Lecture 6
Technology I

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History of Economic Growth and Crises
25 January 2023

Outline of the course

1. The Malthusian Era
2. Fundamental causes of growth
3. Innovation and crises
    1. **Technology**
        1. Narrative: technological progress in Europe until 1750
        2. Impacts of the printing press
        3. Next lecture: Industrial Revolution, interpretations
    2. Finance
4. Unleashing talent

Sources of growth

Mokyr (1990, Ch. 1)

- Growth can occur through four distinct processes
  1. investment (accumulation of capital)
  2. trade (specialization)
  3. population growth (specialization, public goods)
  4. technology and institutions
- This and the next lecture are about **technological progress**:
  - Mokyr's definition: "change in the application of information to the production process in such a way to increase efficiency"
  - "application of information" deliberate: innovation does not necessarily require invention

Antiquity

Mokyr (1990, Ch. 2)

- Technological progress in Antiquity often considered limited
  - there were not many important innovations in agriculture, metallurgy, mining, shipping, machinery...
- May be overly harsh: in the areas that mattered to *them*, the Greeks and Romans achieved huge success
  - e.g. construction, architecture, literature, science, political organization
  - we may also have a biased sample, because tools and devices made of wood or leather may not have survived

Antiquity

Mokyr (1990, Ch. 2)

- Technological innovations that had economic impact
  - Lever and the screw (Greeks)
  - Cement masonry (Romans)
  - Waterwheel (Romans)

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- Much of the technological progress served the public sector
  - paved streets, sewage disposal, water supply, fire protection, war machines, road network...
- Some impressive technologies used only as gadgets
  - steam engine (used to open temple doors)
  - an analog computer (the Antikythera mechanism)

Antiquity

Mokyr (1990, Ch. 2)

- "[...] classical civilizations had the intellectual potential to create complicated technical devises. The question remains why so little of this potential was realized and translated into economic progress"
- "This is not to say that the ancient economy was primitive, poor, or incapable of growth. But its growth derived from [...] organization, trade, order, the use of money, and law"

Middle Ages, 500–1500

Mokyr (1990, Ch. 3)

- European technology lagged behind the Islamic World and the Orient
  - but Europe adopted many innovations made elsewhere
  - Europe also had many important technological breakthroughs
  - in comparison to the rest of the world, Europe caught up and started to push the technological frontier by 1500

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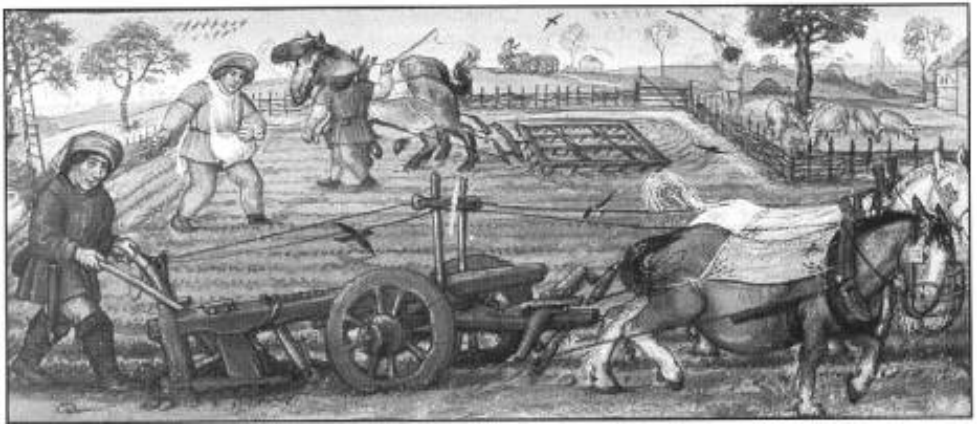
- European progress during the Middle Ages is quite surprising as conditions usually associated with innovation were largely absent
  - low literacy and urbanization rates
  - lots of conflict, little trade
  - infrastructure declined
  - (all particularly true during the early Middle Ages)

Heavy plow, three-field system, new horse collar

Mokyr (1990, Ch. 3)



This picture presents several important innovations of the Middle Ages. The first is the heavy plow that allowed effective cultivation of the soils north of the Alps. The second is the horseshoe and the new kind of horse collar (those used in the Antiquity choked the horse and lost up to 80% of horse's efficiency). The third is the three-field system under which fields rotated between fallow, winter and spring crops.

