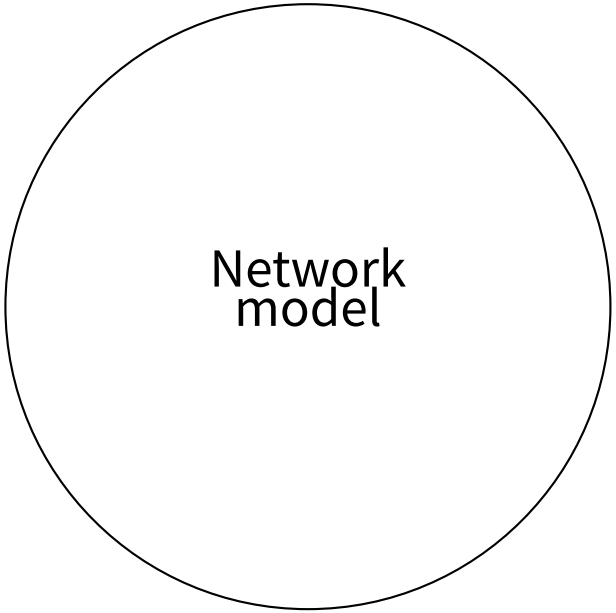
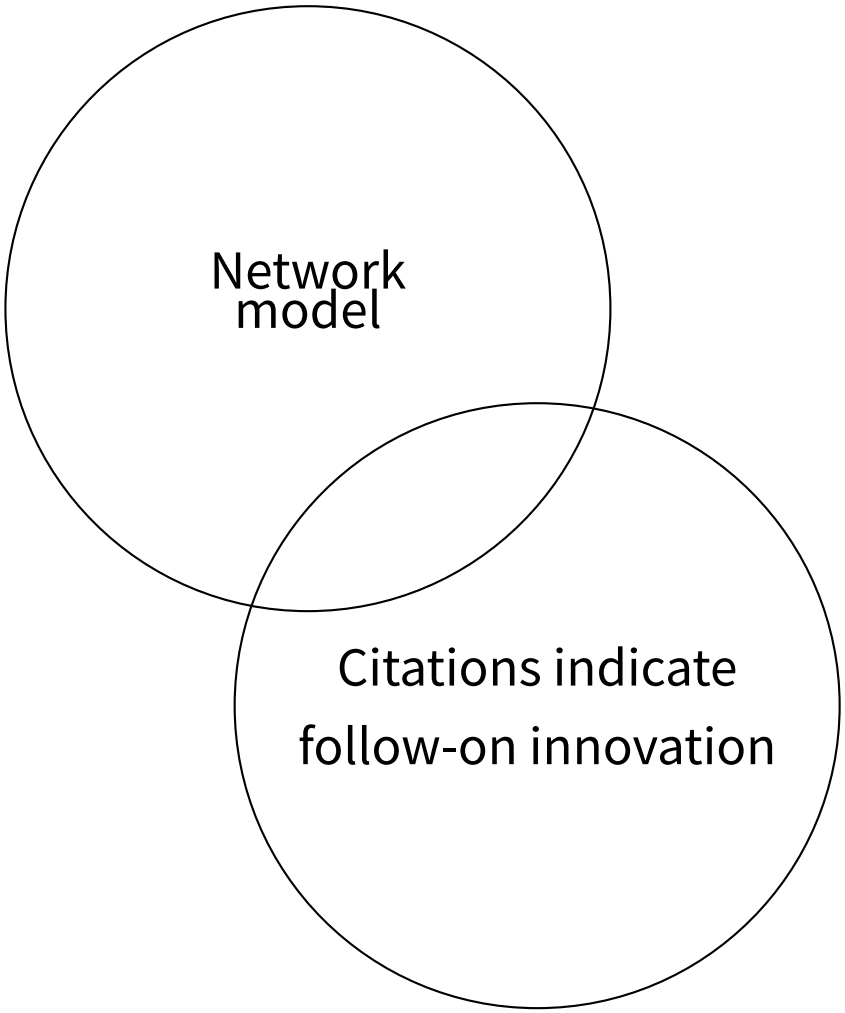
KNOWLEDGE ACCESS AND CUMULATIVE INNOVATION

