b. Fiāt etiā duo alij anguli diuersitatum apud duo puncta.t.et.k.qui sint.e.t.z.⁊.e.k.z. Dico angulum b.maximū horum esse. Continetur enim.b.z.in.d.⁊ ducantur.t.d.e.d.et.k.d quia per septimam tertij.t.z.est lōgior.z.d.igitur per.19.primi erit angulus t.z.d.maior angulo.t.d.z. Sed.e.d.t.equalis est angulo.e.t.d.per diffinitionem circuli:⁊ quintā primi.igitur residuus.z.d.e.maior est residuo.e.t.z.sed e.d.z.equalis est angulo.e.b.z.igitur angulus.e.b.z.maior est angulo.e.t.z. Similiter probabif.e.b.z.maiorē esse.e.k.z. ¶ Vel sic ostende. Sint.h.t.pūcta in arcu.a.b.ductis.e.k.⁊.e.l.perpendicularibus super.h.z.et.t.z.per penultimam primi patet.e.z.longiorem esse.e.k.et.e.k.longiorem.e.l.Sed.e.b e.h.et.e.t.sunt equales:ergo per octauam quinti proportio.e.t.ad.e.l.maior est proportione.h.e.ad.e.k.et.h.e.ad.e.k.proportio maior proportione.b.e. ad.e.z. Ideoq̄z ex ratiōe sinus angulus.b.est maior angulo.h.⁊ angulus.h. maior angulo.t.igitur ⁊c.



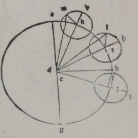
Ex hoc infertur: quanto linea motus apparentis puncto trāsitus medij vicinior fuerit: tanto differentia inter motum apparentem ⁊ equalem maior est.

¶ Idem ostendere poteris de punctis inter.b.et.g.

Hinc etiam constat arcū a longitudine longiori: id est puncto motus minoris ad punctum trāsitus medij esse maiorem arcu a puncto transitus medij ad longitudinem propiorem in punctum motus maioris in duplo maxime diuersitatis.

¶ Nam quanto angulus.a.e.b.est maior angulo.a.z.b.tanto etiā angulus g.z.b.maior est angulo.g.e.b. Ideo angulus.a.e.b.maior est angulo.g.e.b. in duplo anguli.e.b.z.quod est intentum.

Propositio viij.



Secundum modum epicycli dum centrum epicycli in concētrico: planetaq̄ in epicyclo eque cito circueat: fueritq̄ motus minor in longitudine longiori: maxima differentia inter motum equalem ⁊ apparentem continget dum linea motus apparentis a puncto longitudinis longioris quarta circuli distiterit.

¶ Sit concentricus.a.b.g.d.super centro.e.sitq̄z.a.locus centri epicycli dū planeta fuerit in longitudine longiori epicycli.z.vo sit punctus centri epicycli dum linea.e.n.motus apparentis distiterit ab.a.per quartam circuli seu

Cox Proportional Hazards Model - Observatories Size

	Risk of creating an Observatory		
	(1)	(2)	(3)
(ihs) Exposure to Mathematical Astronomy S_t^k	0.344***	0.314***	0.316***
	(0.041)	(0.050)	(0.052)
(ihs) City Population in 1500		0.145*	0.142*
		(0.081)	(0.085)
(ihs) Distance to Vienna (gravity model)			-0.160***
			(0.050)
Log Likelihood	-254.978	-254.139	-253.212

Note: *p<0.1; **p< 0.05; ***p<0.01. 54,390 observations
All the variables are transformed in inverse hyperbolic sine.

A one-unit increase in exposure $\Rightarrow$ +41.0%, +36.9%, +37.2%.