Innovations of the Middle Ages

Mokyr (1990, Ch. 3)

- Blast furnance, cake of soap, cam, canal lock, galleon, cast-iron pot, chimney, cole-fueled fire, cog boat, compass, crank, cross-staff, distilled liquors, eyeglass, flywheel, glass window, grindstone, hops in beer, marine chart, overshoot water wheel, printing press, shingle ski, spinning wheel, suction pump, spring watch, treadle loom, water-driven bellows, weight-driven clock, wheelbarrow, whippletree, windmill...
- Mokyr: "useful tools and ideas that reduced the daily toil and increased the material comfort of the masses"
  - concentrated largely in the private sector
  - preceeded the beginning of European science

Renaissance and beyond, 1500–1750

Mokyr (1990, Ch. 4)

- The period between 1500–1750 is better know for its scientific achievement than big technological innovations
  - however, many important microinventions, adjustements and discoveries from abroad greatly increased productivity
  - during this era Europe emerged as the technological frontier
- The lack of macroinventions is not due to lack of brilliant ideas
  - but constrainted by what could be implemented (think of all the wonderful mechanical ideas of Leonardo da Vinci)
  - much of the progress that eventually solved these practical problems was done during this era

Renaissance and beyond, 1500–1750

Mokyr (1990, Ch. 4)

- "New husbandy" probably the most important innovation
  - gradual expansion of new agricultural practices
  - new crops, elimination of fallowing, stall feeding of cattle
  - inventions mainly capital- or land-saving (i.e. labor intensive)
- Examples of other lines of progress
  - more efficient windmills
  - more widespread use of peat and coal
  - major improvements in blast furnances and mining
  - emergence of technical literature
  - improvements of the spinning wheel

Renaissance and beyond, 1500–1750

Mokyr (1990, Ch. 4)

- The defining feature of this age was the geographic discoveries
  - technological change primarily took the form of observing alien technologies and crops and transplanting them elsewhere
  - may have been a substitute for pushing the technological frontier
- Particularly, the discovery of the New World provided many agricultural "innovations"
  - potato, maize, tobacco, sweet potates, cassava, tomatoes, chili peppers, cacao, peanuts, pineapples...
- ... as well as the exchange of ideas, diseases and populations
  - see Nunn, Qian (2010): The Columbian Exchange, JEP for an excellent overview

Renaissance and beyond, 1500–1750

Mokyr (1990, Ch. 4)

- The age of discoveries was also one of instruments
  - largely driven by the clock-making industry, but also military (precise guns), commerce (precise scales), optics...
- Important spill-over effects to manufacturing
  - mostly realized during the Industrial Revolution (next lecture)


An IT revolution

Movable type printing press

Dittmar (2011)

- First European printing press established in Mainz in 1446–1450
  - during the next 50 years, printing technology diffused across Europe and the price of books fell by 2/3
- The main innovation was a technique to mass-produce the movable type
  - required alloys that were obtained with a precise combination of lead, tin, and antimony
  - an example of technological spillover: Johannes Gutenberg was originally trained as a goldsmith and his father worked with the ecclesiastic mint

Earlier literature

Dittmar (2011)

- Many historians believe that the movable type printing press was a revolutionary innovation
  - Mokyr (2005): one of the most important inventions in history to reduce the cost of accessing existing knowledge
  - Jones (1981): "western progress owed much to the superior means of storing and disseminating information"
  - Gilmore (1952): "the most radical transformation in the conditions of intellectual life [in the west]"
  - Roberts (1996): "dwarfing in scale anything which had occurred since the invention of writing."

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  - Roberts (1996): "dwarfing in scale anything which had occurred since the invention of writing."
- But actual evidence of its impact is scarce
  - Clark (2001): no evidence of aggregate productivity growth associated with the diffusion of movable type printing
  - Mokyr (2005): aggregate effects were small
  - Dittmar (this paper): city-level analysis reveals large effects

Impacts of the printing press: narrative

Dittmar (2011)

- Proposed causal chain
  - print media $\rightarrow$ **localized spillovers** $\rightarrow$ increase in returns to labor $\rightarrow$ more migrants $\rightarrow$ city growth

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  - scholars, merchants, craftsmen and mechanics often gathered in bookshops and houses of printers
  - early adopters attracted booksellers, universities, and students
  - ... and papermills, illuminators, translators

