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TSE M1 Economic History (2021)

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Economic History

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M1, Semester 1, 2022



Plan of the Course

10 sessions of 1 hour and 30 minutes:

- Introduction: what is economic history?
- Modern economic growth in historical perspective
- Institutions and modern economic growth
- Cultural and religious roots to modern economic growth?
- Directed technical change
- Industrialization, urbanization, pollution, and health

Topic 1

What is economic history?

What is economic history?

- A classical approach. [McCloskey \(1976\)](#)
- From classical to modern approach. [Arrow \(1985\)](#) [Solow \(1985\)](#)
- A modern approach. [Abramitzky \(2015\)](#) [Cantoni Yuchtman \(2021\)](#)

A Classical Approach

McCloskey (1976)

- Economic history for itself.
- More and better economic facts.
- Better economic theory.
- Better economic policy.

“Disinterested intellectual curiosity is the lifeblood of real civilization. [...] There is nothing that more divides civilized from semi-savage man than to be conscious of our forefathers as they really were, and bit by bit to reconstruct the mosaic of the long-forgotten past. To weigh the stars, or to make ships sail in the air or below the sea, is not a more astonishing and ennobling performance on the part of the human race in these latter days, than to know the course of events that had long been forgotten, and the true nature of men and women who were here before us.”
Trevelyan (1942)

Economic History for Itself

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“Every economy and every society has an interesting story to tell.”
Mokyr (2003)

⇒ Economic history much alike mathematical economics.

More and Better Economic Facts

- Inductive or deductive approach: facts are necessary.

More and Better Economic Facts

- Inductive or deductive approach: facts are necessary.
- History simply provides more facts.
- Whenever institutions are present, statistics are present.
- Even before: archaeology provides facts about the economy.

More and Better Economic Facts

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 - Penn World Tables: real GDP PPP 182 countries since 1950.
 - Maddison project database: real GDP since 1000.

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 - IPUMS NAPP: full count censuses North Atlantic starting 1703.

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 - Maddison project database: real GDP since 1000.
- More facts about populations:
 - IPUMS USA: full count censuses 1850–1950.
 - IPUMS NAPP: full count censuses North Atlantic starting 1703.
- Other facts:
 - Macrohistory: macro-finance indicators, 17 countries since 1870.
 - World Inequality Database: inequality indices since 1875.

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- Populations: no anonymity rule.
 - USA: linked samples across censuses (IPUMS).
 - France: linked samples across vital records (TRA).

More and Better Economic Facts

- Historical data are routinely richer than modern data.
- Full access to companies' records and manufacturing censuses.
- Populations: no anonymity rule.
 - USA: linked samples across censuses (IPUMS).
 - France: linked samples across vital records (TRA).
- Access dramatically improved recently.

More and Better Economic Facts

- Main limits to more and better facts:
 - Existence of historical data.
 - Inaccuracies and measurement errors.

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 - True.
 - But be creative and knowledgeable about the data production process.

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- Main limits to more and better facts:
 - Existence of historical data.
 - Inaccuracies and measurement errors.
- On existence.
 - True.
 - But be creative and knowledgeable about the data production process.
- On inaccuracies.
 - Less true.
 - Much more cautious approach to data as constructed objects.

“Much of the problem, I think, arises because of the separation in economics between data producers and data analyzers. By and large, we do not produce our own data and, hence, do not feel responsible for it.” Griliches (1974)

More and Better Economic Facts

- History provides better facts through natural experiments.
 - Can we learn from these experiments?
 - People were the same hundred years ago.
 - Structures were different and changed: we can learn a lot from that.
- ⇒ More on that later.

Better Economic Theory

- Obvious that economic history uses economic theory in Popperian sense (as all applied economics).
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In analogous discussions concerning the role of theory in historical research the argument is frequently made (perhaps because it is valid) that the historian will inevitably be guided by some [theory]. [...] Much the same can be said for the use of history by theorists. Even the most scornful ahistorical economist makes some use of history: his own experience, the experience of his generation, or the loose historical generalizations which abound in the folklore of even highly sophisticated societies.

Cameron (1965)

- Theorists routinely use history (although some get facts wrong):
 - Kaldor stylized facts and neoclassical growth theory.
 - Ricardo and rising land rents.
 - Rostow and the stages of growth.
 - Marx and the impoverishment of the working class.

Better Economic Theory

- Economic history to test economic theory.

Better Economic Theory

- Economic history to test economic theory.
- More helpful than contemporaneous economy.
- Enables to test theories in their pure form, as structures sometimes less complex in the past.
- E.g., Koudijs (2015) on information and stock prices volatility.

“Have a very healthy respect for the study of economic history, because that’s the raw material out of which any of your conjectures or testings will come.” Samuelson (2009)

One purpose of history is to broaden our conception of the possible.

Rockoff (1975)

- Learn from historical crises to inform policy.
- Bernanke is among the best examples.

Better Economists?

- Smith, Marshall, Schumpeter, Keynes, Friedman. . .
- The great economists were all deeply historical in their thinking.
- Even if not object of study, the long view helps finding important research questions.

Does the Past Have Useful Economics?

- A classical approach. [McCloskey \(1976\)](#)
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From the Classical to the Modern Approach

Arrow (1985) Solow (1985)

- The (caricatured) classical approach might be a naive view of history.
- History is not just a repository of facts for testing economic theory.

The aim of historical study as such was not simply to serve as a source of data from which to infer and to test social science generalizations.

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- Economic history would just be applied economics with old data.
In this dispensation an economic historian is merely an economist with a high tolerance for dust or a working knowledge of a foreign language.

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Is economics a subject like physics, true for all time, or are its laws historically conditioned?

- By its general statements, economic theory generates new questions for economic history.
- But economic theory emphasizes generality at the expense of particularity.
- Economic history helps the development of economic analysis by defining its historical conditioning.

⇒ Economic history is crucial to assess “external validity.”

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A Modern Approach

Abramitzky (2015)

- Test economic theory.
- Improve economic policy.
- Learn about mechanisms.
- Answer the big questions.

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 - Impact of supply shocks on technological change: Hanlon (2015) uses drop in cotton from US South after Civil War.
 - Effect of ↓ agricultural labor availability on agricultural development: Hornbeck and Naidu (2014) use Great Mississippi Flood of 1927.

- Economic history to improve economic policy.

Better Economic Policy

- Economic history to improve economic policy.
- Historical settings allow counterfactual worlds, or repetition of episodes.
- Again, past financial crises deeply inform current policy.

- Economic history to learn about mechanisms.
 - Typically, economists learn about mechanisms indirectly, e.g. by interactions or heterogeneity across subgroups.
 - Deep knowledge of historical setting and direct (qualitative) historical evidence can be much more convincing.
 - Analytic narratives approach using game theory (see Avner Greif's work).

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 - Why did the Industrial Revolution happen in Europe and not elsewhere?
 - What factors caused the demographic transition?
 - How and why did inequality evolve over time?
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- These are too big to nail. But...

Economic history seems to collectively agree to not limit ourselves to answer only those questions with random variation, of which there are not as many.

Natural Experiments of History

Cantoni Yuchtman (2021)

- Economic history is especially popular in mainstream economics for natural experiments.
- Enable to answer important questions that require historical perspective while keeping applied micro approach and credible causal identification.
- Especially popular in economic growth and development.

⇒ Bridge between economic history and all other disciplines.

Natural Experiments of History

- Taxonomy of three primary motives for examining historical natural experiments:
 - Natural experiments to learn about historical episodes (cat. 1).
 - Natural experiments yielding general economic insights (cat. 2).
 - Natural experiments to understand contemporary development (cat. 3).

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- Taxonomy of three primary motives for examining historical natural experiments:
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 - Natural experiments yielding general economic insights (cat. 2).
 - Natural experiments to understand contemporary development (cat. 3).
- Not mutually exclusive: most research overlaps categories.
- No one motive is better or worse.

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⇒ At the confluence: *AJR's Colonial Origins*

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 - Impact of WWI of female labor force participation: variations from cohort-drafting rules (Boehnke and Gay 2022).

Learn About Historical Episodes: Challenges

- Critique of “looking under the lamppost.”
 - Only study component of episode exhibiting useful identifying variation.
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Learn About Historical Episodes: Challenges

- Critique of “looking under the lamppost.”
 - Only study component of episode exhibiting useful identifying variation.
 - Miss many important historical aspects.
- Sometimes, amounts to argue for inexplicability of historical variation of interest.
- But understanding source of variation is valuable (even beyond LATE).

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 - Causal effect of input relative abundance on technical change: use decline in US South cotton imports to Britain during US Civil War as a source of variation in input availability (Hanlon 2015).

Yield General Economic Insight: Challenges

- Usually nice “existence” results.
- Sometimes lack of insight on mechanisms.
- Go beyond estimating single parameter.
- Critiques of reduced form à la Heckman (2005) and Deaton (2010).

Understand Contemporary Development

- Seek historical experiments to identify the causal role of past events (or initial conditions) on the present.
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 - Long-run effects of disease environment: Alsan (2014) uses suitability for Tze Tze fly as IV for disease environment.

Understand Contemporary Development: Challenges

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 - Especially salient when little data around the experiment: challenges to the exclusion restriction.
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- Spatial correlation when persistence is underestimated (Kelly 2019).
- Reproducibility is challenging, as well as the risk of multiple hypothesis testing.
- Bias toward persistence. When and why does history not persist?

Topic 2

Modern economic growth in historical perspective

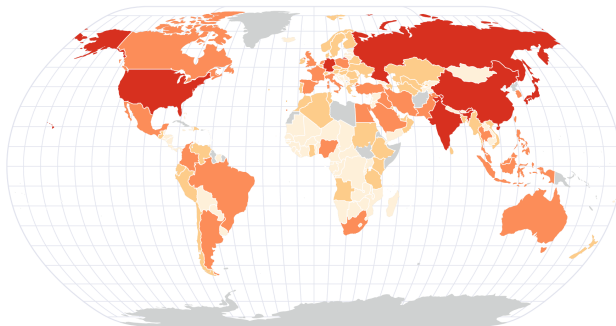
Why are some countries so much richer than others?

- Current cross-country differences in income
- GDP: definition and measurement
- Economic growth and income differences
- Long-run growth: the Great and the Little Divergences
- Britain and modern economic growth
- Overview of deep roots of modern economic growth

Current cross-country differences in income

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2017 PPP-adjusted GDP in bil. 2011 US \$



USA = 18,200. CHN = 18,400. FRA = 2,600. NGA = 835.

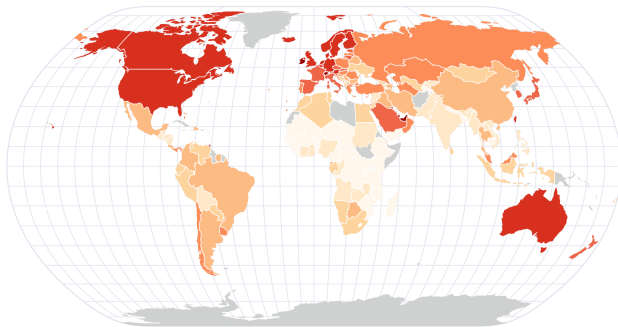
basemap from Natural Earth (CC0) - Penn World Table



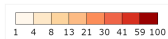
Made with Khartis

Current cross-country differences in income

2017 PPP-adjusted GDP per Capita in thous. 2011 US \$



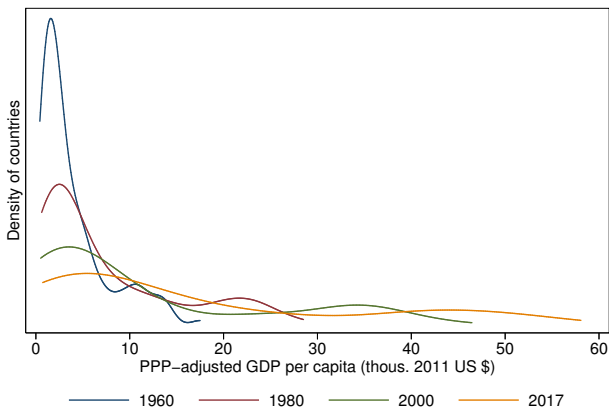
USA = 56. CHN = 13. FRA = 41. NGA = 4.
basemap from Natural Earth (CCO) - Penn World Table 9.1



Made with Khartis

Evolution of cross-country differences in income

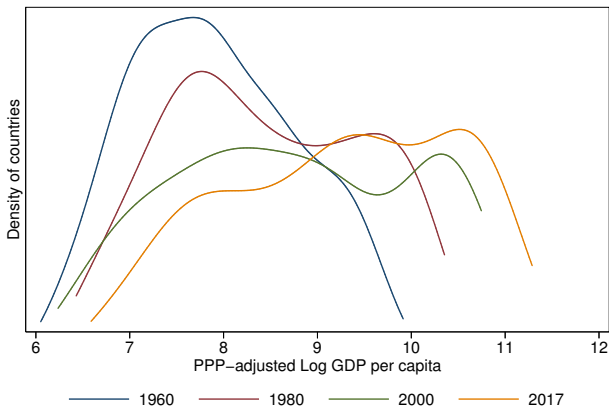
Distribution of Countries: GDP per Capita



Source: Penn World Table 9.1, 110 countries.