NETWORK-ECONOMETRIC EVIDENCE FROM THE REPUBLIC OF LETTERS

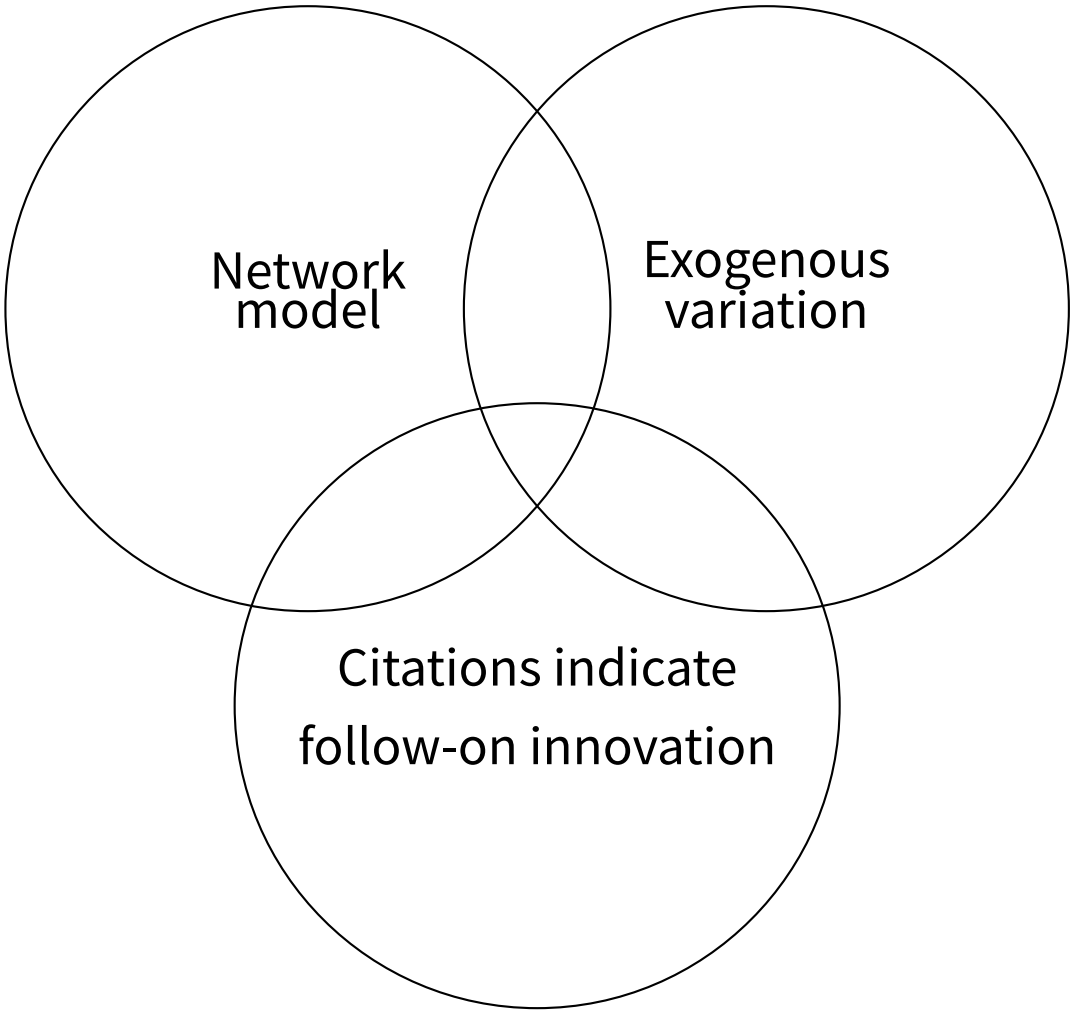
IDEA



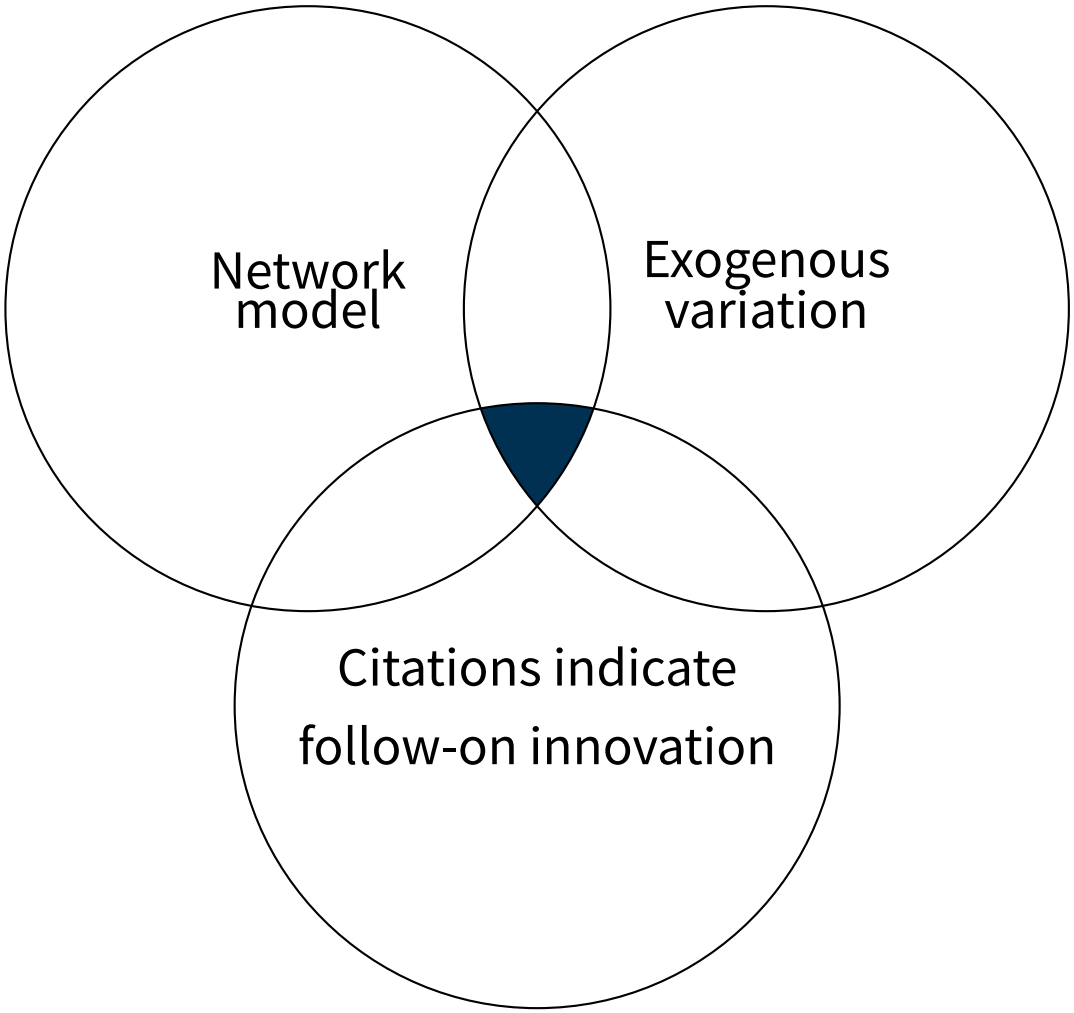
- Citation-based network model of scientists



- Citation-based network model of scientists
- Link formation indicates cumulative innovation



- Citation-based network model of scientists
- Link formation indicates cumulative innovation
- Exogenous variation in the availability of long-distance communication



- Citation-based network model of scientists
- Link formation indicates cumulative innovation
- Exogenous variation in the availability of long-distance communication

RESEARCH QUESTION

How did the re-establishment of packet boats between Dover and Calais in the brief period of peace intervening the Nine Years' War (1688-1697) and the War of the Spanish Succession (1701-1714) affect the formation of citation-based links within a correspondence-based network of early modern European scholars?

Underlying questions:

- Do we see an increase in follow-on innovation as existing knowledge becomes more easily accessible?
- Can we gain valuable insights from the past that help us create an optimal environment for the production of new knowledge?

WHY CARE?

WHY SHOULD WE CARE ABOUT THIS QUESTION?

- Economic growth in advanced economies is mainly innovation-driven. (Acemoglu et al. 2006, Benhabib et al. 2014).
- Innovation is highly cumulative (Arrow 1962).
- Openness facilitates cumulative innovation (Murray et al. 2009).
- Quantifying the impact of knowledge accessibility on follow-on innovation is difficult.
- Historical settings permit analyses we could not conduct with present-day data (see Biasi and Moser 2018).

$\Rightarrow$ This study could provide important insights for shaping policies on open access, open source, cloud storage, and intellectual property rights.

OVERVIEW

- I want to isolate the innovation-spawning effects of a single access technology.
- The ubiquity, complexity, and endogeneity of today's communication and transport technologies typically prevent researchers from doing that.
- Until the mid-19th century, mail services had been the only available technology to effectively exchange insights over distance without traveling.
- I will exploit discontinuities in the availability of cross-channel postal services.
- Citation data from the earliest two academic journals will render the network's links indicative of cumulative innovation: If A cited B, then A used the existing knowledge of B to create something new.
- War-related turmoils in the Channel did not obstruct the bilateral exchange between all scholars.
- Considering each possible pair of scholars as a separate cross-sectional unit gives rise to a quasi-experimental setting.

SETTING

HOW DID I ARRIVE AT THIS PARTICULAR SETTING?

- Communication and transport technologies can be used to access knowledge.
- We typically cannot observe the use of communication technologies.
- By going back to at least the 1840s we can rule out any long-distance communication technology besides mail.
- We now need to find exogenous variation in the provision of postal services.
- The English Channel has provided previous studies with exogenous variation (see Koudijs 2016, Juhász 2018).
- The postal service between Dover and Calais stopped in 1689, recommenced in 1697, and stopped again in 1702.
- We can study how quickly recently created, previously inaccessible knowledge disseminates as well as how much slower recently created, previously accessible knowledge spreads.