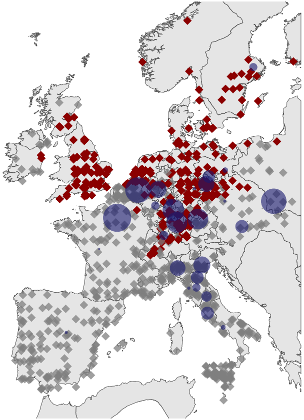
3. Salvatio: Scholasticism, Petrus Lombardus, and his *Sentences*

- 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

- 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)

Exposure to scholasticism in the 30 years prior 1508



1600

Legend: Institution-level exposure bubbles in **blue**. Protestant cities in **red**, Catholic cities in **gray**

Discussion

- Our exposure measure seems to capture the spread of Scholasticisms in Northern and Central Europe, while the same cannot be said for other regions:
  - No Scholasticism in the Iberic peninsula? $\Rightarrow$ The School of Salamanca revitalized and advanced scholastic theology, but flourished only after 1520s, and our measure stops in 1508
  - No Scholasticism in the British Isles? Considering Oxford scholastic tradition $\Rightarrow$ hard to assign fields to fellows in our data, point we are trying to address
  - Not much Scholasticism in Italy? $\Rightarrow$ More prevalent in monasteries and convents rather than universities (more focused on law, medicine, and the classical traditions of philosophy)

Linear probability model

	Protestant in		
	1530	1560	1600
	(1)	(2)	(3)
Exposure to Scholasticism S^c_{1508}	0.001**	0.003**	0.004***
	(0.001)	(0.001)	(0.001)
Presence of university in 1500	-0.036	-0.077	-0.142***
	(0.027)	(0.052)	(0.054)
Observations	867	867	867
Adjusted R^2	0.022	0.059	0.098

Notes: Robust SE clustered by territory (from Rubin) in parentheses.

Counterfactual experiments

What if Fuchs' Botanical Realism was not invented by Fuchs but by other persons is various places?
$\rightarrow$ look into diffusion speed and survival of ideas

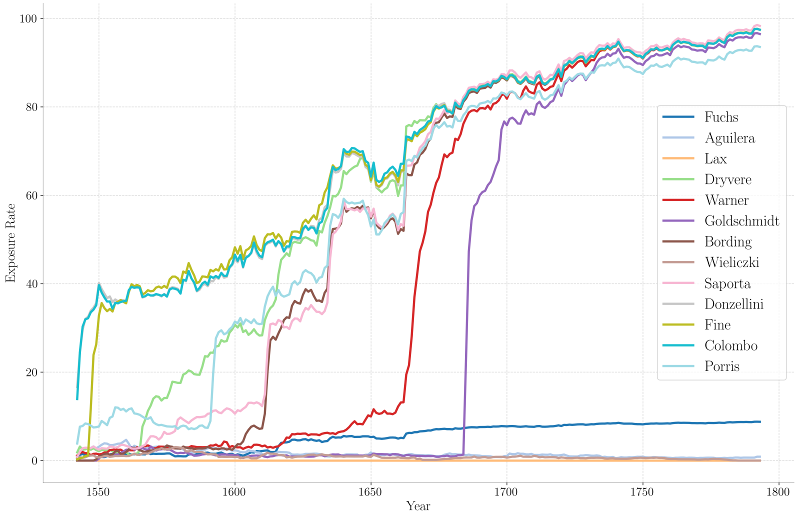
What if some parts of the networks were missing? Academies. Geographical regions. Jesuits
$\rightarrow$ assess the importance / the necessity of these parts

Aim: better understand the topology of the institutional network

Counterfactual experiment 1: Placebo inventors

- How crucial are the identity of pioneers for the spread of ideas in our model?
- We identify some placebo inventors of Botanical Realism in place of Fuchs, and simulate the diffusion of this paradigm from their university (in 1542)
  1. Juan Aguilera in Salamanca
  2. Gaspard Lax de Sarenina in Zaragoza
  3. John Warner in Oxford
  4. Jeremius Dryvere in Louvain
  5. Andreas Goldschmidt in Wittenberg
  6. Mikołaj Mleczko Wieliczki in Cracow
  7. Jacob Bording in Rostock
  8. Antoine Saporta in Montpellier
  9. Girolamo Donzellini in Padua
  10. Oronce Fine in the Royal College
  11. Realdo Colombo in Pisa
  12. Georg Joachim Porris in Leipzig