Evolution of cross-country differences in income

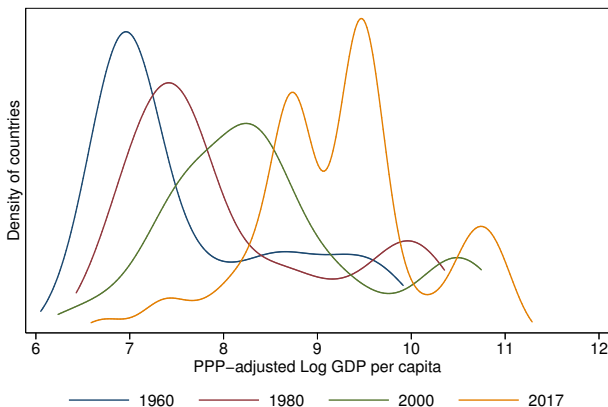
Distribution of Countries: Log GDP per Capita



Source: Penn World Table 9.1, 110 countries.

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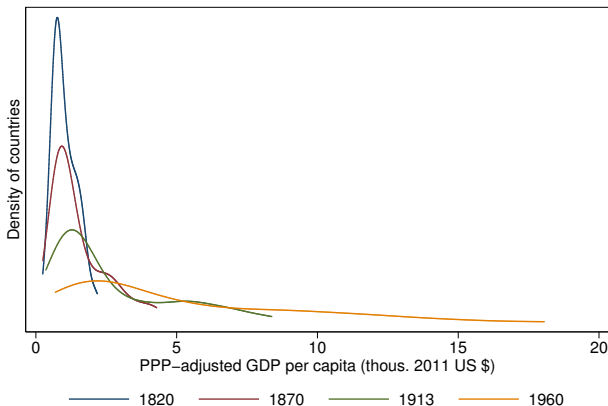
Population-Weighted Distribution of Countries: Log GDP per Capita



Source: Penn World Table 9.1, 110 countries.

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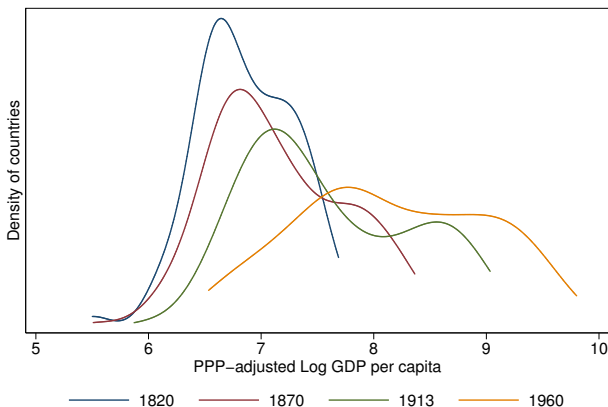
Distribution of Countries: GDP per Capita



Source: Maddison Project Database 2018, 86 countries.

Evolution of cross-country differences in income

Distribution of Countries: Log GDP per Capita



Source: Maddison Project Database 2018, 86 countries.

Data Source: Penn World Table

- Best cross-country GDP modern data: [Penn World Tables 10.0](#).
- Reference paper: [Feenstra, Inklaar and Timmer \(2015\)](#).
- GDP, consumption, TFP measures.
- PPP-adjusted, constant prices (2011 US \$) \implies comparability.
- 183 countries, 1950–2019, yearly.

Data Source: Maddison Project Database

- Best cross-country pre-1950 GDP data source: [Maddison Project](#).
- Reference paper: [Bolt, Inklaar, de Jong and van Zanden \(2018\)](#).
- New version: GDP per capita based on PWT methodology.
- 80 countries pre-1950, starting 1800s (even before).
- Lower data availability than PWT.

GDP: definition and measurement

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- Definition
- A distorted picture
- Income and welfare
- Measuring historical GDP

Definition (Gross Domestic Product)

GDP is the market value of final goods and services newly produced in a country during a given period of time

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- GDP is the most commonly used indicator of economic activity.
- GDP is measured in a currency at **current** prices.
- GDP measures **final** goods and services.
- GDP measures goods newly **produced** during the period considered.

Three equivalent approaches

① Product approach

- Highlights **value-added** of domestic output.
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⇒ Production = Expenditure = Income.

Components

$$\underbrace{Y}_{\text{Final Product}} = \underbrace{C + I + G + (X - M)}_{\text{Expenditure on Final Goods and Services}}$$

- Y : final product (or total income earned by domestic factors).
- C : consumption spendings on goods and services.
- I : investment spendings on capital (and changes in inventories)
- G : government expenditures on goods and services.
- $X - M$: net exports of goods and services.

A distorted picture of reality

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- 1 GDP per capita matters.

A distorted picture of reality

- ① GDP per capita matters.
- ② GDP is a constructed measure, subject to revisions.

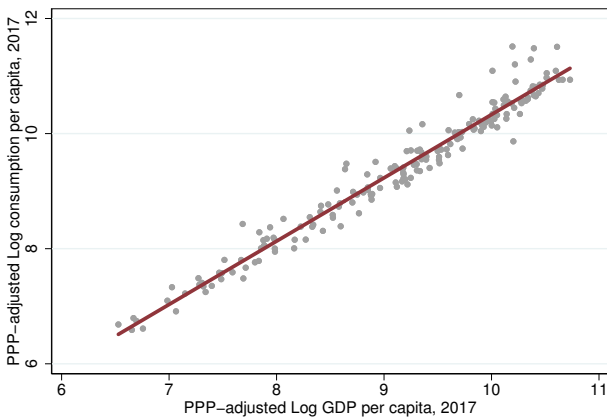
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- ② GDP is a constructed measure, subject to revisions.
- ③ Many things that contribute to wealth are not measured:
 - Goods and services not sold on a market: e.g. home production, child care, clean air.
 - Illegal activities: e.g. drugs, prostitution.
 - Natural resource depletion.
 - Welfare: e.g. leisure, health, inequality, happiness.
 - Digital goods.
 - Changes in quality.

Income per Capita and Consumption per Capita, 2017



Source: Penn World Table 9.1, 182 countries.

Income and welfare

- Jones and Klenow (2016).
- Compute a new welfare measure that combines consumption, leisure, inequality and mortality.

Income and welfare

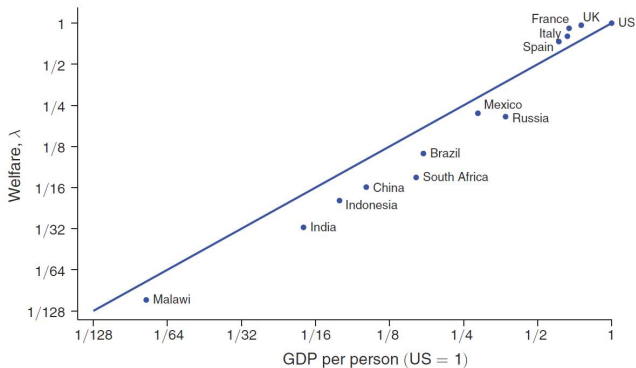
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France vs USA in 2005

Indicator	France	USA
GDP per Capita	67	100
Consumption per Capita	60	100
Life Expectancy	80	77
Leisure (h. work)	535	877
Inequality (Gini)	0.261	0.369
Welfare	92	100

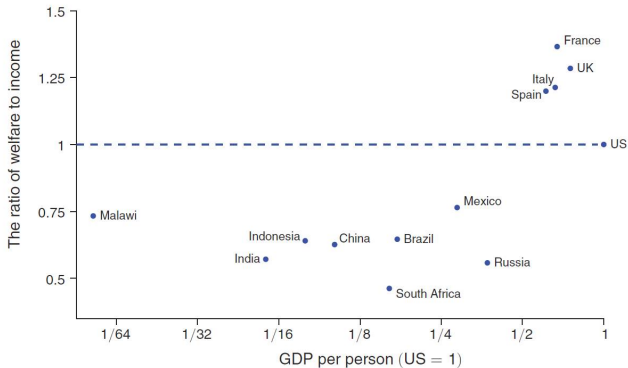
Income and welfare

Welfare and income are correlated at 98%



Income and welfare

Welfare differs from income by about 35%



Measuring historical GDP

de Jong and Palma (2018) Broadberry (2021) Crafts and Woltjer (2021)

- Historical national accounting
- Comparisons over time and space
- Latent variable estimation

- Potential value of growth accounting in economic history:
 - Benchmarking growth performance over the long run.
 - Quantification of contributions to growth of particular sectors or new technology.
 - Understand nature of TFP growth.
- Potential weaknesses of growth accounting in economic history :
 - Highly sensitive to methodology and data quality.
 - Does not tell anything about causality from factor input growth to TFP growth.

Historical national accounting

- Central question: relationship between inputs and outputs.
- Typically, Cobb-Douglas production function:

$$Y = AL^{1-\alpha}K^\alpha$$

- α and $1 - \alpha$: output elasticities of capital and labor.
- A : total factor productivity (TFP).
- Diminishing returns to factor accumulation.

Historical national accounting

- Basic growth accounting equation in growth rates:

$$\Delta \log (Y/L) = \alpha \Delta \log (K/L) + \Delta \log A$$

- Factor share α constant $\simeq 1/3$.
- Issues measuring L and K , but feasible.
- Once estimate Y , get estimate of A .

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- For comparisons across time and space: proper price levels.

⇒ How to estimate Y and convert into PPP?

- Maddison's (2001) *The World Economy: A Millennial Perspective*.
- Result of 50 years of research.
- Maddison (2010) Online database.
- Maddison Project: extends Maddison work.

Four types of GDP data

- Official estimates by national statistical offices (1870–1950).
- Historical estimates based on same methods (pre-1870).
- Historical estimates based on proxy variables (pre-1870).
- “Guesstimates.”

Methods for data-abundant nations

- Most common for pre-1870: output approach.
- Broadberry et al. (2015) *British Economic Growth, 1270–1870*
- Sectors estimated separately with auxiliary data for 1270–1700:
 - Agricultural output.
 - Industrial output.
 - Service sector output.

Britain agricultural output

- Three databases across different periods:
 - Medieval Accounts Database: manorial accounts for land use, crops, animals, livestock products. [Campbell \(2000, 2007\)](#)
 - Early Modern Probate Inventories Database: inventories of Church for same information. [Overton \(1991, 2000\)](#) [Overton et al. \(2004\)](#)
 - Modern Farm Accounts Database: sample of farmers accounts. [Turner et al. \(2001\)](#)

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- Convert output into current prices, weights for real output index.

Britain industrial output

- Many databases for the main industrial sectors up to 1700:
 - Wool and woolen cloth: detailed export records. [Carus-Wilson and Coleman \(1963\)](#)
 - Iron: capacity of blast furnaces and periods of activity. [King \(2005\)](#)
 - Tin: receipts of coinage dues. [Hatcher \(1973\)](#)
 - Leather and food processing: reconstruction of agricultural sector. [Broadberry et al. \(2015\)](#)
 - Construction: cathedral building, housebuilding (population).
 - Book production: titles listed by British Library.

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 - Construction: cathedral building, housebuilding (population).
 - Book production: titles listed by British Library.
- Use series to build industrial production index.

Britain services sector output

- Method from [Deane and Cole \(1962\)](#).
- Broken down into subsectors:
 - Commerce: trade, freight transport, financial services.
 - Housing and domestic services: rate of population.
 - Government: revenues. [O'Brien and Hunt \(1999\)](#)

- Putting it together:
 - Combine output series with sectoral weights based on input-output tables for 1841. [Horrell et al. \(1994\)](#)
 - Use price series to convert into nominal series. [Clark \(2004, 2005, 2006\)](#) [Beveridge \(1939\)](#)
 - Create a chained index of GDP.
 - Divide by population to estimate GDP per capita.

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- Attempts from income side, but changes in working hours (“industrious revolution” 1700–1820).

Methods for data-scarce nations

- Rely on modeling and proxies.

Methods for data-scarce nations

- Rely on modeling and proxies.
- Instead of measuring agricultural output, derive it from demand for food. [Allen \(2000\)](#)

$$Q^A = rcN$$

- Q^A : real agricultural output.
- r : ratio of production to consumption (often $r = 1$).
- c : per capita consumption.
- N : population.

Methods for data-scarce nations

- Real consumption per capita assumed to be a function of its own real price (P^A/P), real prices of other goods (P^{NA}/P) and real income per capita (y).

Methods for data-scarce nations

- Real consumption per capita assumed to be a function of its own real price (P^A/P), real prices of other goods (P^{NA}/P) and real income per capita (y).
- In log-linear form:

$$\ln c = \alpha_0 + \alpha_1 \ln \left(P^A/P \right) + \alpha_2 \ln \left(P^{NA}/P \right) + \beta \ln y$$

- P^A/P : agricultural product prices in real terms.
- P^{NA}/P : non-agricultural product prices in real terms.
- y : real income per capita.
- α_0 : constant.
- α_1 : own-price elasticity of demand.
- α_2 : cross-price elasticity of demand.
- β : income elasticity of demand.

- Adding-up property of linear demand:

$$\alpha_1 + \alpha_2 + \beta = 0$$

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- Values from developing countries:
 - $\alpha_1 = -0.6$.
 - $\alpha_2 = 0.1$.
 - $\implies \beta = 0.5$.

- Estimate non-agricultural output Q^{NA} :

$$Q = Q^A + Q^{NA} \iff Q = \frac{Q^A}{1 - (Q^{NA}/Q)}$$

- Q^{NA}/Q : share non-agricultural output.

\implies Proxied by urbanization rate, e.g., Bairoch (1988).