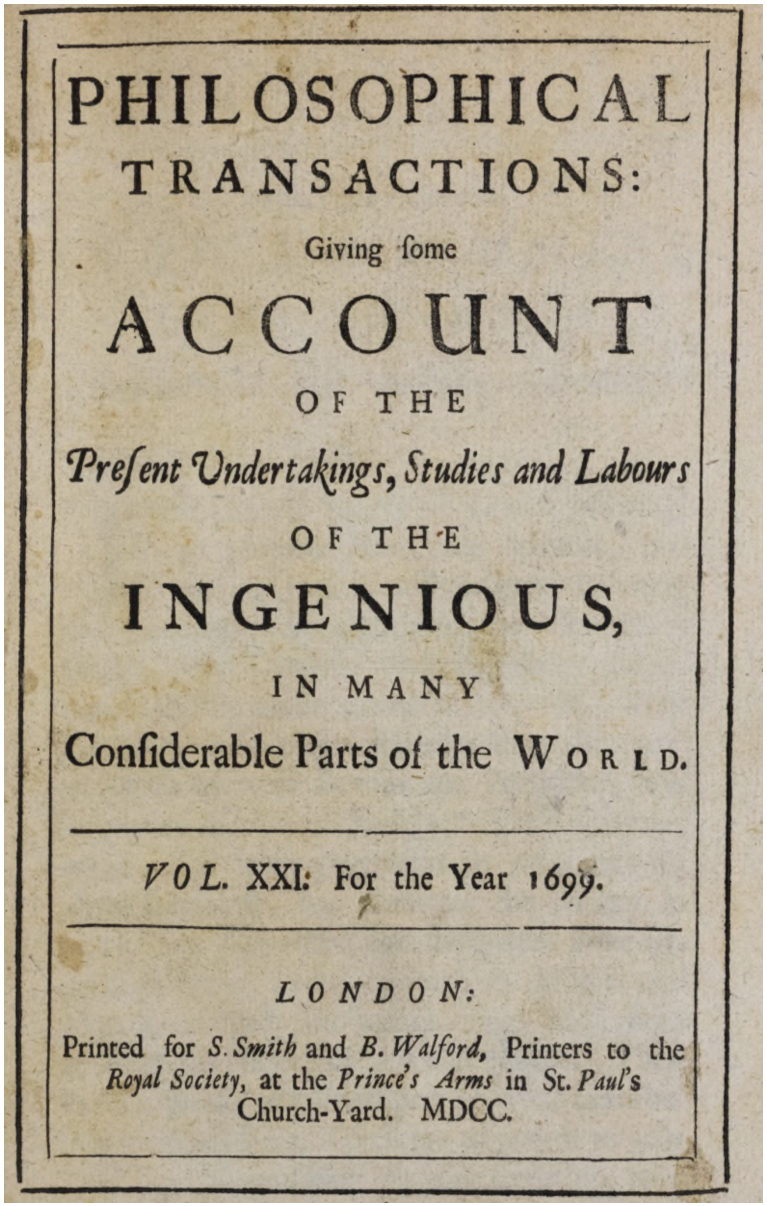
WHY IS THIS AN INTERESTING SETTING?

- The setting is of utmost interest as this era laid the foundation for today's scientific environment.
- The setting allows us to follow virtually the entire scientific community over the years succeeding the birth of modern science.
- The members of the Republic of Letters
  - provided the groundwork for numerous inventions that later drove the First Industrial Revolution,
  - created a significant portion of the basic knowledge that we still rely on today,
  - supplied society with useful knowledge and practical solutions to common problems.
- The origins of several scientific subfields date back to scholars in the sample.

HISTORICAL BACKGROUND

- The concepts of the earliest two academic journals differed.
- Le Journal des Sçavans
  - first published in January 1665
  - 79 % book reviews, but higher page count than Phil. Trans.[1]
  - the most prominent fields were theology (17 %) and history (11%).[2]
- Philosophical Transactions
  - first published in March 1665
  - articles account for 90 % of the content.[3]
  - emphasized the natural sciences
- The citation data will be transcribed from the articles that were published in the 1681 to 1709 issues of the two journals.
- The scientific article started out as a letter.

[1] (Banks 2015, p. 2)
[2] ibid.
[3] I transcribed the tables of contents of the 122 issues that were published between 1691 and 1709. 64 of the 683 items are book reviews.



PHILOSOPHICAL
TRANSACTIONS:
Giving ſome
ACCOUNT
OF THE
Preſent Undertakings, Studies and Labours
OF THE
INGENIOUS,
IN MANY
Conſiderable Parts of the WORLD.

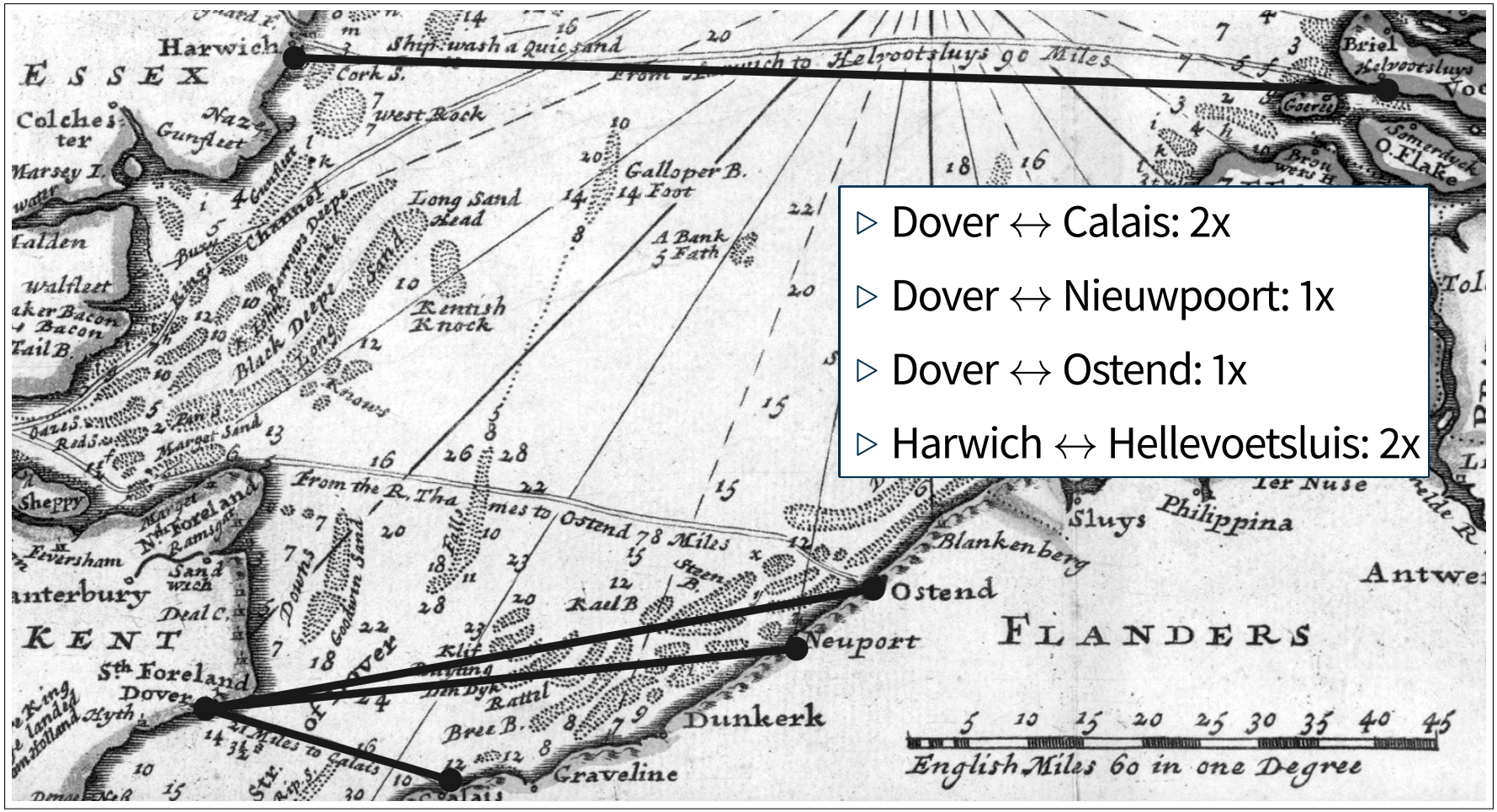
VOL. XXI: For the Year 1699.