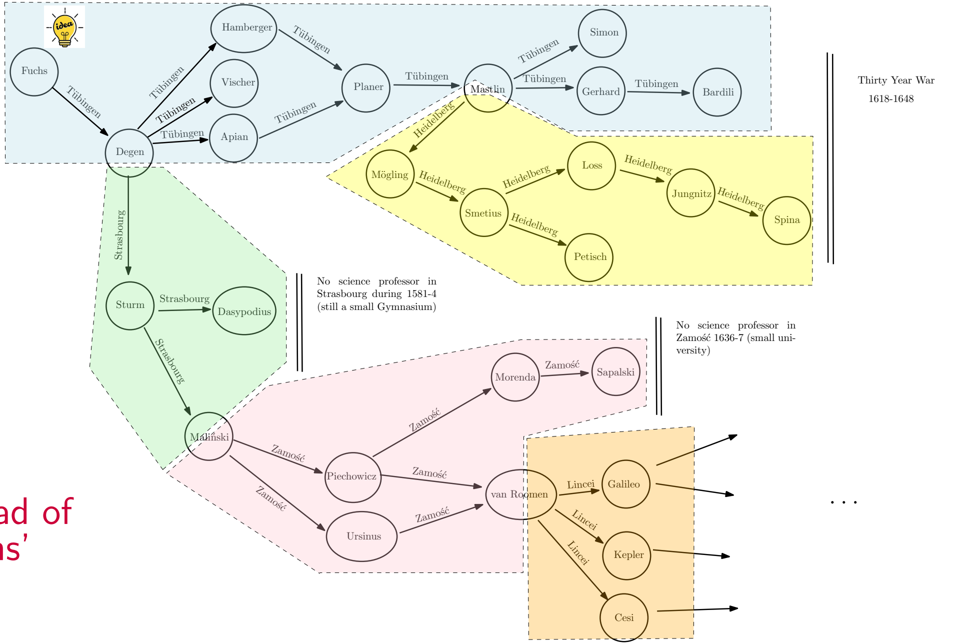
Share of exposed scholars (medicine+science) – average over simulations



Discussion

- In three cases (Aguilera in Salamanca, Wieliczki in Cracow, and Lax in Zaragoza), the idea fails to spread
- In nine cases, nearly all the scientists active in the network encounter the idea by the end of the period in all the simulations, but
  - Donzellini (Padua), Colombo (Pisa) and Fine (Royal College), achieving the fastest spread
  - Goldschmidt (Wittenberg) and Warner (Oxford), relatively slow diffusion before the 1650s
- Fuchs plateaus at around 10%, meaning the idea survives in only some of the simulations, and dies out in the other cases
- $\rightarrow$ diffusion process generated by our model is **non-ergodic**: the distribution of an idea dependents on its initial conditions (analogy with QWERTY (David 1985))

The spread of Fuchs' idea



Counterfactual experiment 2: Absence of academies

- 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 (100)

	Q1	Median	Q3
Botanical Realism			
No direct effect in 1600	100	100	100
No ACAD at all in 1600	100	100	100
Mathematical Astronomy			
No direct effect in 1600	76	78	83
No ACAD at all in 1600	73	77	81
Botanical Realism			
No direct effect in 1750	25	29	34
No ACAD at all in 1750	0	0	0
Mathematical Astronomy			
No direct effect in 1750	20	26	31
No ACAD at all in 1750	3	7	16

1600: only a few (mostly informal) academies.
They do not matter for exposure to Botanical Realism (both columns are at 100)
Help spread of Mathematical Astronomy

1750: academies matter more and more directly and are necessary component of the network for Botanic Realism, important component for Mathematical Astronomy

Counterfactual 3: absence of specific regions

	Q1	Median	Q3
Botanical Realism			
No Italian Peninsula	0	0	0
No British Isles	75	88	89
No France	53	65	81
No Iberic Peninsula	95	95	95
No Holy Roman Empire	0	0	0
Mathematical Astronomy			
No Italian Peninsula	0	0	0
No British Isles	82	97	99
No France	65	78	96
No Iberic Peninsula	100	100	100
No Holy Roman Empire	92	96	99