- Many use long-run estimate inappropriately.
- Careful to distinguish direct and indirect approaches.
- Same series can mix both e.g. Netherlands pre-1510 vs 1510–1807. van Zanden and van Leeuwen (2012)

Data reliability grades

A. Data reliability grades		
Reliability grade	Margin of error	Average margin of error
A. Firm figures	\pm less than 5%	\pm 2.5%
B. Good figures	\pm 5% to 15%	\pm 10%
C. Rough estimates	\pm 15% to 25%	\pm 20%
D. Conjectures	\pm more than 25%	\pm 40%

Source: Broadberry (2021) based on Feinstein (1972)

Data reliability grades

B. Reliability assessments for GDP in the Netherlands, China, and Japan	
	Grade
<i>Netherlands</i>	
1347-1510	C
1510-1650	B
1650-1750	A
1750-1807	B
<i>China</i>	
Northern Song (980-1120)	B
Ming (1400-1620)	B
Qing (1690-1840)	A
<i>Japan</i>	
Ancient (730-1150)	D
Medieval (1250-1450)	C
Tokugawa (1600-1846)	B

Source: Broadberry (2021) based on van Zanden and van Leeuwen (2012) and Broadberry, Guan and Li (2018)

Comparisons over time and space

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 - Inflation rates make output value change.
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 - Accounts for price and expenditure weights differences across countries

⇒ International weights: 1990 Geary-Khamis international dollars

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⇒ International weights: 1990 Geary-Khamis international dollars

- Benchmark: 1990 GKIS\$ 400 \simeq subsistence level.

Issues with historical GDP estimates

Blum and Clovin (2018) chap 46

- Within countries:
 - Deflation issues: changing baskets of goods over time.
 - Heterogeneous sources: systematic and changing biases.

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- Main point of HGDP is not precision but order of magnitude.
- Still: need reliable comparative picture of living standards.

⇒ Don't take Maddison at face value, check underlying sources.

A latent variable model of GDP: measurement error

Fariss et al. (2022)

- Sources of measurement error:
 - In demographic data: incentives to misreport or inaccuracies due to weak capacity or rare censuses.
 - In GDP data: heterogeneous sources and reporting; base years are used to weight relative contributions of each sector but might change fast over time.

A latent variable model of GDP: data sources

- Datasets:
 - 1950–2019, World [Penn World Tables 10.0](#)
 - 1870–2001, Europe and U.S. [Broadberry and Klein \(2012\)](#)
 - 1830–1973, Europe [Bairoch \(1976\)](#)
 - 1500–2018, World [Maddison Project Database](#)
 - 1500–1850, England, Holland, Italy, Spain, Japan, China, India [Broadberry \(2015\)](#)
- Put together and render comparable through PPP measures from PWT.

A latent variable model of GDP: estimation

- Dynamic latent variable model to generate prediction intervals.
- Precision derived from combination of:
 - Agreement across different sources.
 - Extent of cross-sectional and temporal coverage within a given source.
- Resulting estimates enable to include uncertainty in the analysis by taking repeated random draws from the posterior distribution.

Economic growth and income differences

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- Let g : growth rate, T = time, $GDP_0 = 1$. Then

$$GDP_T = (1 + g)^T$$

- Suppose $g_A = 2\%$ and $g_B = 0\%$.
 - After 100 years, A 7 times richer than B.
 - After 200 years, A 52 times richer than B.

Economic growth and income differences

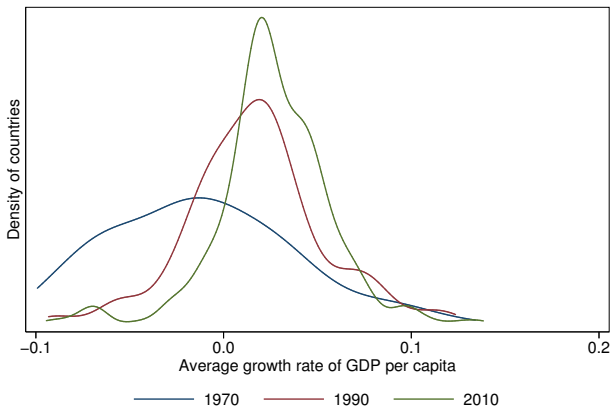
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- Suppose $g_A = 2\%$ and $g_B = 0\%$.
 - After 100 years, A 7 times richer than B.
 - After 200 years, A 52 times richer than B.
- How long to:
 - double GDP? $\log 2 / \log(1 + g)$. If $g = 2\%$, then 35 years.
 - decuple GDP? $\log 10 / \log(1 + g)$. If $g = 2\%$, then 116 years.

Economic growth and income differences

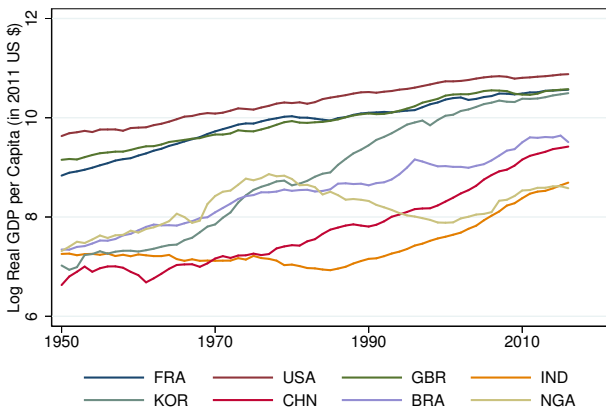
Distribution of GDP per Capita Growth Rates



Source: Penn World Table 9.1

Economic growth and income differences

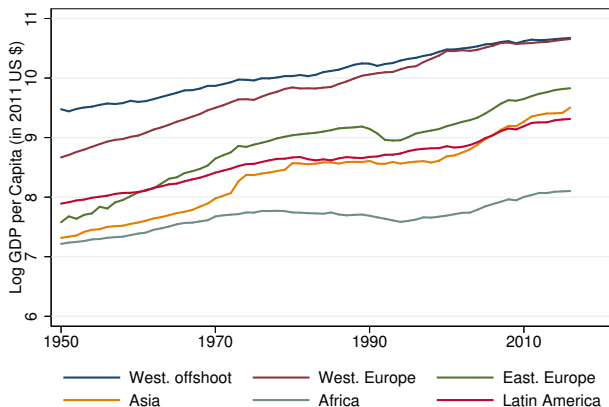
Evolution of Income per Capita across Countries



Source: Maddison Project Database 2018.

Economic growth and income differences

Evolution of Income per Capita across Continents



Source: Maddison Project Database 2018.

Long-run growth: the Great and the Little Divergences

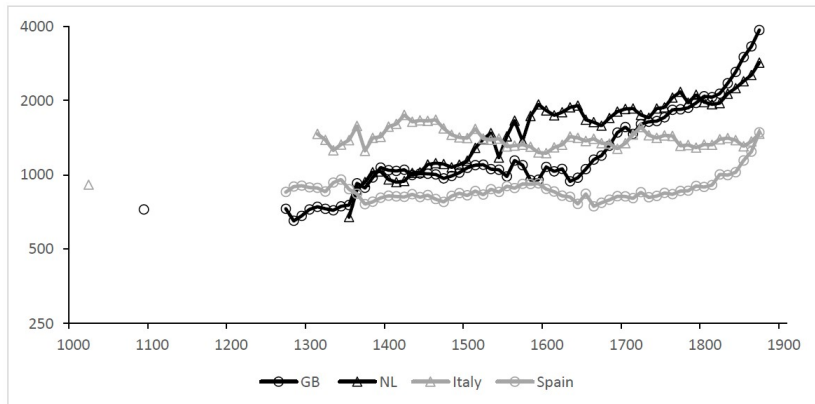
Broadberry (2021) Court (2020)

- Europe's Little Divergence
- Asia's Little Divergence
- The Great Divergence

⇒ New estimates enable to revise past views from e.g., Maddison (2001)

Europe's Little Divergence

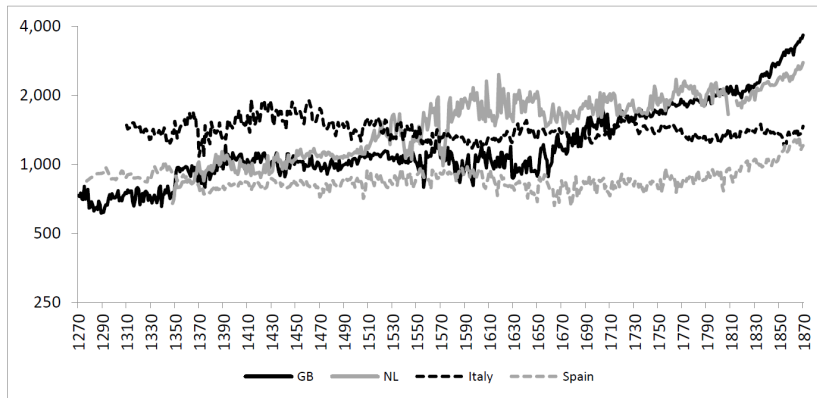
GDP per Capita in Europe, 1270–1870 (1990 GKl\$, Log scale)



Source: Broadberry (2020) based on Broadberry et al. (2015), van Zanden and van Leeuwen (2012), Malanima (2011), and Alvarez-Nogal and Prados de la Escosura (2013).

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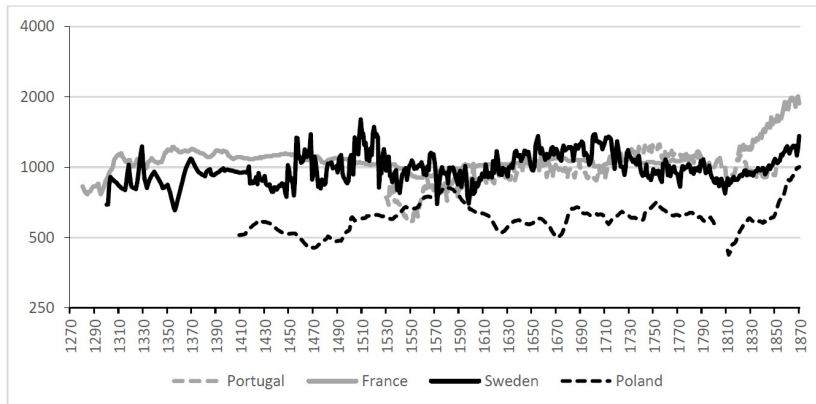
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Source: Broadberry (2020) based on Palma and Reis (2019), Ridolfi (2016), Krantz (2017), Schon and Krantz (2012), Malinowski and van Zanden (2017).

Europe's Little Divergence

- First turning point: Black Death (1348).
 - Before: Italy and Spain richer than GB and NL.
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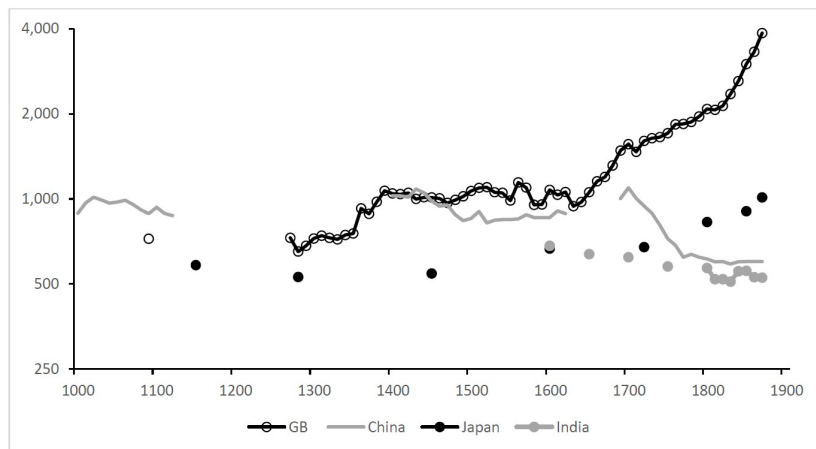
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⇒ Europe's Little Divergence (North-West vs rest) circa 1500

Asia's Little Divergence

GDP per Capita in Asia, 1000–1870 (1990 GKIS\$, Log scale)



Source: Broadberry (2020) based on Broadberry et al. (2015), Broadberry, Guan and Li (2018), Bassino, Broadberry, Fukao, Gupta and Takashima (2015), Broadberry, Custodis and Gupta (2015)

Asia's Little Divergence

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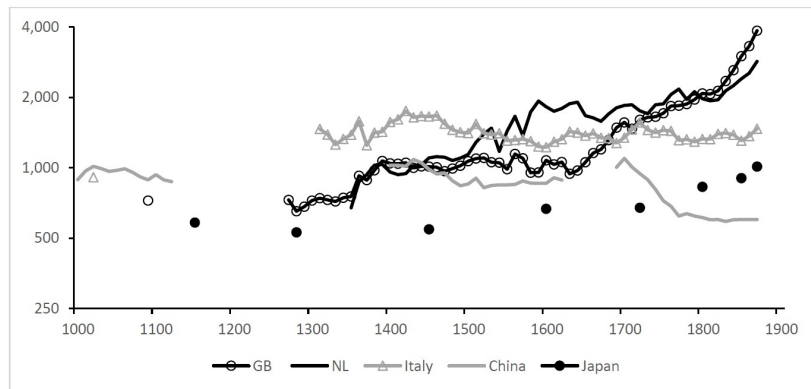
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⇒ Asia's Little Divergence (Japan vs China) circa 1700

The Great Divergence

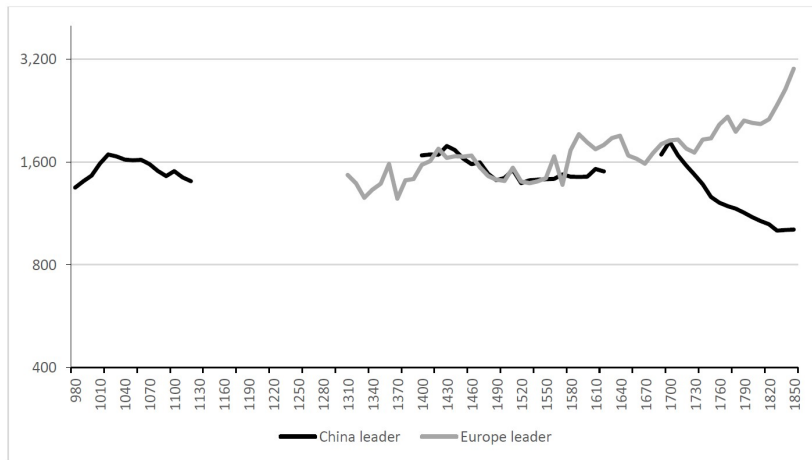
GDP per Capita in Europe and Asia, 1000–1870 (1990 GKI\$, Log scale)



Source: Broadberry (2020) based on Broadberry et al. (2015), van Zanden and van Leeuwen (2012), Malanima (2011), Broadberry, Guan and Li (2018), Bassino, Broadberry, Fukao, Gupta and Takashima (2015).