LONDON:
Printed for *S. Smith* and *B. Walford*, Printers to the *Royal Society*, at the *Prince's Arms* in St. *Paul's* Church-Yard. MDCC.

[Source: Royal Society (2017)]

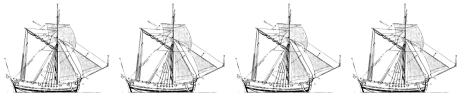
- Via letters and the first scientific journals
- Over long distances and across borders
- Between about 1,200 elite scholars (Ultee 1987, p. 100)
- High degree of international correspondence
- Communication across the Channel was essential (see Ultee 1987, p. 107).
- Conflicts impeded the transmission of mail and distorted the exchange of ideas.

WEEKLY PACKET BOAT SERVICE IN 1688



- Dover ↔ Calais: 2x
- Dover ↔ Nieuwpoort: 1x
- Dover ↔ Ostend: 1x
- Harwich ↔ Hellevoetsluis: 2x

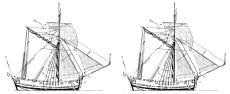
[David Rumsey Map Collection]

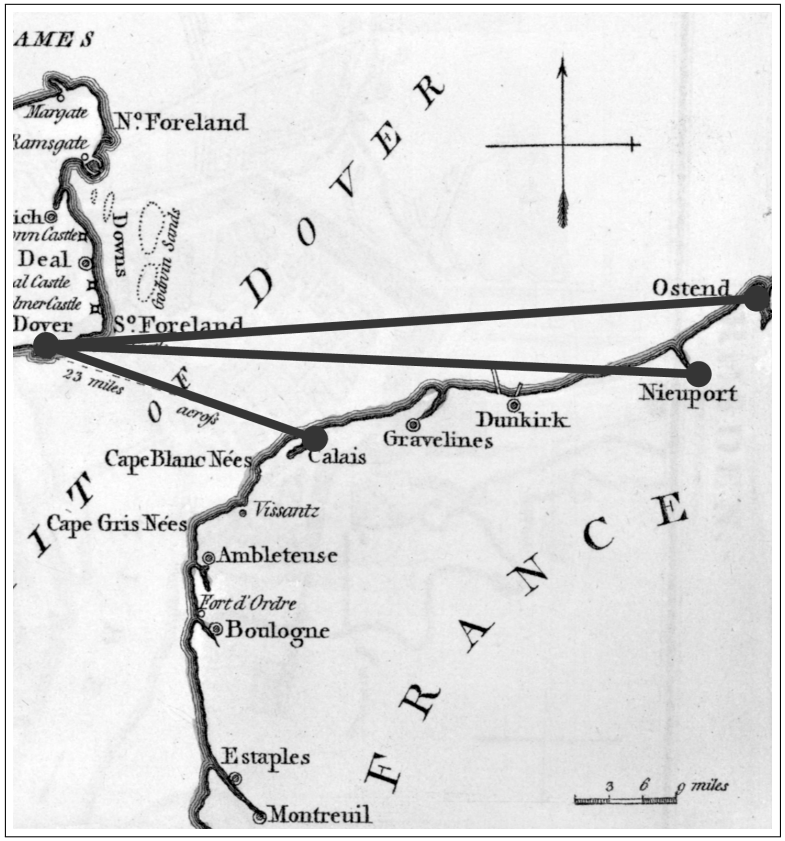
- Dover: 
- Harwich: 

NINE YEARS' WAR (1688-1697)

[https://en.wikipedia.org/wiki/File:Nine_Years_War_-_Spanish_Netherlands_campaign_1689-97.PNG, 04/29/2020]

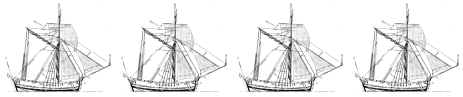
- Belligerents: France & Jacobites vs. the Grand Alliance
- Main fighting in the Spanish Netherlands, the Rhineland, Savoy and Catalonia
- Distorted bilateral correspondence on the Continent and across the Channel
- Domestic British mail service was largely unaffected.

- Packet service from Dover was discontinued in 1689.
- Service between Harwich and Hellevoetsluis was extended: 
- Connection between Falmouth and A Coruña was established: 

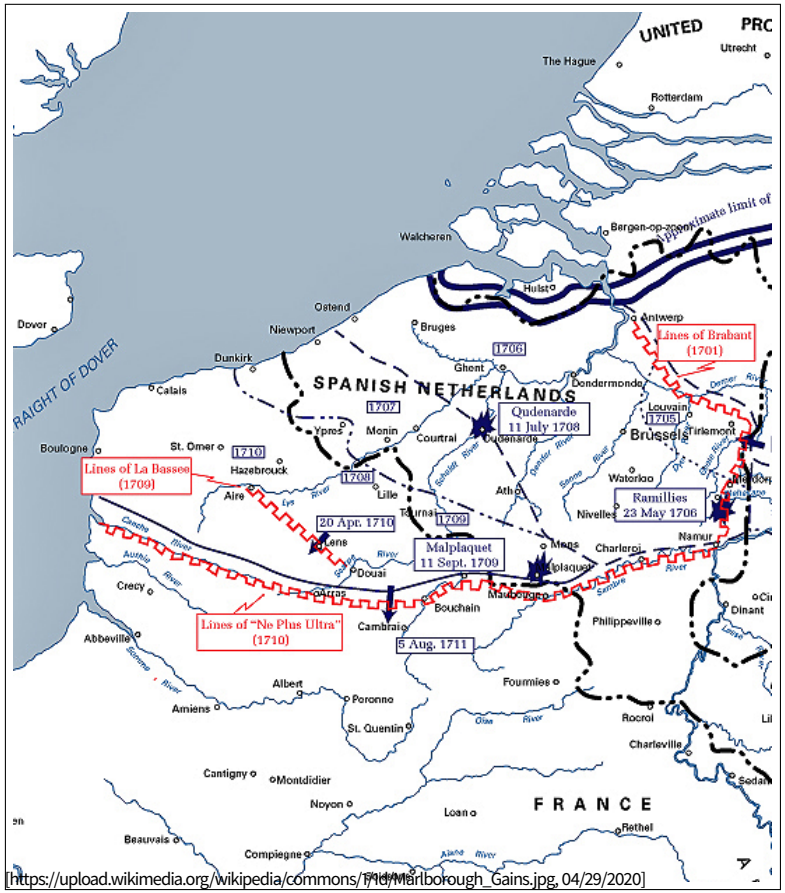


[David Rumsey Map Collection]

- Peace of Ryswick in the fall of 1697
- Dover packet service recommenced
- Harwich packet service continued
- Lisbon replaced A Coruña as destination of the two Falmouth packets in 1701
- Two boats were added to this route in 1703 to ensure weekly mail service.