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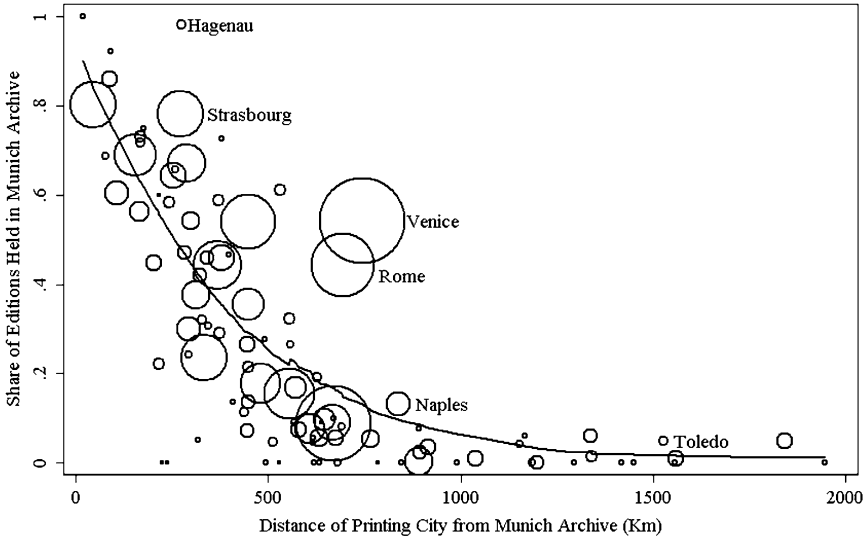
  - early adopters attracted booksellers, universities, and students
  - ... and papermills, illuminators, translators
- Local spillovers: transportation costs
  - books heavy and fragile, sensitive to damp
  - often it was cheaper to reprint than trade
- Supply-side constraints limited diffusion around 1450–1500

Archive holdings and distance from printing city

Dittmar (2011)



This figure presents data for the 100 cities with the highest output of incunabula editions 1450–1500. For each city it shows what share of its editions are held in the Bayerische Staatsbibliothek in Munich and how far the city is from Munich. Markers are scaled to reflect the magnitude of city book production. Fitted values estimated with locally weighted regression. Data on total incunabula production from ISTC.

Impacts of the printing press: narrative

Dittmar (2011)

- Context: Medieval cities
  - urban death rates exceeded urban birth rates
  - high wages attracted migrants
  - commerce more important than industrial production
- Starting in the 1480s, European presses produced a stream of "commercial arithmetics" or "merchants' manuals"
  - combined instruction in accounting and arithmetic with non-quantitative guidance on business practice
  - promoted merchants ability to calculate interest rates, profit shares, exchange rates, adopt double-entry bookkeeping...
- Suggests that printing delivered special benefits to locations that were propitious for commerce, e.g. port cities

Cumulative output of Merchants' Manuals

Dittmar (2011)

Impacts of the printing press: narrative

Dittmar (2011)

- Availability of inexpensive texts helped the spread of literacy
  - urban middle classes the principal purchasers of books
  - in the 15th century, it became expected that the children of the bourgeoisie would attend school
  - school books generated high returns for Renaissance printers
- The role of print media in the diffusion of industrial innovations was probably more limited
- Next: conforting this narrative with data

Data

Dittmar (2011)

- City locations and populations from the "Bairoch data"
  - 2,204 European urban agglomerations that ever reached 5,000 inhabitants between 1000 and 1800
  - centennial data up to 1700, then every 50 years to 1850
- Printing presses
  - *ISTC*: nearly every book printed from movable type before 1501 (records location of publication)
  - *L'Apparition du Livre*: documents 181 historic cities that adopted the printing press 1450–1500
  - Clair (1976): documents the establishment of printing presses in 188 historic cities 1450–1500
- New data on city characteristics
  - located on navigable rivers, sea ports, sites of Roman settlement, political or religious centers, measures of economic institutions

Print media and log city growth: cross-section

Dittmar (2011)