Exposure in 1793

Removing any single region from the network has little impact, except for the region where the idea originated

$\rightarrow$ shows the resilience of the network

Counterfactual 4: absence of Jesuits

	Q1	Median	Q3
Botanical Realism			
No direct effect	93	97	98
No Jesuits at all	90	93	94
Mathematical Astronomy			
No direct effect	91	95	97
No Jesuits at all	91	95	97


(AI)

The Jesuits: 10.9% of all scholars (aft. 1500).

They matter surprisingly little

Network effect is small: they form a network of their own, disconnected from the others

Conclusion

European scholars were part of an interconnected academic network: mobility + academies

We investigate its role by combining an affiliation network derived from original microdata with an epidemiological model

Main message: The network was dense enough to – alone – foster the spread and preservation of ideas across time and space as early as 1100

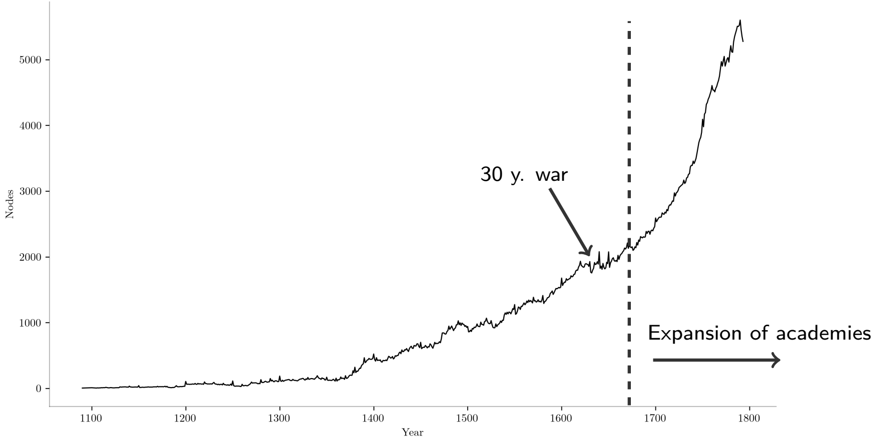
→ Interpersonal exchanges within institutions play a role (alongside other channels of diffusion governed by a gravity model)

Mechanisms: Both mobility and academies amplify intellectual exchange

Allowed to safeguard ideas when universities were forced to close (30 y. war)

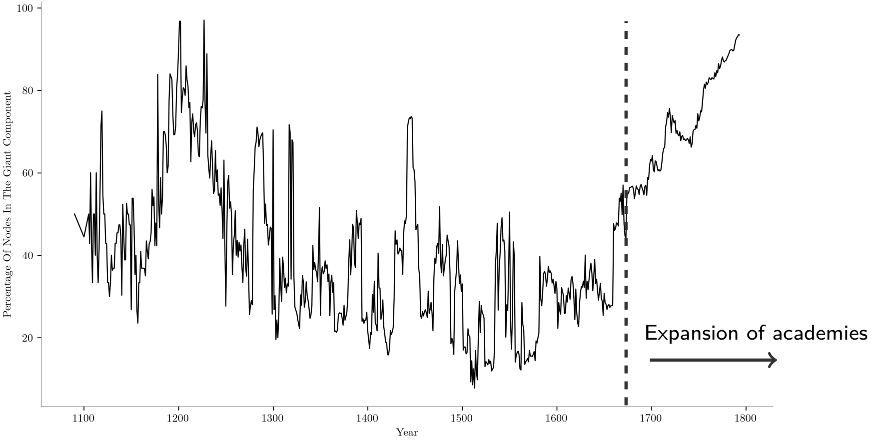
Can this density and resilience explain Europe's advance in premodern period?