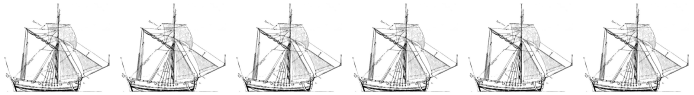
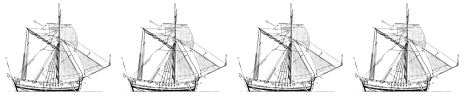
- Dover: 
- Harwich ↔ Hellevoetsluis: 
- Falmouth ↔ Lisbon: 

WAR OF THE SPANISH SUCCESSION (1701-1714)



[https://upload.wikimedia.org/wikipedia/commons/7/7d/Marlborough_Gains.jpg, 04/29/2020]

- Habsburg Spain, Holy Roman Empire, Dutch Republic, Great Britain,..
- vs. France, Bourbon Spain, Bavaria,..
- Portugal switched sides in May 1703.
- Fighting on the exterior lines of France
- Pré Carré: Double line of fortresses guarding the French border to the Spanish Netherlands

- Packet service from Dover was discontinued in 1702.
- Harwich ↔ Hellevoetsluis: 
- Falmouth ↔ Lisbon: 

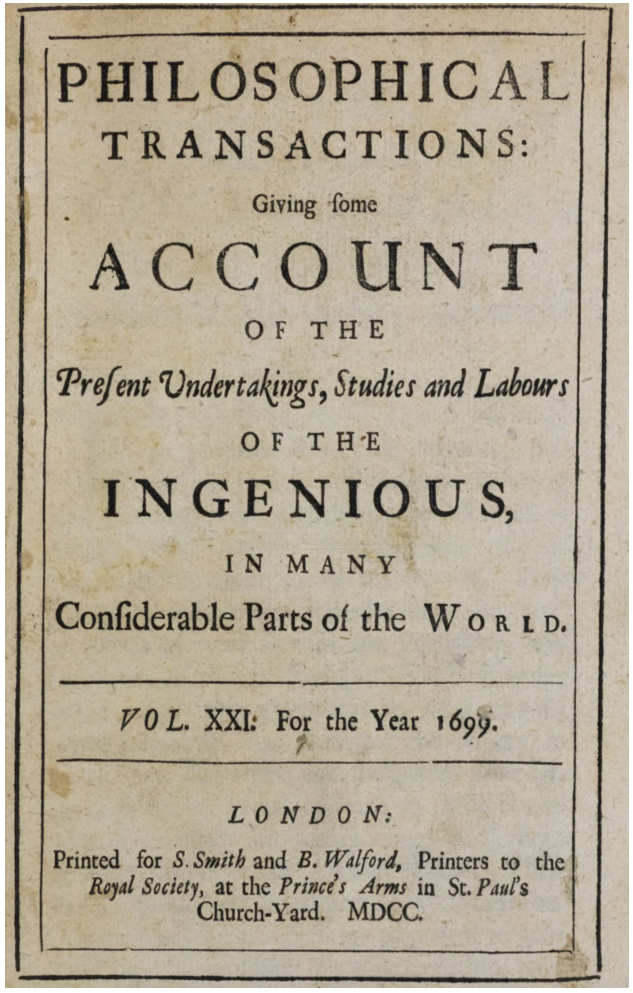
LITERATURE

- Knowledge access and innovation
  - Iaria, Schwarz, and Waldinger (2018)
  - Biasi and Moser (2018)
  - Andrews (2020)
  - Berkes and Nencka (2020)
- Knowledge access and other economic outcomes
  - Jensen (2007)
  - Goyal (2010)
  - Aker (2010)
  - Allen (2014)
  - Feigenbaum and Rotemberg (2014)
  - Koudijs (2016)
  - Steinwender (2018)

- Trade costs and innovation
  - Agrawal, Galasso, and Oettl (2017)
  - Bernard, Moxnes, and Saito (2019)
  - Catalini, Fons-Rosen, and Gaulé (2019)

- Intellectual property rights and cumulative innovation
  - Biasi and Moser (2018)
  - Williams (2013)
  - Galasso and Schankerman (2015)
  - Sampat and Williams (2015)

APPROACH



PHILOSOPHICAL
TRANSACTIONS:
Giving ſome
ACCOUNT
OF THE
Preſent Undertakings, Studies and Labours
OF THE
INGENIOUS,
IN MANY
Conſiderable Parts of the WORLD.

VOL. XXI: For the Year 1699.

LONDON:
Printed for *S. Smith* and *B. Walford*, Printers to the *Royal Society*, at the *Prince's Arms* in St. *Paul's* Church-Yard. MDCC.

[Source: Philosophical Transactions of the Royal Society of London (2017) Archive of all Online Content January 1665 - January 1886]

- Use citations to measure innovation.
- Identify all authors and cited scientists who are mentioned in the 1691 to 1709 issues of the two earliest scientific journals.
- Record all citation links between the scholars.
- Add geographic coordinates for the annual modal location of each scholar.
- Use a network formation model to estimate the effect of the re-establishment of the packet boat service between Dover and Calais.