	Dependent Variable Is Log City Growth			
	Pre-Adoption	Post-Adoption		
(1)	(2)	(3)	(4)	(5)
Independent Variable	Growth 1400–1500	Growth 1500–1600	Growth 1500–1700	Growth 1500–1800
Print Adoption 1450–1500	0.07	0.19***	0.26***	0.30***
	(0.08)	(0.06)	(0.08)	(0.09)
Editions Per Capita	0.03	0.03*	0.04	0.05
	(0.03)	(0.02)	(0.03)	(0.03)
University	−0.12	0.02	0.17*	0.17*
	(0.11)	(0.07)	(0.09)	(0.09)
Roman Site	0.08	−0.01	0.09	0.04
	(0.06)	(0.05)	(0.08)	(0.07)
Capital	0.31**	0.95***	1.46***	1.98***
	(0.13)	(0.16)	(0.20)	(0.27)
Freedom Index	−0.23	0.27***	0.29**	−0.07
	(0.14)	(0.10)	(0.13)	(0.14)
Atlantic Port	0.16	0.34***	0.64***	0.76***
	(0.18)	(0.09)	(0.14)	(0.12)
Mediterranean Port	0.21*	0.15	0.57***	0.65***
	(0.13)	(0.12)	(0.15)	(0.17)
Baltic Port	−0.16	0.25**	0.55**	0.37
	(0.18)	(0.12)	(0.22)	(0.24)
Navigable River	0.14*	0.18***	0.23***	0.39***
	(0.08)	(0.06)	(0.09)	(0.09)
Log Population	−0.22***	−0.30***	−0.42***	−0.64***
	(0.04)	(0.04)	(0.05)	(0.05)
Country FE	Yes	Yes	Yes	Yes
Observations	291	495	515	622
R Squared	0.33	0.32	0.35	0.47

Estimates from

$$\ln\left(\frac{POP_{it+1}}{POP_{it}}\right) = \alpha + \beta T_i + X_i\gamma + \epsilon_{it}$$

i.e. regressing the log growth of city i between years t and $t+1$ on a dummy for the city adopting a print press between 1450–1500, T_i, and a vector of other observable variables X_i.

Column 2 shows that cities that adopted the printing press in the late 1400s grew no faster than other cities in 1400–1500. Columns 3–5 show that they experienced faster growth after 1500.

Print media and log city growth: dif-in-dif

Dittmar (2011)

(1) Variable	(2) All Cities Balanced Sample	(3) Exclude German Cities	(4) Exclude Italian & Dutch Cities	(5) Exclude If East of Elbe River	(6) Only Port Cities	(7) Only Cities Without Ports
Print × Yr1400	0.09	0.10	0.09	0.11	0.27	−0.04
	(0.16)	(0.18)	(0.20)	(0.17)	(0.38)	(0.16)
Print × Yr1500	0.34**	0.39**	0.41**	0.34**	1.39***	0.10
	(0.15)	(0.17)	(0.18)	(0.16)	(0.42)	(0.15)
Print × Yr1600	0.13	0.22	0.08	0.16	0.73**	−0.01
	(0.16)	(0.17)	(0.20)	(0.16)	(0.34)	(0.17)
Print × Yr1700	0.19	0.25	0.16	0.22	0.84**	0.00
	(0.14)	(0.16)	(0.17)	(0.14)	(0.42)	(0.15)
Atlantic × Yr1400	0.12	0.27	0.13	0.12	−0.32	—
	(0.31)	(0.33)	(0.37)	(0.31)	(0.52)	—
Atlantic × Yr1500	0.43*	0.55**	0.38	0.44*	−0.24	—
	(0.25)	(0.28)	(0.28)	(0.25)	(0.52)	—
Atlantic × Yr1600	0.42*	0.49*	0.33	0.45**	0.47	—
	(0.22)	(0.25)	(0.24)	(0.22)	(0.38)	—
Atlantic × Yr1700	0.60***	0.73***	0.64***	0.62***	0.32	—
	(0.19)	(0.20)	(0.21)	(0.19)	(0.38)	—
R squared	0.55	0.57	0.58	0.54	0.77	0.53
Observations	1,010	875	710	850	225	785
Adopting Cities	83	71	53	78	16	67
Nonadopting Cities	119	104	89	92	29	90

Note. This table presents estimates of Equation (1) using the balanced panel of cities with population data observed every 100 years 1300–1800. The dependent variable is log population growth: $\ln\left(\frac{POP_{t+100}}{POP_t}\right)$, where POP_t is city population in year t and $t = 1300, \ldots, 1700$. Print is an indicator variable for cities that adopted the printing press 1450–1500. The variables Yr1400, . . . , Yr1700 are indicators for 100-year periods starting 1400, . . . , 1700. Atlantic is an indicator variable for cities that were historic ports on the Atlantic Ocean. Regressions control for city, country, and year fixed effects; country cross year fixed effects; Mediterranean port cross-year fixed effects; and log population. See Data Appendix for details on the construction of the control variables. Heteroskedasticity-robust standard errors clustered by city are in parentheses. Significance at the 90%, 95%, and 99% confidence levels are indicated by *, **, and ***, respectively.