The Great Divergence

GDP per Capita in Leading Regions of China and Europe, 980–1850 (1990 GK\$, Log scale)



Source: Broadberry (2020) based on Broadberry, Guan and Li (2018).

The Great Divergence

- Year 1000:
 - Leadership of China at \$1,000.
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 - Compare leading regions (Yangzi Delta vs Italy, NL, UK)

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⇒ The Great Divergence (Europe vs Asia) circa 1700

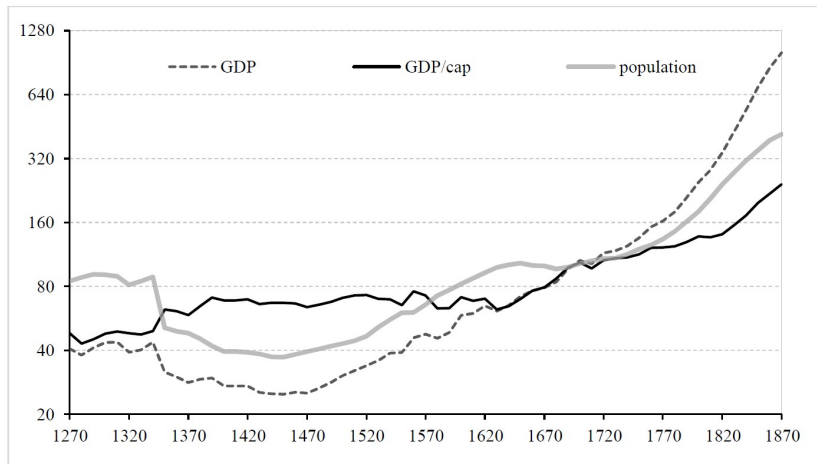
Britain and modern economic growth

Broadberry (2021)

- British economic growth in long-run perspective
- Characteristics of modern economic growth

British economic growth in long-run perspective

Real GDP, Population, and Real GDP per Capita in England (1270–1700) and Great Britain (1700–1870), Averages per Decade, Log Scale, 1700 = 100



Source: Broadberry (2020) based on Broadberry, Guan and Li (2018).

British economic growth in long-run perspective

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 - GDP per K plateau.
 - Population recovers.

British economic growth in long-run perspective

- Post-Civil War (1650s–1700):
 - Population stagnation.
 - Strong GDP and GDP per K growth.

British economic growth in long-run perspective

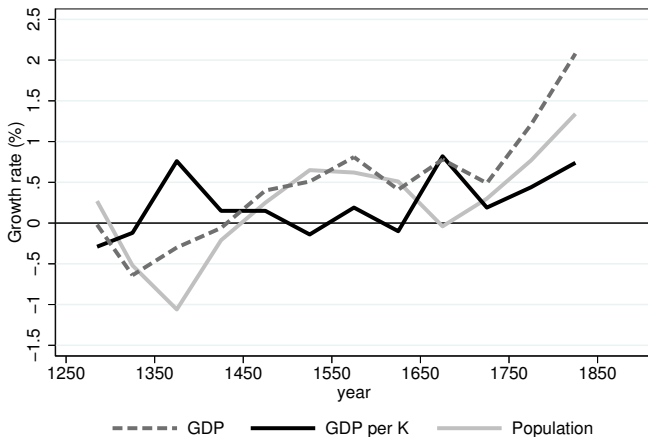
- Post-Civil War (1650s–1700):
 - Population stagnation.
 - Strong GDP and GDP per K growth.
- Industrial Revolution (1700–1850s):
 - Population growth resumes.
 - GDP per K growth positive.
 - Growth positive, stable, no shrinking.

Revision of past views

- Britain entered the Industrial Revolution richer than assumed.
- Britain grew less during the Industrial Revolution than assumed.

Characteristics of modern economic growth

Real GDP, Population, and Real GDP per Capita Growth in England (1270–1700) and Great Britain (1700–1870), Averages per 50-Years



Source: Broadberry (2020) based on Broadberry et al. (2015).

Characteristics of modern economic growth

- Pre-industrial growth:
 - GDP per K growth fast after Black Death and Civil War.
 - Population declines (land/labor $\uparrow \implies$ output/capita \uparrow)
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 - Structural change: shift from agriculture to industry and services.

China, Europe, and the Great Divergence

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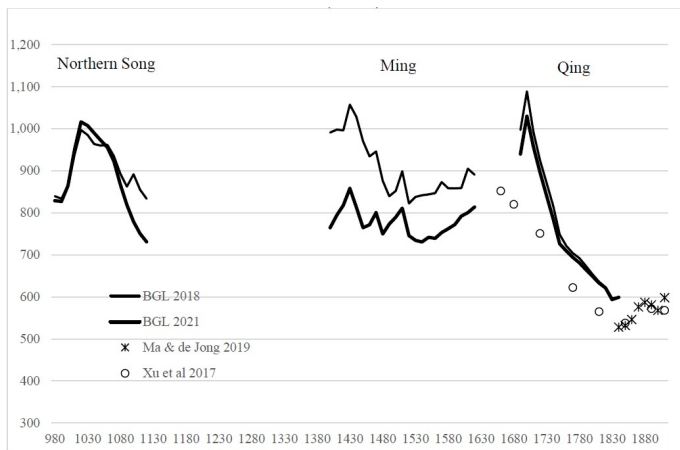
- Important questions:
 - Was China ever really wealthy?
 - When did China fall behind?
 - Was it the result of positive growth in Europe or negative growth in China?
- Estimates for China 980–1840 by [Broadberry et al. \(2018\)](#):
 - Britain caught up with China as a whole by 1400.
 - The Great Divergence with the richest parts of China circa 1700.
 - Due to both rising incomes in Europe and falling incomes in China.

China, Europe, and the Great Divergence

- Issues in Broadberry et al. (2018) pointed out by Solar (2021):
 - Constructed based on only 2 series: grain output and population.
 - Government sector share too high (e.g., 30% of GDP in 1400), requiring downward correction for Ming (1368–1644)
 - Benchmark to anchor series in 1840 was too high.
 - China leader estimated with constant upward adjustment of 75% based on 1820s benchmark when textile booming there (perhaps relative income different in other periods).

China, Europe, and the Great Divergence

Estimates of China's GDP per capita, 980–1910



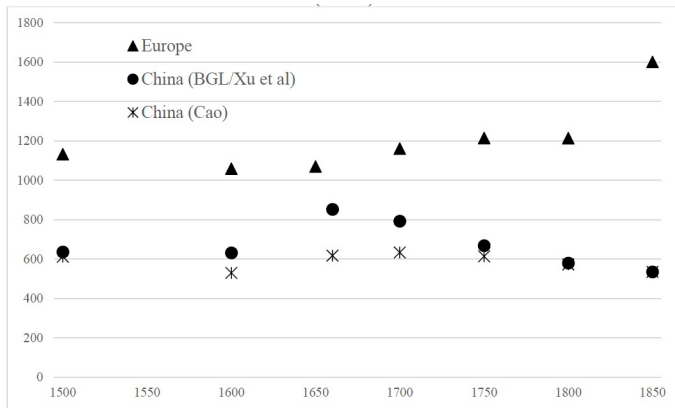
Source: Solar (2021) based on Broadberry et al. (2018, 2021), Ma and de Jong (2019), and Xu et al. (2017).

China, Europe, and the Great Divergence

- Alternative: compare Western Europe to China.
 - Use series from Britain, Holland, France, Spain Italy, Germany (80% of Europe population).
 - With revised estimates, from 1500 on, Europe always richer than China.
 - Perhaps divergence in trends from 1650s.
 - High degree of uncertainty remains.

China, Europe, and the Great Divergence

GDP per capita in “Europe” and China, 1500–1850



Source: Solar (2021) based on Palma and Reis (2019), Ridolfi and Nuvolari (2021), de Vries (1994), Malanima (2010), Broadberry et al. (2018, 2021), Ma and de Jong (2019), and Xu et al. (2017).

Why did Britain industrialize first?

Why did Britain industrialize first?

⇒ The “Holy Grail” of economic history

- Overview of main answers for British exceptionalism (1700–1850).
Blum and Colvin (2018) chap 24, Hoffman (2020), Court (2020)
 - 1 Institutions
 - 2 A culture of growth and useful knowledge
 - 3 Factor prices and technological change
 - 4 Demography and the European Marriage Pattern
 - 5 Trade and colonialism
 - 6 Geography and coal
- Fundamental difficulties

- North and Weingast's long-standing argument.
 - Balance of power between sovereign and society through Parliament.
 - Secured property rights.
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 - Secured property rights.
 - Enables much higher per capita tax revenues (fiscal capacity).
- Enables efficient warfare, gains from trade, merchant marine.
- Develop of transportation network (natural monopoly).
- Representative institutions enable urbanization and agglomeration effects.

A culture of growth and useful knowledge

- Joel Mokyr's (and McCloskey's) view:
 - “Scientific Revolution” (17th century) \implies “Industrial Enlightenment”
 - Large supply of useful knowledge and mechanical skills.
 - Knowledge and belief in innovation.
- Abundant supply of useful skills.
 - Widespread practice of apprenticeship in Britain.
 - Migration patterns of skilled artisans from Britain to continental Europe.
- A role for culture and religion?

Factor prices and technological change

- Robert Allen's view:
 - High wages, cheap capital and resources (coal).
 - Relative factor prices \implies High demand for innovation.
 - Profitable to mechanize and substitute machines for labor.

Factor prices and technological change

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 - High wages, cheap capital and resources (coal).
 - Relative factor prices \implies High demand for innovation.
 - Profitable to mechanize and substitute machines for labor.
- But debated measurement problem (only proxies cost of labor):
 - Wage data mostly for daily wage.
 - Working hours very different across country, season, region, sector.
 - New series show British wages not as high as estimated.

Demography and the European Marriage Pattern

- Unified growth theory links economic growth to demographic changes.
- European Marriage Pattern:
 - High female celibacy.
 - Late marriage.
 - Nuclear families.
- Incentives for human capital investment.

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- But very little evidence of link between EMP and growth.

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 - Food: sugar mostly, tea and coffee.
 - Raw materials: cotton, timber.
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- Was it an essential factor?
 - Assumes only colonies could supply food and materials.
 - Assumes imported food was essential.
 - Assumes British farmers would have faced diminishing returns in agriculture.
- Little evidence (from Britain perspective):
 - Abundant worldwide supply (slightly higher prices).
 - Little share of caloric intake (14% in 1840s).
 - British agriculture highly productive.

- Potential advantages of Britain's abundant coal deposits:
 - Increasingly important source of heat.
 - Mine floods \implies incentives for steam engines.
 - Main power for textile mines nearby production centers (e.g., Lancashire).

- Potential advantages of Britain's abundant coal deposits:
 - Increasingly important source of heat.
 - Mine floods \implies incentives for steam engines.
 - Main power for textile mines nearby production centers (e.g., Lancashire).
- But prevalent in many European locations.
- Ability to exploit and transport coal matters (institutions).

What can explain the Great Divergence?

Blum and Colvin (2018) chap 23

- Explanations for “Why Britain” slightly different than for “Why Europe.”

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- Applies to the Great Divergence:
 - Warfare and inter-state competition due to land and political fragmentation.

Topic 3

Institutions and modern economic growth

What is the role of institutions in the emergence of modern economic growth?

Plan

- Defining institutions
- Constitutions and commitment
- Long-run empirical evidence

Defining institutions

Defining institutions

North (1990, 1991)

“Institutions are the rules of the game in a society or, more formally, are the humanly devised constraints that shape human interaction. In consequence [institutions] structure incentives in human exchange, whether political, social, or economic.” North (1990)

Defining institutions

- Key elements:
 - Humanly devised.
 - Place constraints on individual behavior.
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Defining institutions

- Key elements:
 - Humanly devised.
 - Place constraints on individual behavior.
 - Shape human interaction and affect incentives.
- Institutions influence economic, political and social relations among households, individuals and firms.
- Rational-theoretic approach:
 - Importance of theory of selection of institutions.
 - Selection through centralized (bargaining) or decentralized (evolutionary competition) process.