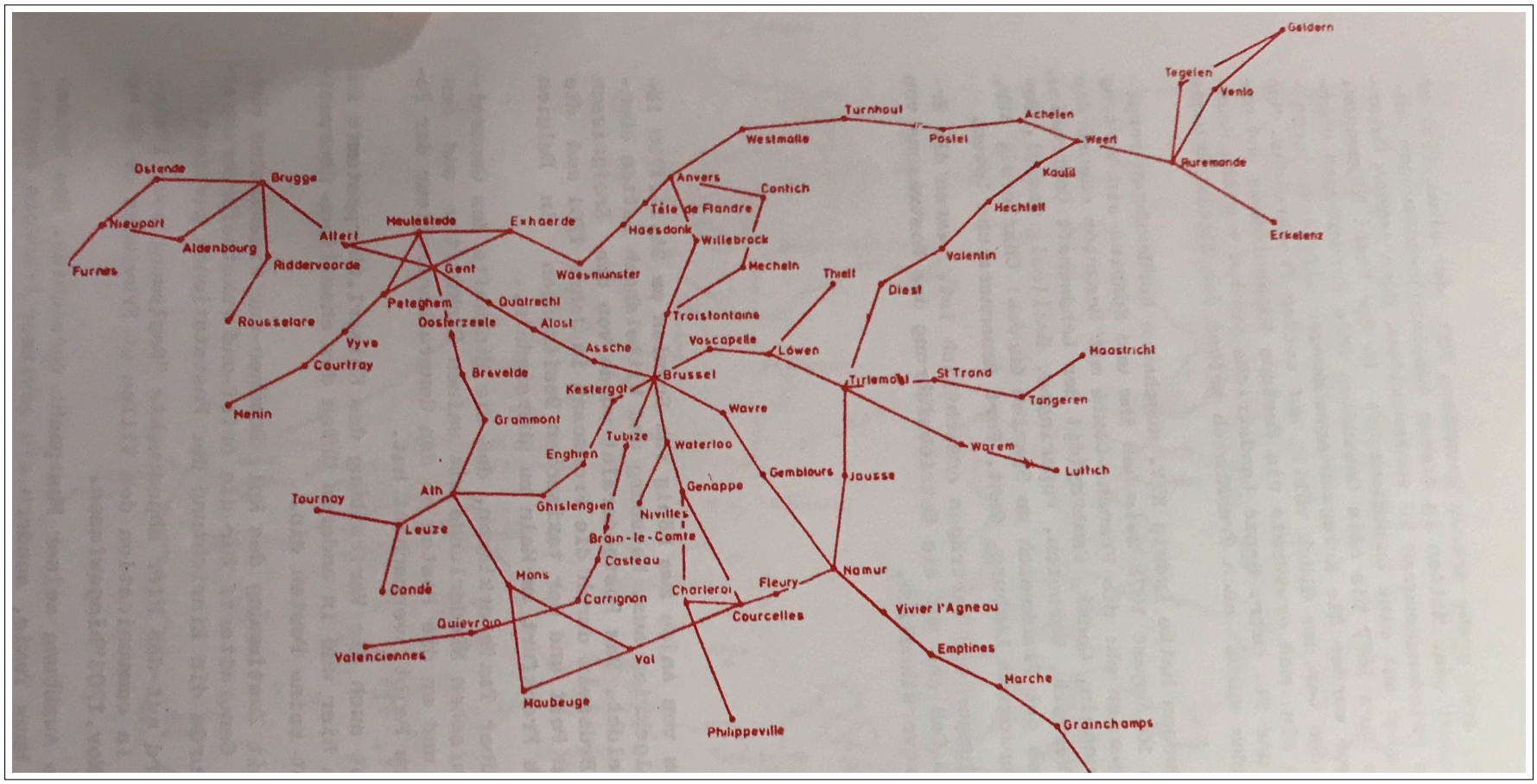
DATA

Allgemeines
Gelehrten-
LEXICON,
Darinne
die Gelehrten aller Stände
sowohl männ- als weiblichen Geschlechts,
welche vom Anfange der Welt bis auf ietzige Zeit
gelebt, und sich der gelehrten Welt bekannt
gemacht,
Nach ihrer Geburt, Leben, merckwürdigen Geschichten, Absterben und Schrifften
aus den glaubwürdigsten Scribenten
in alphabetischer Ordnung beschrieben werden.
Dritter Theil
M——R
heraus gegeben von
Christian Gottlieb Jöcher,
der H. Schrifft Doctore, und der Geschichte öffentlichem Lehrer auf der hohen Schule zu Leipzig.
Mit Röm. Kayserl. wie auch Königl. Pohln. und Churfürstl. Sächsis. allergnädigsten Privilegiis.
LEIPZIG,
in Johann Friedrich Gleditschens Buchhandlung.
MDCC LI.

[Jöcher (1751)]

- Philosophical Transactions
- Le Journal des Sçavans
- Fellow Directory of the Royal Society
- Oxford Dictionary of National Biography
- Arcenas et al. (2020)
- Cultures of Knowledge (2020)
- Jöcher (1750-1751)
- Nicéron (1727-1745)
- Meta and text data of journal articles
- Wikipedia
- Google maps
- ...

Postal routes, postage rates, packet boat service:



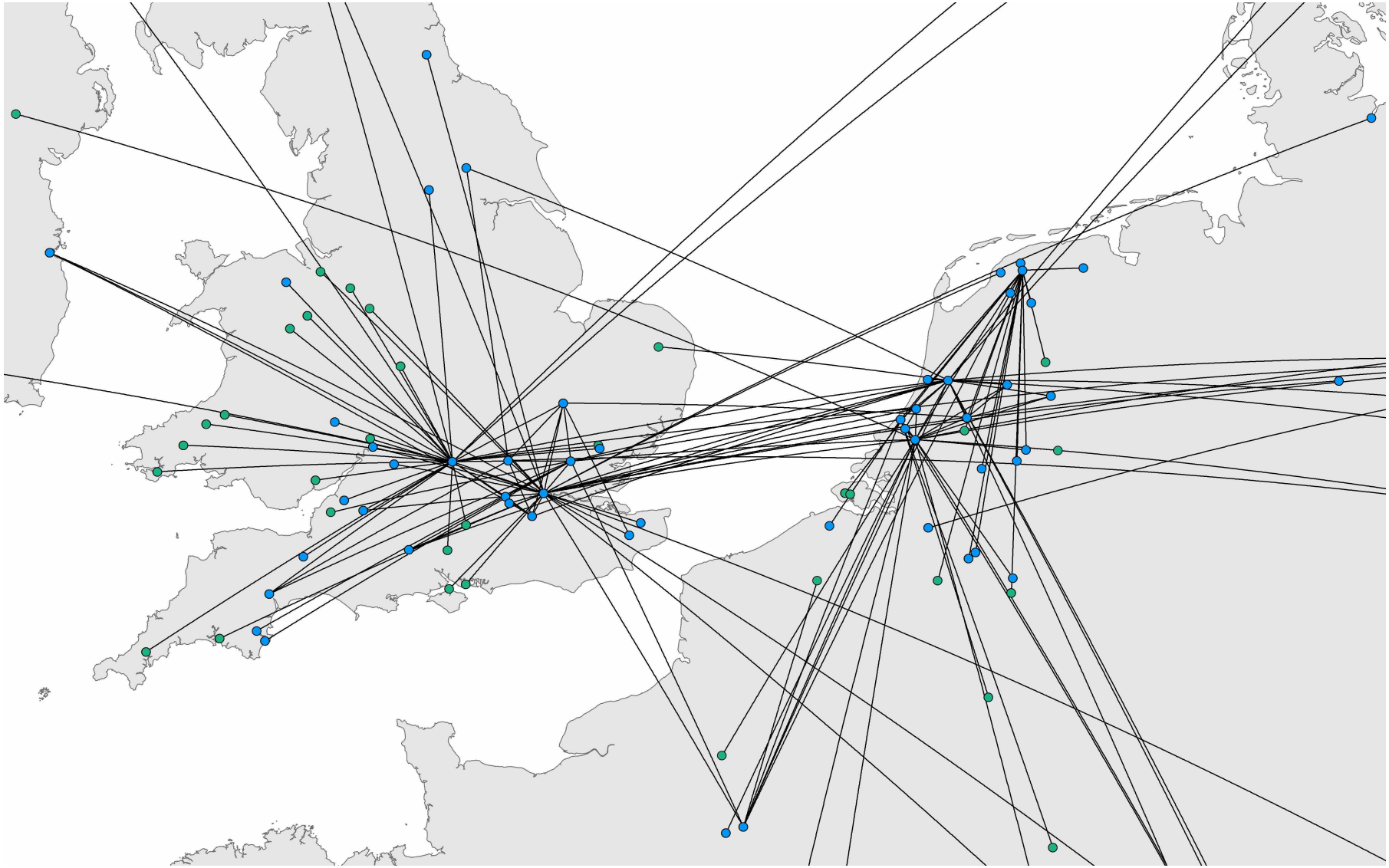
[Münzberg (1989)]

- Goss (1932), Norton (1950)
- Münzberg (1989)
- Joyce (1893)
- Trinder (1998)
- Royal Mail Archive
- Hemmeon (1912)