Estimates from

$$Y_{it} = \theta_i + \delta_t + \sum_{1300}^{1700} \alpha_t D_t T_i + X_{it}\gamma + \epsilon_{it}$$

where Y_{it} is the log city growth, θ_i is city dummies, δ_t is year dummies, D_i is a dummy for each year, T_i is a dummy for being an early adopter and X_i is a vector of other observable variables.

Estimates suggest that the print effect is not driven by the particular region in which cities were located, but was driven by the growth advantages enjoyed by ports that adopted printing.

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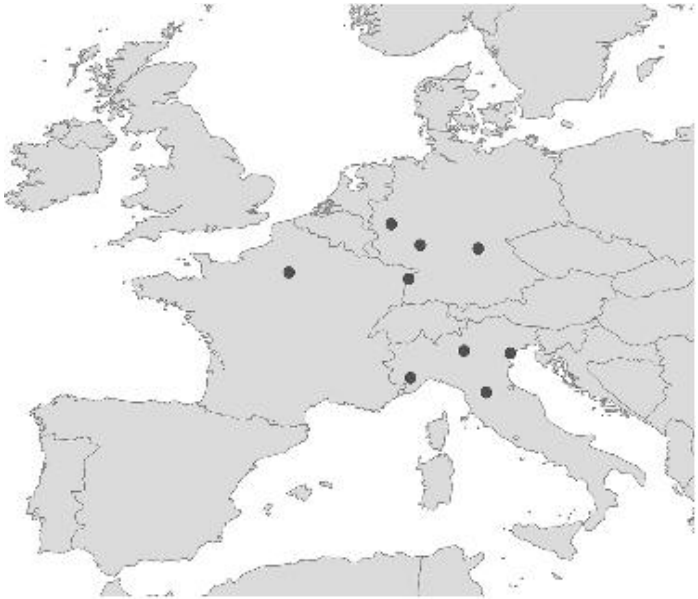
- Is this plausible?
  - perhaps the cities that got printing presses were the ones that would have grown faster in any case
- Solution: use distance to Mainz as an instrumental variable
  - printers were mostly apprentices or business associates of Gutenberg (or their apprentices) for the first 50 years
  - not a perfect monopoly, but the first known "blueprint" manual on the production of movable type was only printed in 1540
  - see the paper for details of how the technology spread

Diffusion: cities with printing in 1450

Dittmar (2011)

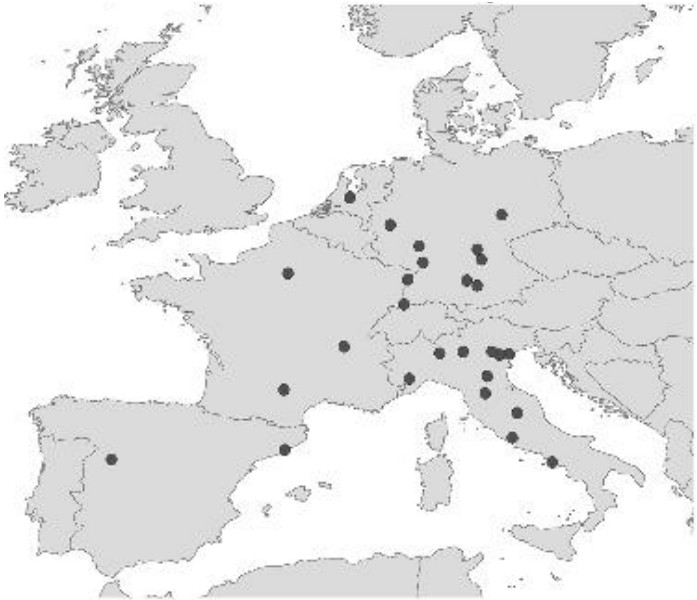
Diffusion: cities with printing in 1460

Dittmar (2011)