Defining institutions

- Examples:
 - Property rights.
 - Functioning markets.
 - Contractual opportunities.

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- Examples:
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- What economic institutions do:
 - Shape the structure of economic incentives.
 - Ensure allocation of resources to efficient uses.
 - Determine distribution of economic revenues.
- “Good” economic institutions stimulate proximate causes of growth:
 - Physical capital accumulation.
 - Human capital accumulation.
 - Development of better technologies.
- Usually: enforcement of property rights and equality of opportunity.

Defining institutions

Greif and Kingston (2011)

- Some disagree with rational-choice approach to institutions.

Defining institutions

Greif and Kingston (2011)

- Some disagree with rational-choice approach to institutions.
- Complementary view: institutions as equilibria.
 - Emphasize theory of motivation and expectations.
 - Institutions emerge as equilibrium in a game of multiple equilibria.
 - Helps explain why “bad” institutions might persist.

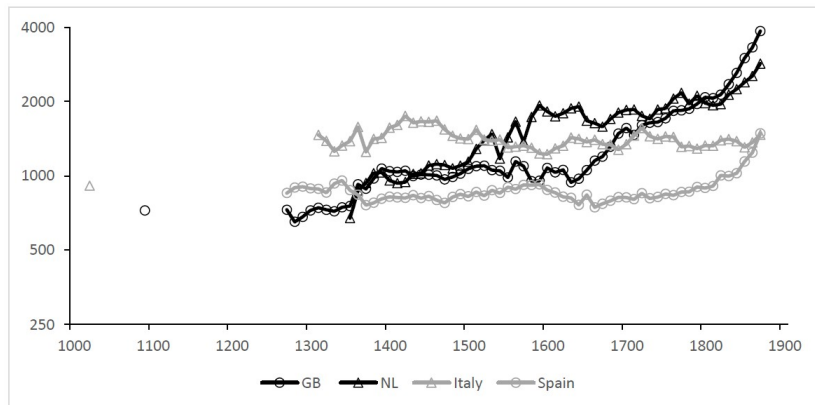
Constitutions and commitment

Constitutions and commitment

- Historical context
- Constitutions and commitment
- Criticism

Historical context: industrial revolution in Britain

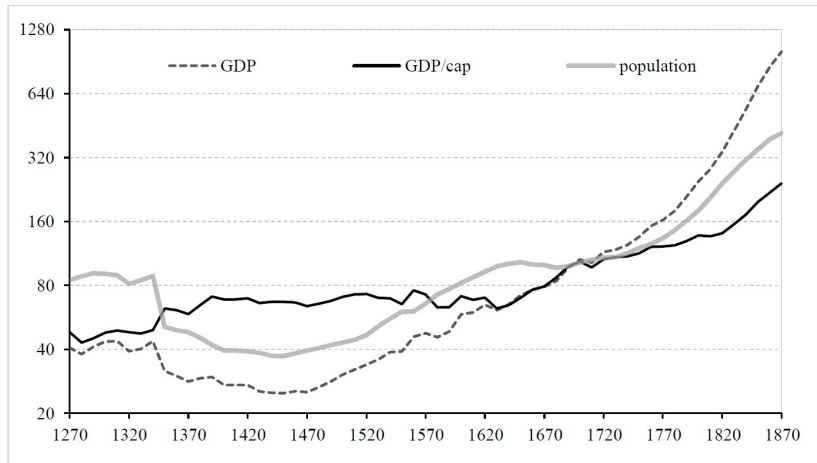
GDP per Capita in Europe, 1270–1870 (1990 GK\$, Log scale)



Source: Broadberry (2020) based on Broadberry et al. (2015), van Zanden and van Leeuwen (2012), Malanima (2011), and Alvarez-Nogal and Prados de la Escosura (2013).

Historical context: industrial revolution in Britain

Real GDP, Population, and Real GDP per Capita in England (1270–1700) and Great Britain (1700–1870), Averages per Decade, Log Scale, 1700 = 100



Source: Broadberry (2020) based on Broadberry, Guan and Li (2018).

Historical context: political revolution in Britain

- English Civil War (1642–1651).
 - Conflict between monarchy (Charles I) and Parliamentarians over expropriations.
 - Parliament prevailed, setting up Commonwealth (Cromwell).

Historical context: political revolution in Britain

- English Civil War (1642–1651).
 - Conflict between monarchy (Charles I) and Parliamentarians over expropriations.
 - Parliament prevailed, setting up Commonwealth (Cromwell).
- Instability \implies Charles II restored by Parliament 1660.
- 1680s: James II reestablish Crown supremacy over Parliament.
- Glorious Revolution of 1688.
 - Parliament overthrow James II.
 - Revolutionary Settlement and Declaration of Rights.
 - \implies Parliamentary supremacy.

North and Weingast (1989)

- Strong states and expropriation risk.
 - First goal of a state: national defense, protection against invasion.
 - Achieving this goal \implies strong state.
 - But this implies risk of predation by the state.

Constitutions and commitment

North and Weingast (1989)

- Strong states and expropriation risk.
 - First goal of a state: national defense, protection against invasion.
 - Achieving this goal \implies strong state.
 - But this implies risk of predation by the state.
- High expropriation risk \implies Smaller expected returns to investment
 \implies Smaller incentives for effort, investment, innovation.
- Affects people, but also the state (through tax base).

\implies States face trade-off between expropriation or not.

Constitutions and commitment

- Suppose trade-off in favor of no expropriation.
 - Sovereign wants to establish property rights.
 - Promise to enforce these today and in the future.

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 - Private citizens understand this, so don't invest today.
- ⇒ Sovereign must make credible commitment not to revise property rights.

Constitutions and commitment

- Two ways to solve commitment problem.

Constitutions and commitment

- Two ways to solve commitment problem.
- Reputation when repeated interactions.
 - Reneging on earlier promises tarnishes reputation.
 - Long-run costs decrease incentives for short-run expropriation.
 - But requires valuation of future revenues (so little turnover).
 - Unconstrained rulers cannot use reputation alone.

Constitutions and commitment

- Two ways to solve commitment problem.

Constitutions and commitment

- Two ways to solve commitment problem.
- Create credible commitment devices.
 - Voluntarily restrict ability to expropriate in future.
 - Constitutions (checks and balances) play this role today.
 - Glorious revolution 1688 created such device.

- Before the Glorious Revolution: Crown expropriated wealth.
 - Forced loans, not repaid on time or in full.
 - Sale of monopolies in settled industries.
 - Sale of public offices (reducing value of other offices).
 - Seizure of property.

Constitutions and commitment

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 - Seizure of property.
- House of Commons composed by wealthy class (targets).

- Institutional changes after the Revolution:
 - Legal disputes over property tried in common law courts.
 - Statute of Monopolies: prohibition of creation of monopolies by sale of patents to existing businesses.
 - Changes in rules of labor mobility and land tenure (enclosures).
- ⇒ Legislative and judiciary independent from monarchy.

- Why no tyranny of Parliament?
 - Balance of power between Crown, Parliament, courts.
 - Fractionalized elites with diverse interests (merchants vs landowners).

Constitutions and commitment

- Constitution and commitment \implies secure property rights
- Many benefits

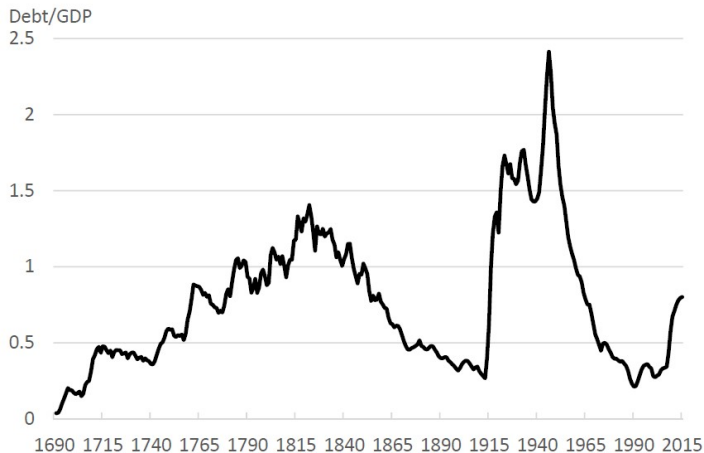
Constitutions and commitment

- Constitution and commitment \implies secure property rights
- Many benefits
 - \uparrow borrowing capacity of government.
 - Major advantage for warfare, leading to gains from trade.
 - Development of private capital markets.
 - Less rent-seeking activities by special-interest groups.
 - Incentives for investment and innovation.

\implies Inclusive institutions were crucial to secure property rights and spur modern economic growth.

Constitutions and commitment

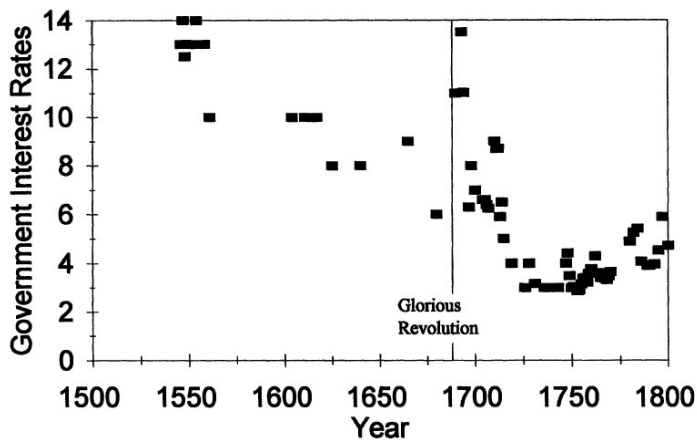
Government Debt to GDP for Britain (1691–2015)



Source: Steinsson (2020) based on Barro (1987) and Thomas and Dimsale (2017).

Constitutions and commitment

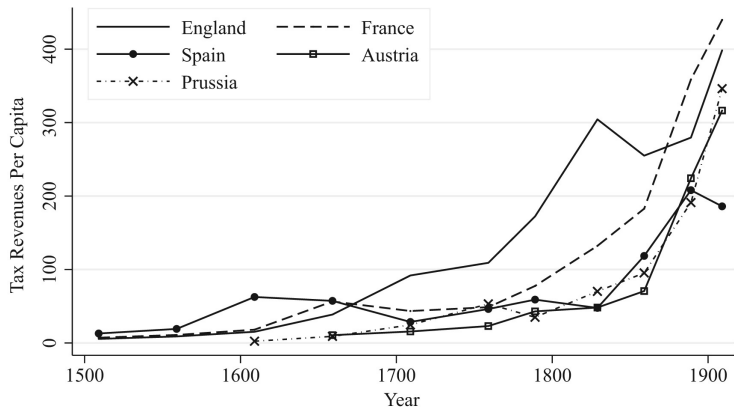
Interest Rates on Government Debt in England



Source: Steinsson (2020) based on Clark (1996).

Constitutions and commitment

Log Tax revenues per capita for five European powers



Source: Johnson and Koyama (2017) based on Karaman and Pamuk (2013).

Ogilvie and Carus (2014)

- No reason why wealth holders seek policies beneficial to the whole economy.
- Other key institutional features matter.

Strong parliaments and growth

- Many examples of strong parliaments which created institutions not beneficial to economic growth.

Strong parliaments and growth

- Many examples of strong parliaments which created institutions not beneficial to economic growth.
- Poland.
 - Strong Parliament, controlled by large landowners.
 - Enforced legal privilege and second serfdom (16th–19th centuries).
 - Prevented policies to allocate resources efficiently and undertake productive investments.

⇒ Concentration of power in homogeneous parliamentary representation impede growth.

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Strong parliaments and growth

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- German state of Württemberg.
 - Strong Parliament with representatives from diverse commercial and industrial communities (16th–19th centuries).
 - Granted legal monopolies to special-interest groups (guilds, merchant companies. . .)
 - Prevented policies beneficial to whole economy, generating stagnation through monopolistic competition.

⇒ Promotion of particularized institutions rather than generalized institutions matter for growth.

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- Dutch Republic.
 - Strong Parliament with representatives of each Seven Provinces (16th–18th centuries).
 - Business elites could secure rents at the expense of overall economy.
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⇒ Parliaments do not guarantee diversity of views and growth-enhancing policies.

Other institutional features

Ogilvie and Carus (2014)

- Key distinction: generalized vs particularized institutions.
 - Generalized institutions: rules apply uniformly to all. Good.
 - Particularized institutions: rules apply by group membership (gender, religion, race, parentage, guilds). Bad.

Other institutional features

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- Key distinction: generalized vs particularized institutions.
 - Generalized institutions: rules apply uniformly to all. Good.
 - Particularized institutions: rules apply by group membership (gender, religion, race, parentage, guilds). Bad.
- Need simultaneously two types of institutions:
 - Guaranteeing private property.
 - Enforcing contracts (enables resource allocation to best use).