Pre-period: 6/1694 to 5/1698

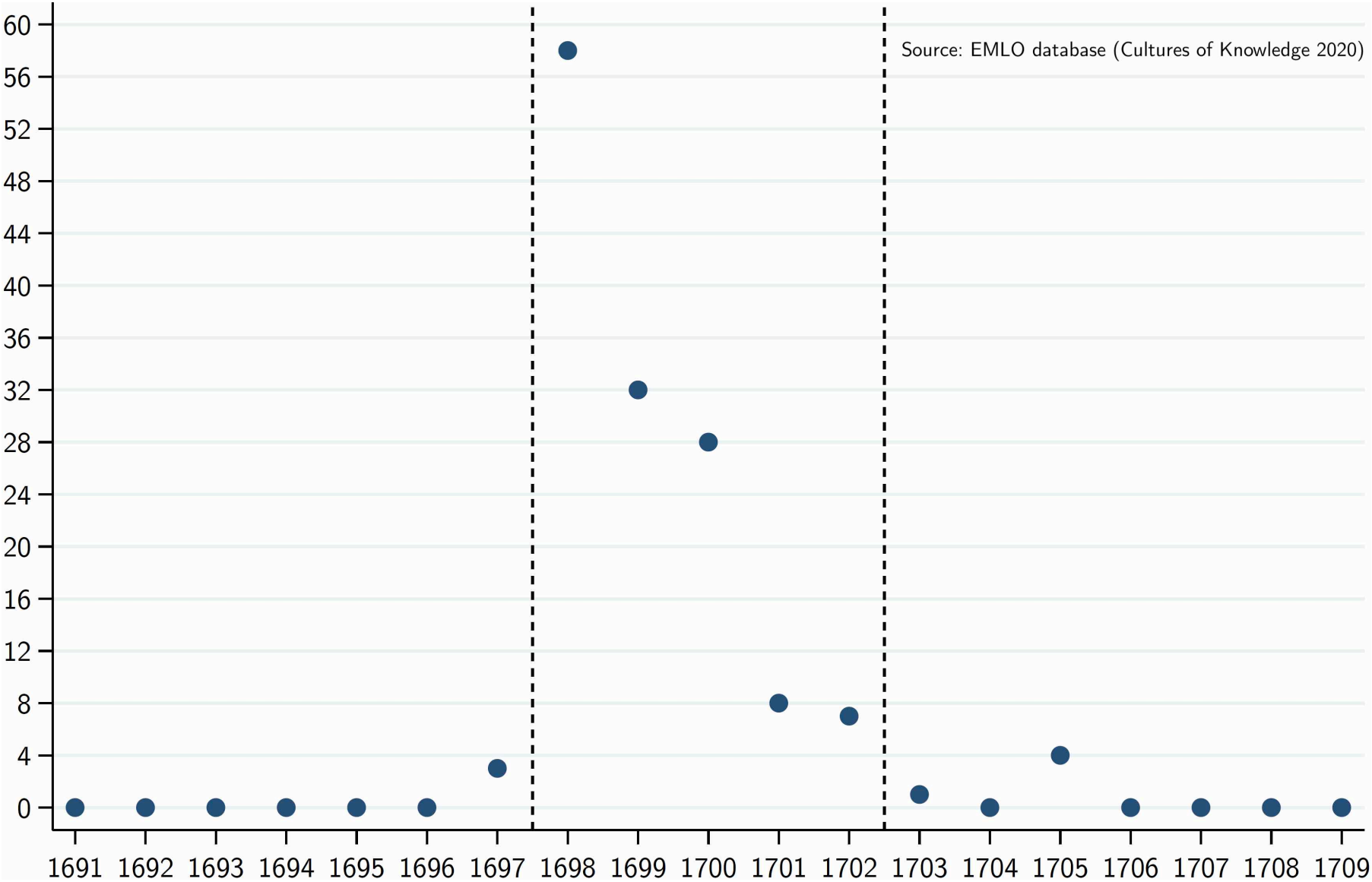
Treatment period: 6/1698 to 5/1702

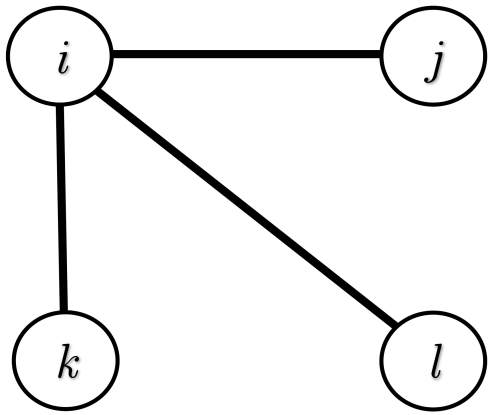
Post-period: 6/1702 to 5/1706



IDENTIFICATION STRATEGY

Direct letter exchange between England and France was only possible in the treatment period.





- A network consists of nodes $\mathcal{N} = \{1, ..., N\}$ and edges $\mathcal{E}$.
- Each scholar i will be a node, each citation an edge.
- A dyad is a pair of nodes, regardless of whether the two nodes are linked or not.

- Dyads are the units of observation in a network.
- Dyads are denoted by the involved nodes, e.g. ij is the dyad of scholars i and j.
- Edges determine the value of the dyads.
- Let D_{ijt} be the value of dyad ij in time period t.
- Here:

$$D_{ijt} = \begin{cases} 1 & \text{if scholar } i \text{ cited scholar } j \text{ (or vice versa) in period } t \\ 0 & \text{otherwise.} \end{cases}$$

$$D_{ijt} = \mathbb{1}\left(\gamma D_{ijt-1} + W'_{ijt}\theta + A_{ij} - U_{ijt} \geq 0\right) \tag{1}$$

- D_{ijt-1}: Link in the previous period
- W_{ijt}: Vector that contains the variable of interest and dyad-level controls
- A_{ij}: Dyadic fixed effect
- U_{ijt}: "match-by-period specific utility shock"[4] iid standard-logistic across dyads and over time

[4] Graham (2013), p. 267.

- If (A1) to (A3) in Graham (2017) hold, the likelihood for (1) can be written as:

$$
\begin{aligned}
& P\left(\boldsymbol{D}_t = \boldsymbol{d}_t | \boldsymbol{D}^{t-1}, \boldsymbol{X}, \boldsymbol{A_0}\right) \\
= & \prod_{i=1}^{N} \prod_{j=i+1}^{N} \prod_{t=1}^{T} P\left(D_{ijt} = d_{ijt} | D_{ij}^{t-1} = d_{ij}^{t-1}, X_i, X_j, A_{ij}\right) \\
= & \prod_{i<j}^{N} \prod_{t=1}^{T} \left[\frac{\exp(\gamma d_{ij,t-1} + W_{ijt}'\theta + A_{ij})}{1 + \exp(\gamma d_{ij,t-1} + W_{ijt}'\theta + A_{ij})}\right]^{d_{ijt}} \\
& \cdot \left[\frac{1}{1 + \exp(\gamma d_{ij,t-1} + W_{ijt}'\theta + A_{ij})}\right]^{1-d_{ijt}} \quad \forall\, i \neq j.
\end{aligned}
\tag{2}
$$

- The model can be estimated with network-versions of Honoré's and Weidner's (2020) moment conditions.