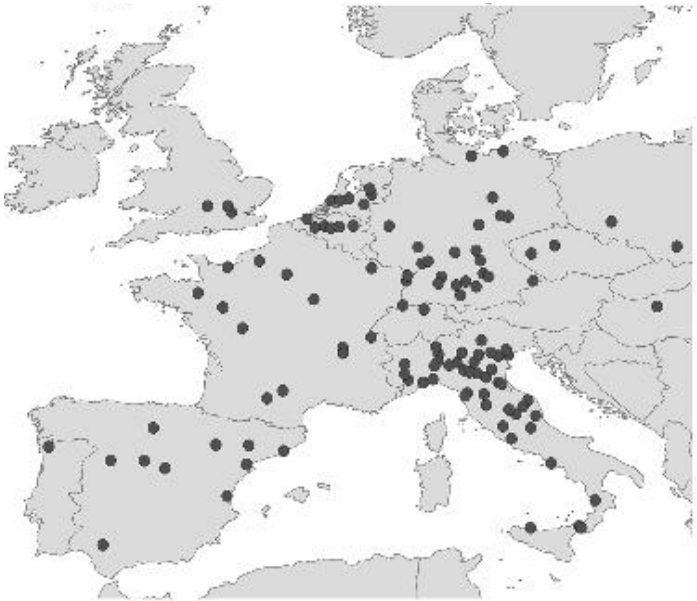
Diffusion: cities with printing in 1470

Dittmar (2011)



Diffusion: cities with printing in 1480

Dittmar (2011)



Diffusion: cities with printing in 1490

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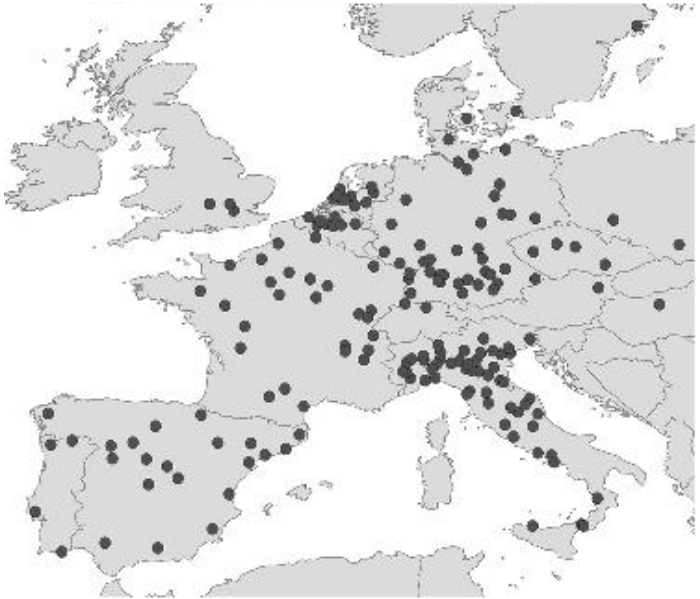
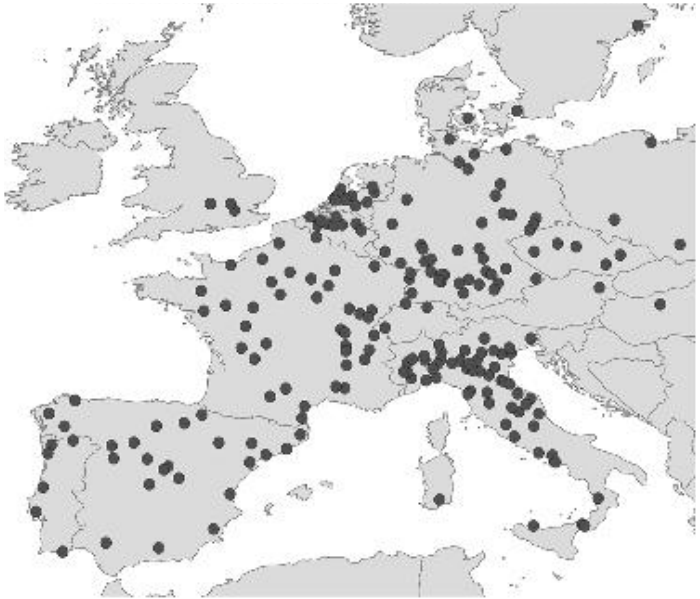


Diffusion: cities with printing in 1500

Dittmar (2011)



Assessing the validity of the instrument

Dittmar (2011)