Long-run empirical evidence

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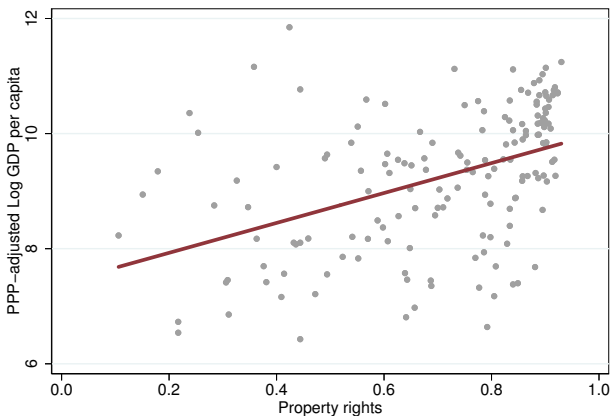
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Long-run empirical evidence

- Do institutions matter for long-run development?
- Extremely difficult question due to endogeneity.
- Long-run empirical evidence from AJR's "Colonial origins":
 - Contemporaneous correlations. [AJR \(2005\)](#)
 - Reversal of fortune. [AJR \(2002\)](#)
 - Colonial origins. [AJR \(2001\)](#)

Correlations between Institutions and Development

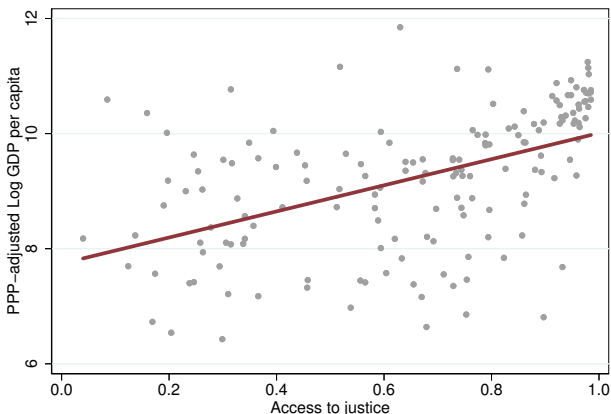
Log GDP per Capita and Property Rights, 2016



Source: V-Dem 9, Maddison Project Database 2018, 160 countries.

Correlations between Institutions and Development

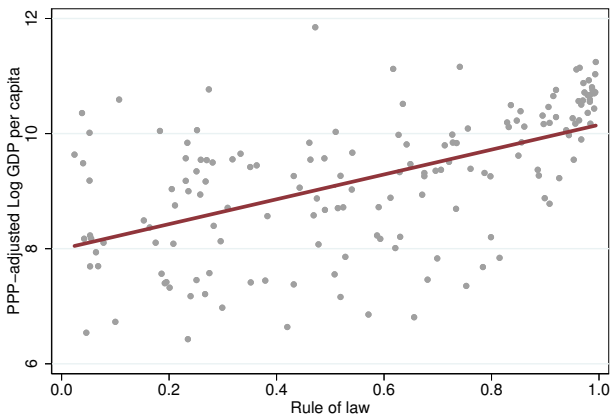
Log GDP per Capita and Access to Justice, 2016



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Correlations between Institutions and Development

Log GDP per Capita and Rule of Law, 2016



Source: V-Dem 9, Maddison Project Database 2018, 160 countries.

Correlations between Institutions and Development

$$Y_{cy} = \alpha + \beta X_{cy} + \varepsilon_{cy}$$

Year	Property	Justice	Law	Countries
1960	1.64***	1.73***	1.78***	133
1980	1.84***	1.81***	1.83***	140
2000	2.78***	2.77***	2.66***	162
2016	2.60***	2.27***	2.16***	160

Source: V-Dem 9, Maddison Project Database 2018.

Dependent variable: *log* GDP per capita.

*** Significant at the 1 percent level.

Data Source: Varieties of Democracy

- Best cross-country institutions data source: [V-Dem](#).
- 450+ indicators, 81 indices, 202 countries, 1789–2018.
- Consistent coding, extremely complete.
- Vastly superior to alternatives.

Data Source: Varieties of Democracy

- Property rights (v2xc1_prpty).
 - Question: Do citizens enjoy the right to private property?
 - Scale: Ordinal, converted to interval by the measurement model, from low to high 0–1.

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 - Scale: Ordinal, converted to interval by the measurement model, from low to high 0–1.
- Rule of Law (v2x_rule).
 - Question: To what extent are laws transparently, independently, predictably, impartially, and equally enforced, and to what extent do the actions of government officials comply with the law?
 - Scale: Interval, from low to high (0–1). Index combining 15 indicators.

Data Source: Other Institutions Datasets

- [Polity IV Project](#) (1800–2015).
- [Freedom House](#) (1973–2018).
- [Political Regimes](#) (1800–2015). [Boix et al. \(2012\)](#)
- [Word bank governance indicators](#) (1996–2017). [Kaufmann et al. \(2010\)](#)
- [Lexical Index of Electoral Democracy](#) (1800–2013). [Skaaning et al. \(2015\)](#)
- [Unified Democracy Score](#) (1946–2012). [Penstein et al. \(2010\)](#)
- [Political Institutions and Events](#) (1917–2013). [Przeworski et al. \(2013\)](#)

Identification Issues

- Can we interpret these relationships as causal?

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 - Reverse causality: wealthy countries could afford better institutions.
 - Omitted variable bias: Z causes both institutions and development such as geography or culture.

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- Can we interpret these relationships as causal?
- Identification issues:
 - Reverse causality: wealthy countries could afford better institutions.
 - Omitted variable bias: Z causes both institutions and development such as geography or culture.
- General solution: find exogenous source of variation.

Reversal of fortune

- Acemoglu, Johnson and Robinson (2002)
- Use colonization as a natural experiment to assess the causal impact of institutions on economic development.

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Reversal of fortune

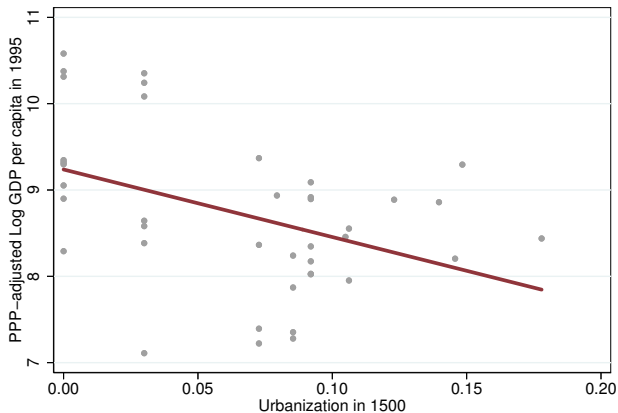
- Acemoglu, Johnson and Robinson (2002)
- Use colonization as a natural experiment to assess the causal impact of institutions on economic development.
- Question: richest ancient civilizations are today among poorest nations. Why?
- Document reversal of relative income among former colonies.
- Evidence that institutions matter for long-run economic development.
- Geography, culture, luck cannot account for the reversal.

Reversal of fortune

- Which countries in this experiment?
 - Colonized by Europeans between 15th and 19th centuries.
 - Excludes Ireland, Russia, Middle East.
- How to capture prosperity before colonization (1500)?
 - Maddison data: too little sample size.
 - Urbanization: captures high agricultural productivity.
 - Population density.
 - Sample sizes small when paper written.

Reversal of fortune

Urbanization in 1500 and Log GDP per Capita in 1995 Former European Colonies



Source: Penn World Table 9, CEPII GeoDist, AJR (2002), 40 countries.

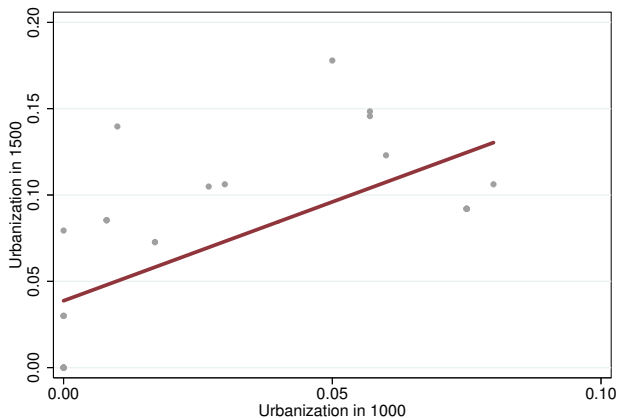
Reversal of fortune

Dependent variable:	log GDP per capita (PPP) in 1995			
	(1)	(2)	(3)	(4)
Urbanization 1500	-8.56*** [2.35]	-11.79** [4.74]	-8.41*** [3.04]	-10.59** [4.71]
Geography	No	Yes	No	Yes
Natural resources	No	Yes	No	Yes
Colonizer	No	No	Yes	Yes
Religion	No	No	Yes	Yes
R2	0.22	0.70	0.31	0.79
Countries	40	40	40	40

*** Significant at the 1 percent level. ** Significant at the 5 percent level.

Reversal of fortune: timing

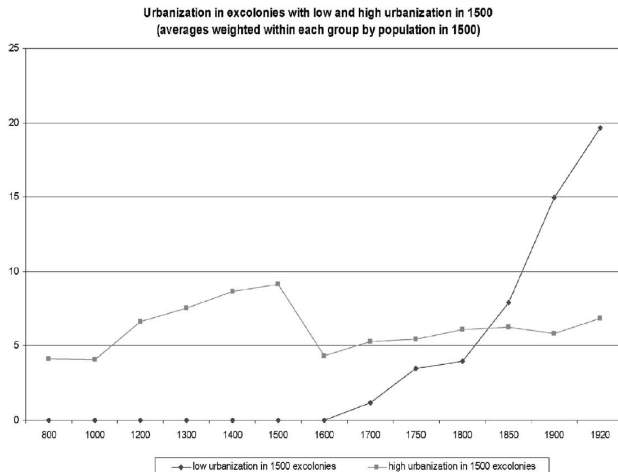
Urbanization in 1500 and 1000
Former European Colonies



Source: AJR (2002), 30 countries.

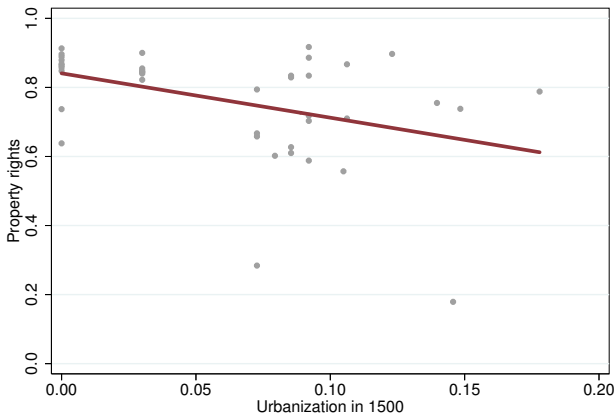
Reversal of fortune: timing

Evolution of Urbanization in Former European Colonies



Reversal of fortune: institutions

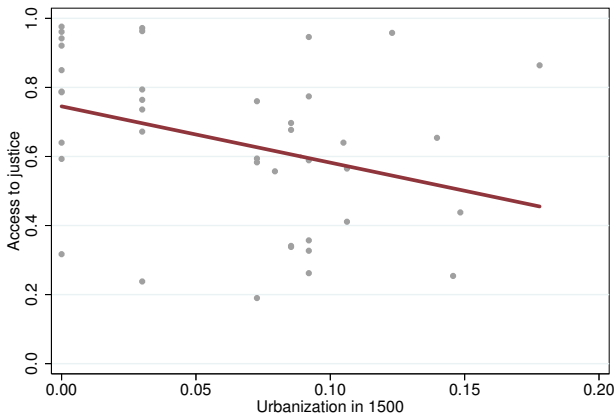
Urbanization in 1500 and Property Rights in 2016
Former European Colonies



Source: V-Dem 9, AJR (2002), 40 countries.

Reversal of fortune: institutions

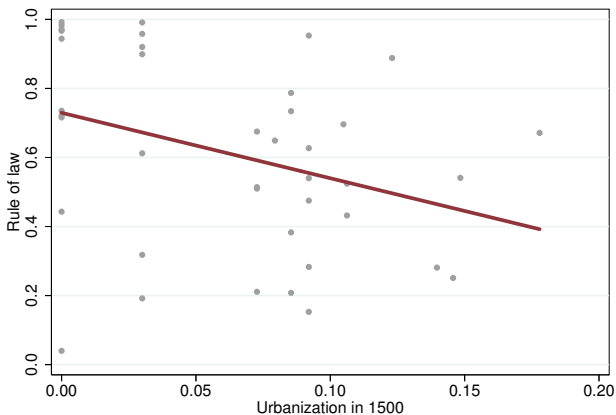
Urbanization in 1500 and Access to Justice in 2016
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Reversal of fortune: institutions

Urbanization in 1500 and Rule of Law in 2016
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Reversal of fortune: institutions

- Evidence of institutional reversal.
 - High urbanization in 1500 \implies “extractive institutions.”
 - Low urbanization in 1500 \implies “inclusive institutions.”

Reversal of fortune: institutions

- Evidence of institutional reversal.
 - High urbanization in 1500 \implies “extractive institutions.”
 - Low urbanization in 1500 \implies “inclusive institutions.”
- Explains also the timing:
 - Good institutions \implies incentives for K and HK accumulation.
 - Institutions are more important when opportunity to industrialize.

Reversal of fortune: institutions

- Factors for choice of colonial institutions:

Reversal of fortune: institutions

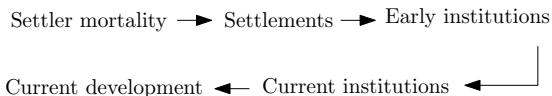
- Factors for choice of colonial institutions:
 - Economic profitability of extractive institutions.
 - Dense population \implies large supply of labor.
 - Pre-existing system of tax administration \implies continue.