Let $w_{ts} \coloneqq w_{ijt} - w_{ijs}$. For $T = 3$ and $d_{ij0} = 0$, the moment conditions are:

$$m_{\mathrm{O}}^{(a)}(d, x_i, x_j\gamma, \theta) = \begin{cases} \exp(w_{12}'\theta) & \text{if } d = (0,1,0) \\ \exp(w_{13}'\theta - \gamma) & \text{if } d = (0,1,1) \\ -1 & \text{if } (d_1, d_2) = (1,0) \\ \exp(w_{32}'\theta) - 1 & \text{if } d = (1,1,0) \\ 0 & \text{otherwise} \end{cases}$$

$$m_{\mathrm{O}}^{(b)}(d, x_i, x_j, \gamma, \theta) = \begin{cases} \exp(w_{23}'\theta) - 1 & \text{if } d = (0,0,1) \\ -1 & \text{if } (d_1, d_2) = (0,1) \\ \exp(w_{31}'\theta) & \text{if } d = (1,0,0) \\ \exp(\gamma + w_{21}'\theta) & \text{if } d = (1,0,1) \\ 0 & \text{otherwise} \end{cases}$$

$$\forall i \neq j \in \mathcal{N}.$$

$$D_{ijt} = \mathbb{1}\left(\sum_{\tau=1}^{\rho}(\gamma_{g\tau}D_{ijt-\tau} + \delta_{g\tau}F_{ijt-\tau}) + W'_{ijt}\theta_g + \sum_{\tau=-T_0^*}^{T_0^*-T_M^*}\alpha_{g\tau}\mathbb{1}\left(t - T_0^* = \tau\right)\right.$$
$$+ \sum_{\tau=0}^{T_0^*-T_M^*}\beta_{g\tau}\mathbb{1}\left(t - T_0^* = \tau\right) + \sum_{\tau=1}^{T-T_M^*}\eta_{g\tau}\mathbb{1}\left(t - T_M^* = \tau\right) + \sum_{\tau=0}^{T_M*-T_0^*}\pi_{g\tau}S_{ij}\mathbb{1}\left(t - T_0^* = \tau\right)$$
$$\left. + \sum_{\tau=1}^{T-T_M^*}\lambda_{g\tau}S_{ij}\mathbb{1}\left(t - T_M^* = \tau\right) + A_i + A_j - U_{ijt} \geq 0\right) \tag{3}$$

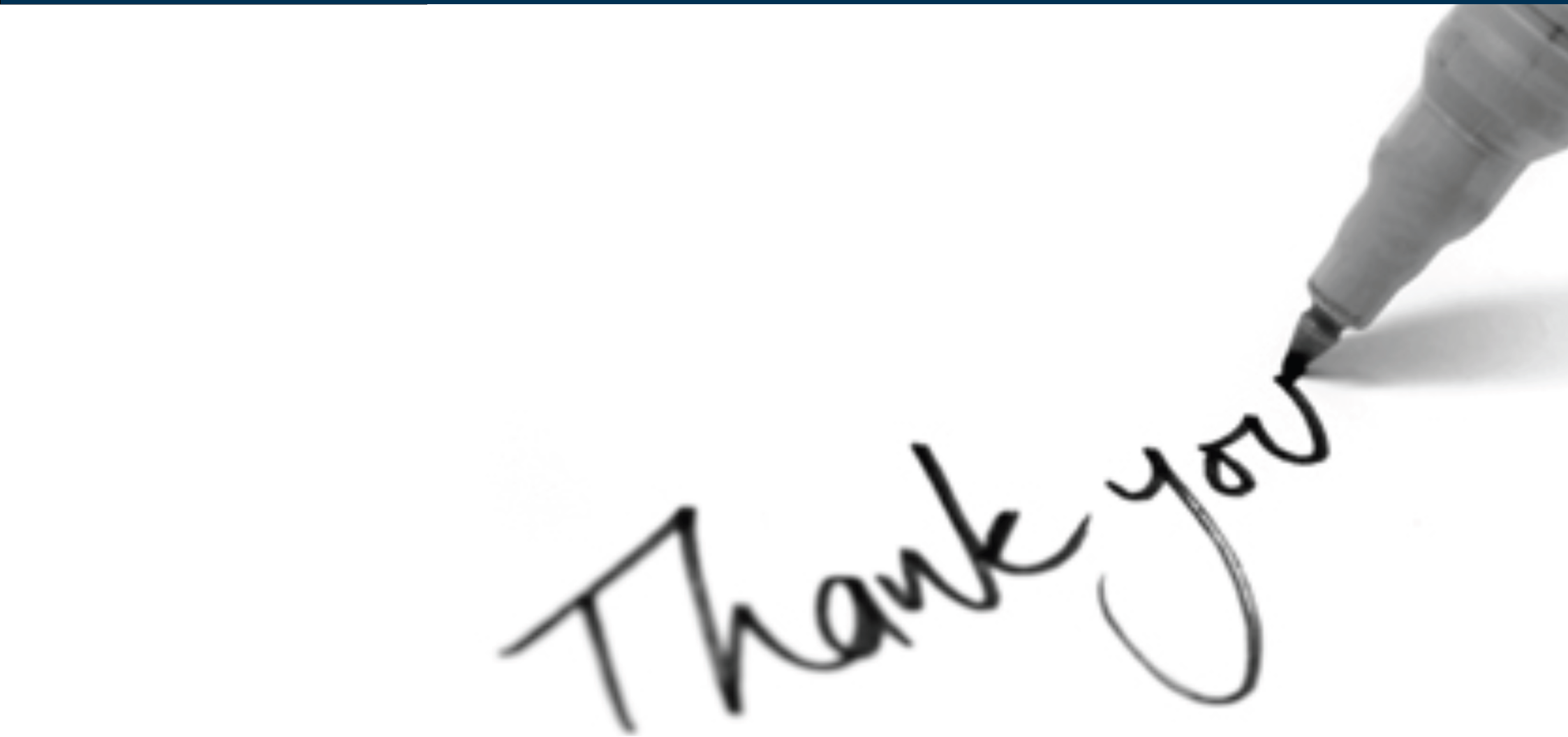
- $F_{ijt-\tau} = \sum_{k=1}^{N} D_{ikt-\tau}D_{jkt-\tau}$: Number of common friends in the previous periods
- W_{ijt}: Residuals from separately regressing the respective editor and journal fixed effects on the group-specific time trend, also distance and whether scholars were members of the same association.
- $S_{ij} := \frac{\sum_{k=1}^{N}(G_{ik}+G_{jk})}{2(N-2)}$ captures spillovers. G_{ij} indicates whether a dyad is treated or not. This means S_{ij} is the share of dyad ij's connections that were affected by the opening of the channel.

SUMMARY OF THE ECONOMETRIC APPROACH

- Drop dyads that don't change status.
- Normalize the moment conditions.
- Estimate the model parameters separately for both groups via GMM.
- Plug in the parameter estimates and use CMLE to estimate the fixed effects.
- Compute the linking probabilities for each group and period.
- Compare the two groups' pre- to post-period changes in the linking probability.
- This difference will provide an estimate of the "average treatment effect on the treated pairs".
- Fafchamps' and Gubert's (2007) approach can be used to derive an analytical expression of the variance.

NEXT STEPS

- Continue the extensive data collection.
- Write up the econometric approach (separate paper).


Thank you