(1)	(2)	(3)	(4)	(5)
Regression Model	Log Growth 1400–1500	University in 1450	Log Size in 1500	Log Growth 1500–1600
Log Distance to Mainz	−0.05	0.00	−0.11	−0.03***
	(0.04)	(0.01)	(0.08)	(0.01)
Observations	269	410	410	410
R Squared	0.23	0.12	0.31	0.22

There is highly significant relationship between distance from Mainz and growth in 1500–1600 (col 5) but there is no *statistically significant* differences in growth in 1400–1500 (col 2). Note, however, that the *point estimate* for the pre-reform period is larger than for post period! Cities close to Mainz are not statistically significantly different from other cities in terms of their the likelihood of hosting a university in 1450 (col 3) or population level in 1500 (col 4). The regressions also control for ports, navigable rivers, Roman sites, capitals, longitude, latitude, the interaction between longitude and latitude, the DeLong–Shleifer index of institutions, and log city population in the previous period.

2SLS estimates

Dittmar (2011)

(1)	(2)	(3)
	1st Stage	2nd Stage
	Adopt Print	City Growth
Regression Model	1450–1500	1500–1600
Log Distance to Mainz	-0.06^{***}	
	(0.01)	
Adopt Print 1450–1500		0.58^{**}
		(0.29)
Observations	410	410
R squared	0.34	0.15
F Statistic (IV)	20.74^{***}	82.07^{***}

There is a strong first-stage (distance from Mainz predicts adopting the technology). The second stage estimate suggests that the impact of adoption on city growth in 1500-1600 is 0.58 log points (or 78 percentage points). Regressions also control for: log city population in 1500, port location, navigable rivers, location on Roman sites, political capitals, city latitude, city longitude, the interaction between latitude and longitude, and the DeLong–Shleifer freedom index of regional institutions.

A falsification exercise

Dittmar (2011)

(1) IV Employs Distance From	(2) IV Estimate of Print Effect	(3) IV Estimate t Statistic
Mainz	0.58	2.03**
Amsterdam	−3.00	0.95
London	1.20	0.34
Paris	−14.25	0.12
Venice	0.08	0.55
Wittenberg	2.21	0.64

Comparison of estimates obtained using distance from Mainz as the IV with results obtained using distance from other important cities: Amsterdam, London, Paris, Venice, and Wittenberg (the city from which Protestant ideas diffused, see below). "This evidence supports the singular importance of distance from Mainz" (p. 1160).

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Why are IV estimates larger than OLS?

Dittmar (2011)

- The motivation for the IV approach was the concern that OLS estimates may be biased upwards
  - but IV estimates are more than twice as large as OLS (imply that printing accounted for 68% of total city growth)

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  - the cities that would benefit most would be close to Mainz
- Explanation 3: Exclusion restriction does not hold
  - direct positive impact of being close to Mainz

Printing and religion

Dittmar (2011)

- Print media important for the diffusion of the Protestant Reformation 1517–1648
  - increased demand for print media, particularly for the Bible
  - thus the impact of the printing press could be partly confounded with the impact of Protestantism
- Becker and Woessmann (2009)
  - use distance to Wittenberg as an IV for Protestantism
  - argue that Protestantism increased literacy and thus affected economic outcomes through human capital
- Dittmar arguest that his results are unlikely to capture the impact of Protestantism because
  - Luther's calls for the reform first appear in 1517, while printing press diffusion took place already in 1450–1500
  - results not affected by controlling for distance to Wittenberg

Printing press: conclusions

Dittmar (2011)

- Dittmar argues that adopting the printing press in 1450–1500 caused a 20–78 percentage points increase in city growth
  - imply that the impact of printing accounted for 18–68% of European city growth between 1500 and 1600
  - impacts concentrated in port cities
- Suggests that movable type print technologies had a very substantial effects in European economic history

Papers for essays

- Hanlon, W. (2015): Necessity Is the Mother of Invention: Input Supplies and Directed Technical Change. *Econometrica* 83(1): 67-100
  - present empirical support for models of directed technological change using the disruption in the supply of American cotton for the Brittish textile industry as a research design.
- Juhász, Réka (2018): Temporary Protection and Technology Adoption: Evidence from the Napoleonic Blockade. *AER*, 108(11): 3339-76
  - presents empirical support for infant industry argument using the attempt to stop British goods from entering Continental Europe during the Napoleonic Wars as a research design