Reversal of fortune: institutions

- Factors for choice of colonial institutions:
 - Economic profitability of extractive institutions.
 - Dense population \implies large supply of labor.
 - Pre-existing system of tax administration \implies continue.
 - Whether Europeans could settle.
 - Low density \implies Europeans settle \implies protect their property.
 - Same institutions as home \implies incentives for Europeans to settle.

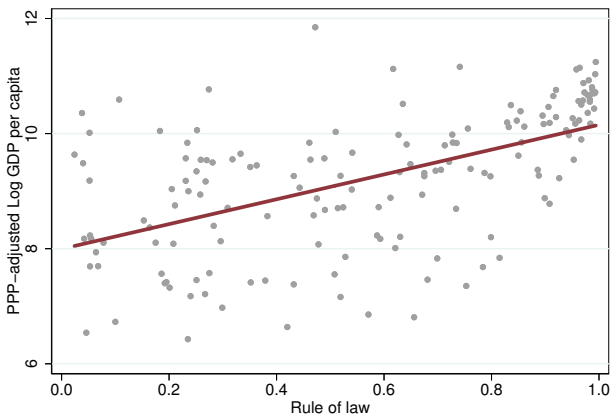
Colonial origins

- Acemoglu, Johnson and Robinson (2001)
- Show that disease environment shaped incentives to settle.
- Use settler mortality as an IV for current institutions.
- Show causal impact of current institutions on current development.



Colonial origins

Log GDP per Capita and Rule of Law, 2016. Causal?



Source: V-Dem 9, Maddison Project Database 2018, 160 countries.

Colonial origins

- Impact of current institutions on current economic performance:

$$\log y_i = \mu + \alpha R_i + \mathbf{X}'_i \gamma + \varepsilon_i$$

Colonial origins

- Impact of current institutions on current economic performance:

$$\log y_i = \mu + \alpha R_i + \mathbf{X}'_i \gamma + \varepsilon_i$$

- First stage: impact of settler mortality on current institutions.

$$R_i = \zeta + \beta \log M_i + \mathbf{X}'_i \delta + \nu_i$$

- y : income per capita.
- R : measure of institutions.
- \mathbf{X} : controls.
- M : settler mortality rate.

Colonial origins

- Impact of current institutions on current economic performance:

$$\log y_i = \mu + \alpha R_i + \mathbf{X}'_i \gamma + \varepsilon_i$$

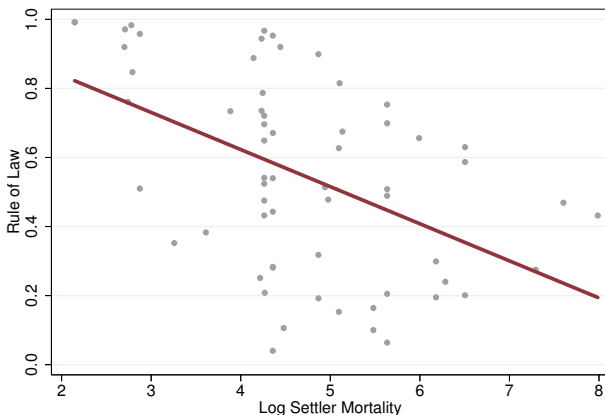
- First stage: impact of settler mortality on current institutions.

$$R_i = \zeta + \beta \log M_i + \mathbf{X}'_i \delta + \nu_i$$

- y : income per capita.
 - R : measure of institutions.
 - \mathbf{X} : controls.
 - M : settler mortality rate.
- Exclusion restriction: settler mortality only affect development through institutions.

Colonial origins: first stage

Settler Mortality and Rule of Law, 2016 Former European Colonies



Source: V-Dem 9, AJR (2001), 62 countries.

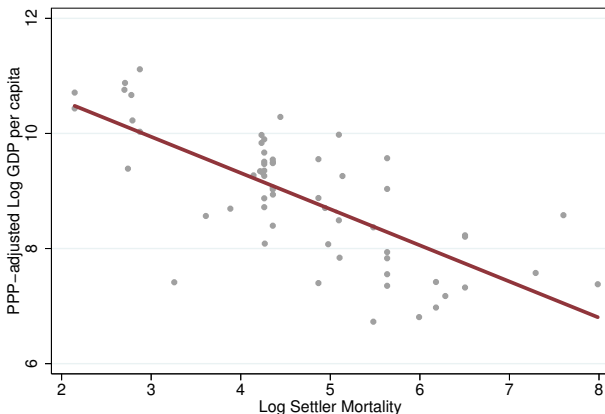
Colonial origins: first stage

Dependent variable:	Rule of Law in 2016			
	(1)	(2)	(3)	(4)
Log settler mortality	-0.11*** [0.02]	-0.05* [0.03]	-0.10*** [0.02]	-0.05* [0.03]
Geography	No	Yes	No	Yes
Colonizer	No	No	Yes	Yes
R2	0.23	0.29	0.28	0.35
Countries	62	62	62	62

*** Significant at the 1 percent level. * Significant at the 1 percent level.

Colonial origins: reduced form

Settler Mortality and Log GDP per Capita, 2016
Former European Colonies



Source: Maddison Project Database 2018, AJR (2001), 62 countries.

Colonial origins: reduced form

Dependent variable:	Log GDP per Capita in 2016			
	(1)	(2)	(3)	(4)
Log settler mortality	-0.63*** [0.08]	-0.42* [0.13]	-0.58*** [0.09]	-0.44*** [0.13]
Geography	No	Yes	No	Yes
Colonizer	No	No	Yes	Yes
R2	0.52	0.64	0.57	0.67
Countries	61	61	61	61

*** Significant at the 1 percent level. * Significant at the 1 percent level.

Colonial origins: IV regressions

Dependent variable:	Log GDP per Capita in 2016			
	(1)	(2)	(3)	(4)
Rule of Law in 2016	5.80*** [0.84]	6.88* [2.28]	5.84*** [0.92]	7.17*** [2.57]
Geography	No	Yes	No	Yes
Colonizer	No	No	Yes	Yes
Countries	61	61	61	61

*** Significant at the 1 percent level. * Significant at the 1 percent level.

Colonial origins: interpretation

- Once institutions purged, little role of geography.
- Rationale for raw correlation between development and geography:
 - Europeans had little immunity to tropical diseases.
 - They tended to settle in temperate latitudes.
 - Explains how geography partly shaped historical institutions.

Colonial origins: interpretation

- Once institutions purged, little role of geography.
- Rationale for raw correlation between development and geography:
 - Europeans had little immunity to tropical diseases.
 - They tended to settle in temperate latitudes.
 - Explains how geography partly shaped historical institutions.
- Colonial culture? No effect of identity of colonizer.

Colonial origins: criticisms

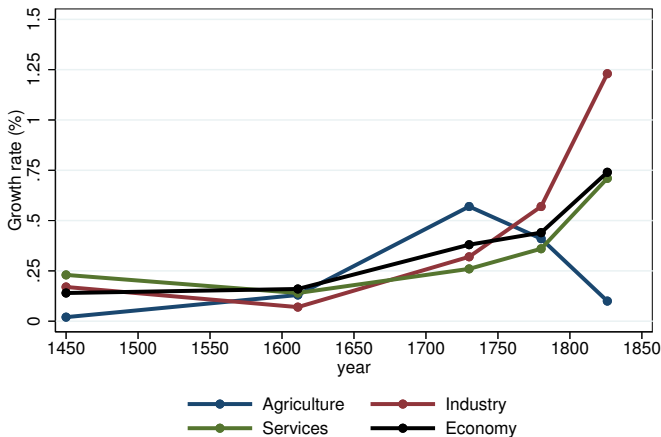
- Large literature resulting from these two papers.
- Criticisms, e.g. [Albouy \(2012\)](#) (after 5 unpublished comments).
 - Reliability and comparability of European settler mortality rates.
 - Procedure of clustering standard errors.
 - Weak instrument problem.
- Responses in [AJR \(2012\)](#) (after 3 unpublished replies).
- Big picture is robust.

Topic 4

Cultural and religious roots to modern economic growth?

Productivity growth in Britain

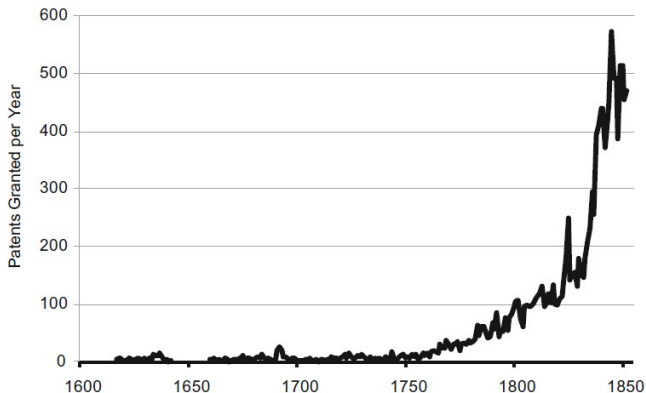
Sectoral Annual Average Productivity Growth Rates in England (1381–1700) and Great Britain (1700–1870)



Source: Broadberry (2020) based on Broadberry et al. (2015).

Important innovations

Patents per year in England (1660–1851)



Source: Clark (2014) based on Mitchell (1988).

Important innovations

“A wave of gadgets swept over England.” Ashton (1948)

- Textile sector:
 - Hargreaves spinning jenny (mid-1760s)
 - Arkwright water frame (late 1760s)
 - Crompton mule jenny (late 1770s)
- Steam power:
 - Newcomen engine (1710s)
 - Watt steam engine (1760s)

⇒ Wave of simultaneous innovations.

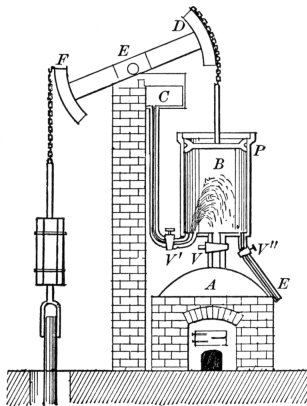
Important innovations

Spinning jenny



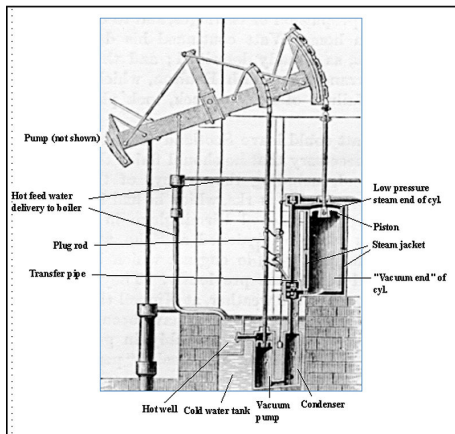
Important innovations

Newcomen engine



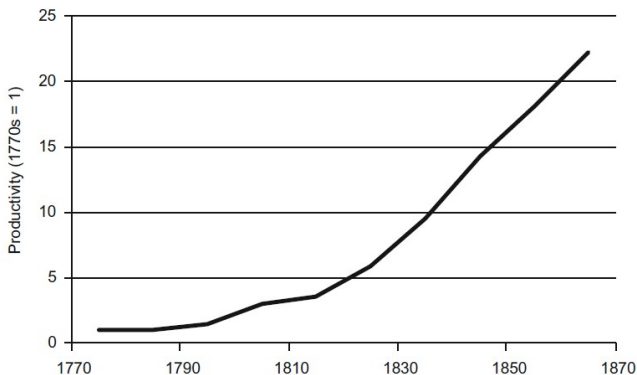
Important innovations

Watt steam engine



Important innovations

Cotton spinning and weaving productivity (1770–1869)



Source: Clark (2014) based on Harley (1998).

Cultural roots of the Great Enrichment

The Enlightenment

Mokyr (2009, 2016, 2021) McClosley (2016)

- Crucial change: ideas and culture of Enlightenment.
 - Ideas of progress 18th century Northwest Europe.
 - Mankind can improve condition through science and rationality.
 - Especially in Britain: advocate empiricism (e.g., Bacon).
- Precursor to Industrial Revolution?
- More than science, a culture of and useful knowledge?

The Enlightenment

- Before: inferiority complex with respect to ancient wisdom that impeded scientific and technological progress, even accusations of heresy.
- After 1500 in Europe: Renaissance scholars rediscovered ancient scientific writings.
- By late 17th century, skepticism and intellectual deference largely gone (e.g., Newton physics).

The Enlightenment

- From late 15th and great voyages, new scientific instruments and tools, confrontation of old wisdom with discoveries (Copernicus, Galileo, ...).
- Institutional change (Reformation) and improved technology (printing press) encouraged rapid proliferation of intellectual innovations, creating a market for ideas.
- 16th and 17th century Europe:
 - Large demand for scientific innovation through patronage of leading scholars of princes and the wealthy, and universities and academies.
 - Applications of innovations to military matters or tutors for princes: highly competitive demand side.
 - Highly competitive supply side for wealth and rise in social standing, and open evaluation of reputation through the Republic of Letters.

The Enlightenment

- A specific set of conditions enabled this market for ideas to emerge in Europe in 1500–1700.
- Europe's political fragmentation of city states, duchies, bishoprics creating competition to attract scholars.
- Suppressing new ideas became impossible due to scholars' outside options.
- This market for ideas saw the emergence of the belief in progress.