Number of nodes over time



Back to Network

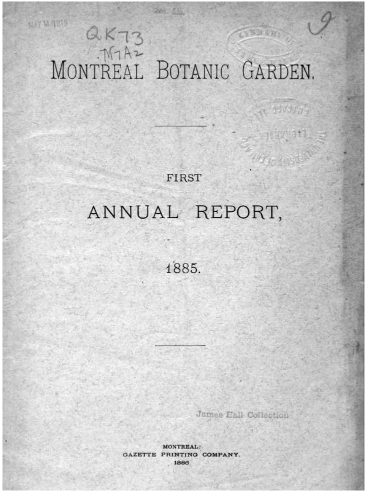
Percentage of nodes in the giant component



Back to Network

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


QK73
.M7A2
9

MONTREAL BOTANIC GARDEN.

FIRST

ANNUAL REPORT,

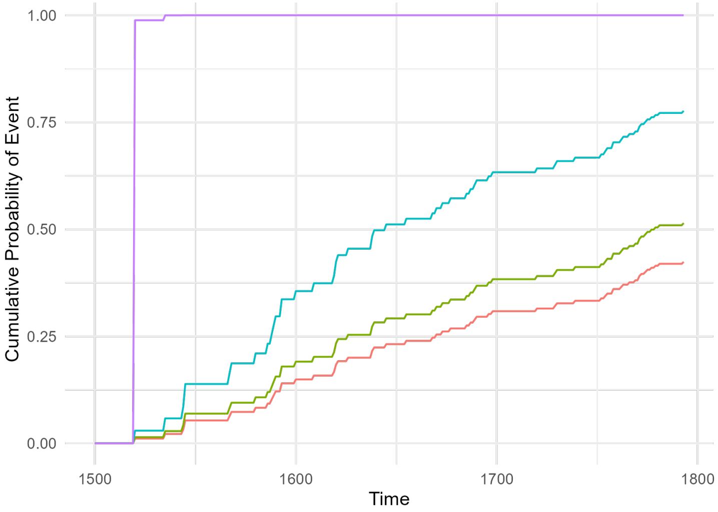
1885.

James Hall Collection

MONTREAL:
GAZETTE PRINTING COMPANY.
1886

Back to Fuchs

Size effects - Botanic Gardens



Probability of getting a Botanic Garden for different exposure to Botanical Realism

purple line: constant exposure of 6 (max),

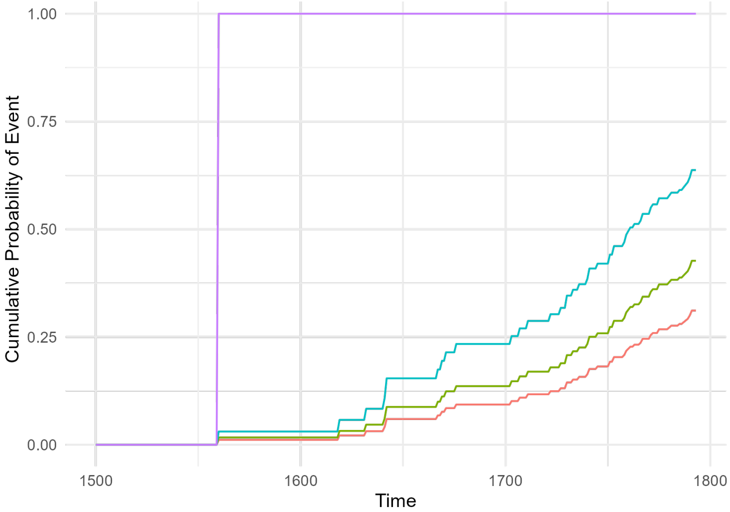
blue line: constant exposure of 1,

green line: constant exposure of 0.27 (mean),

red line: constant null exposure.

Back to Cox

Size effects - Observatories



Probability of getting an observatory for different exposure to Mathematical Astronomy

purple line: constant exposure of 7.8 (max),

blue line: constant exposure of 1,

green line: constant exposure of 0.4 (mean),

red line: constant null exposure.

Back to Cox