Useful knowledge

- Relatively few of these innovations found applications in the early inventions of the Industrial Revolution, especially in the cotton industry.
- But crucial inventions required such innovations, such as hydraulic and steam power.
- Attitudes from the Enlightenment drove the practical innovations later on.
- Formal knowledge increasingly found applications later on, after the 1820s (chemistry, thermodynamics, electricity).

- For economic performance, innovations should be translated to ingenious devices that could be scaled up and repaired by local mechanics.
- It required a large availability of skilled artisans throughout the country, which Britain had (not France).
- Apprenticeship was key, especially a country-wide market for apprentices.

Why did not occur before?

Steinsson (2020), chap 2

- There were always thinkers before.

Why did not occur before?

Steinsson (2020), chap 2

- There were always thinkers before.
- Diffusion of ideas was limited:
 - Without writing, technological regressions if no transmission (e.g., Tasmania).
 - When writings rare, subject to destruction (e.g., Alexandria).
 - Suppression of knowledge by interest groups (e.g., Church).

Why did not occur before?

Steinsson (2020), chap 2

- There were always thinkers before.
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⇒ The watershed moment: the printing press?

The Printing Press

- Movable printing press: Gutenberg 1450s.
- A watershed moment?
 - Altered balance between suppression and spread of knowledge.
 - Enabled rapid diffusion of knowledge.

The Printing Press

- Challenge 1: invented in China in 11th century.
 - Chinese characters: thousands of pieces to transport.
 - Not as useful invention for diffusion.

The Printing Press

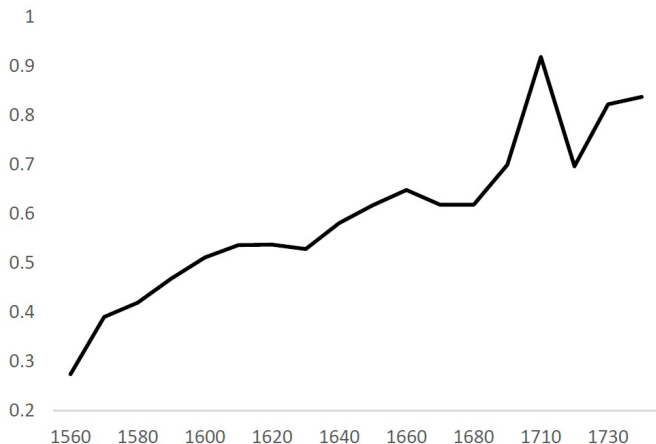
- Challenge 1: invented in China in 11th century.
 - Chinese characters: thousands of pieces to transport.
 - Not as useful invention for diffusion.
- Challenge 2: Industrial Revolutions occurred 300 years later.
 - Took time to weaken knowledge suppression forces.
 - Reformation (16–17th) precursor to Enlightenment (17–18th).
 - Printing press (15th) precursor to Reformation (16–17th).

The Reformation

- Luther against Catholic Church's indulgences (1510s Wittenberg).
- Effective use of printed pamphlet in German to spread ideas.
- Reformation laid ground for Enlightenment:
 - Censorship less severe in protestant locations (Britain, NL).
 - Reformation encouraged literacy (Bible reading).
 - Literacy rose massively before the Industrial Revolution.
 - Also a consequence of decline in book prices.

Literacy rates

Literacy rate of husbandmen in London and Middlesex (1560–1740)

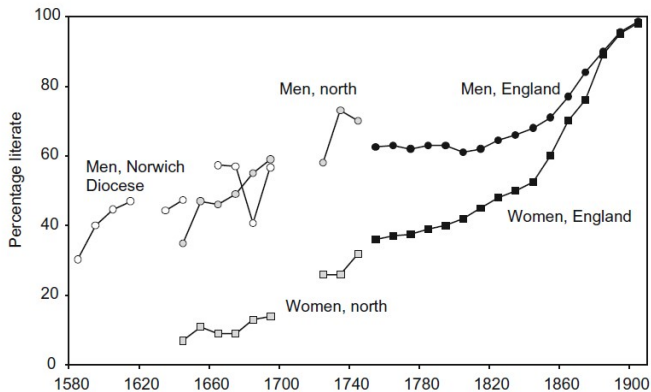


Literacy: fraction of witnesses who can sign ecclesiastical records or court depositions

Source: Steinsson (2020) from Cressy (1980) and Houston (1982).

Literacy rates

Literacy rate in England (1580–1920)



Literacy: fraction of witnesses who can sign ecclesiastical records, court depositions, or marriage registers

Source: Clark (2014) based on Schofield (1973), Houston (1982), Cressy (1977), and Clark (2007).

A Protestant prosperity?

Protestant prosperity

- “Culture of growth” encapsulates complex causal links:
 - The printing press
 - The Reformation and Protestantism
 - Literacy
 - The Enlightenment
 - The Industrial Revolution

Protestant prosperity

- “Culture of growth” encapsulates complex causal links:
 - The printing press
 - The Reformation and Protestantism
 - Literacy
 - The Enlightenment
 - The Industrial Revolution
- ⇒ Let’s try to disentangle these empirically.

Becker and Woessmann (2009)

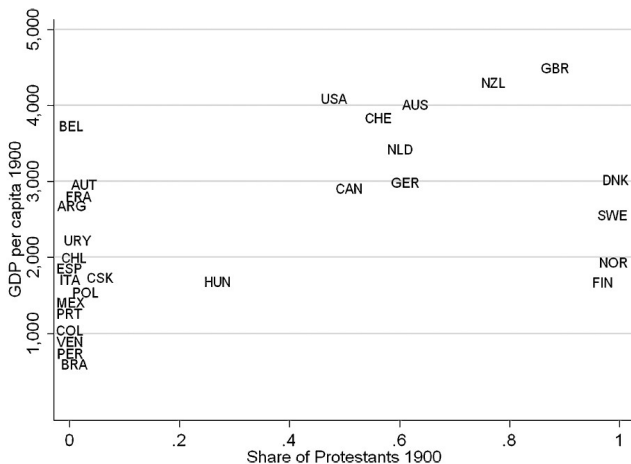
- “Was Weber wrong? A human capital theory of protestant economic history.”

Becker and Woessmann (2009)

- “Was Weber wrong? A human capital theory of protestant economic history.”
- Weber: Protestant ethic and the spirit of capitalism (early 1900s).
 - Empirical foundation: Protestant locations more prosperous.
 - Protestantism and religious sanctification of labor and saving.
 - Resulted in strong work ethic and capitalism.
 - Contrast with Catholicism, focused on morality and asceticism.

Protestant prosperity

Cross-Country Pattern of Protestantism and GDP per Capita, 1900



Source: Becker and Woessmann (2009).

Protestant prosperity

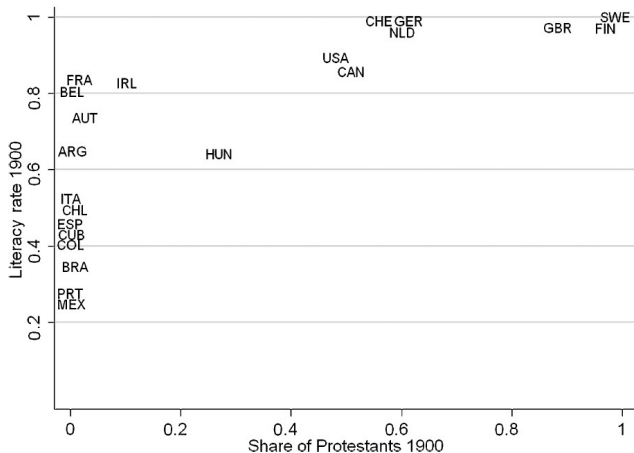
- Empirical test for Protestantism \implies prosperity:
 - Correlation: local prevalence of Protestantism and prosperity in 1900?
 - But omitted variable problem: other factors may cause both (e.g., literacy).

Protestant prosperity

- Empirical test for Protestantism \implies prosperity:
 - Correlation: local prevalence of Protestantism and prosperity in 1900?
 - But omitted variable problem: other factors may cause both (e.g., literacy).
 - Need instrumental variable:
 - Relevance: correlation with variation in Protestantism.
 - Exogeneity: uncorrelated with other determinants of prosperity.
- \implies Focus on component of variation in Protestantism uncorrelated with other determinants of prosperity.

Protestant prosperity

Cross-Country Pattern of Protestantism and Literacy, 1900



Source: Becker and Woessmann (2009).

Protestant prosperity: instrument

- Literacy as an instrument?
 - Relevance: more literate locations more likely to adopt due to Luther's emphasis on reading Bible in vernacular.
 - Exogeneity: literacy affects directly prosperity (information, innovation, contracting, . . .).

Protestant prosperity: instrument

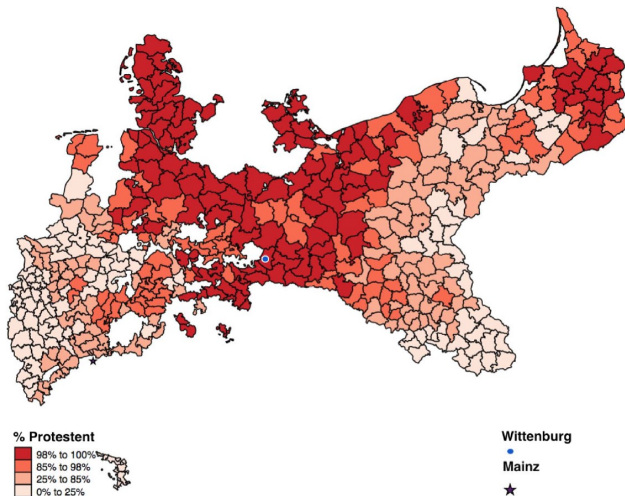
- Literacy as an instrument?
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- Distance to Wittenberg:
 - Relevance: more likely to adopt if more exposed to Luther ideas; travel and transmission of information was slow.
 - ⇒ The Reformation diffused from Wittenberg.

Protestant prosperity: instrument

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- Distance to Wittenberg:
 - Relevance: more likely to adopt if more exposed to Luther ideas; travel and transmission of information was slow.
 - ⇒ The Reformation diffused from Wittenberg.
 - Exogeneity: before the Reformation, Wittenberg unimportant place.
 - ⇒ No direct prosperity effect of being close to Wittenberg.

Protestant prosperity: instrument

Protestant Population Share in Prussia in 1871



Source: Steinsson (2020) based on Becker and Woessmann (2009).

Protestant prosperity: data

- Sample: 452 counties of Prussia, dominant German State.
- Treatment: Protestant population share in 1871.
- Instrument: distance to Wittenberg.
- Outcomes:
 - Income tax revenue per capita in 1877.
 - Annual incomes for elementary school teachers in 1886.
 - Share labor force in manufacturing in 1882.
- Balancing variables:
 - Urbanization rate in 1500.
 - Indicators for imperial city, university, school in 1517.

Protestant prosperity: first-stage

- Formal test of instrument relevance (first-stage regression):

$$\text{PROT}_i = \alpha + \beta \text{DIST}_i + \mathbf{X}'_i \gamma + \varepsilon_i$$

- PROT_i : population share of Protestants in county i in 1871.
- DIST_i : distance to Wittenberg in km.
- \mathbf{X}_i : vector of control variables (share younger than 10, share Jews, share female, share born in municipality, household size, population size,...).
- ε_i : error term.

Protestant prosperity: first-stage

First-Stage: Protestantism and Distance to Wittenberg

Dependent Variable:	Share Protestants
Distance to Wittenberg in km	-0.095 (0.011)
Number of Observations	452
1st-Stage F-Statistic	74.2

Notes: These estimates are taken from Table III in Becker and Woessmann (2009). Standard errors are in parentheses. The control variables included in the regression are: % age below 10, % Jews, % females, % born in municipality, % of Prussian origin, average household size, ln(population size), population growth from 1867-1871 in %, % missing education info, % blind, % deaf-mute, % insane.

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Source: Steinsson (2020) based on Becker and Woessmann (2009).

- Each 100km is associated with \downarrow Protestant share of 9.5 pp.
- Precise estimate: clearly reject that $\beta = 0$.
- F-statistics $> 10 \simeq$ “strong instrument”.

Protestant prosperity: exogeneity

- Corroboration of instrument exogeneity.
- Instrument not correlated with observable economic characteristics prior to Reformation that may affect subsequent prosperity.
- Find proxies for economic or educational development.

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- Instrument not correlated with observable economic characteristics prior to Reformation that may affect subsequent prosperity.
- Find proxies for economic or educational development.

$$Y_i = \alpha + \beta \text{DIST}_i + \mathbf{X}'_i \gamma + \varepsilon_i$$

- Y_i : Urbanization, imperial city, university, school in 1500s.
- DIST_i : distance to Wittenberg in km.
- \mathbf{X}_i : vector of control variables (share younger than 10, share Jews, share female, share born in municipality, household size, population size,...).
- ε_i : error term.

Balance Tests: Pre-Protestant Prosperity and Distance to Wittenberg

Dependent Variable:	Imperial City in 1517	Urbanization in 1500	University in 1517	School in 1517
Distance to Wittenberg (in 100 km)	0.0034 (0.0071)	0.00006 (0.00013)	-0.0019 (0.0047)	-0.0073 (0.0099)
Number of Observations	452	452	452	333
R^2	0.0005	0.0004	0.0004	0.002

Notes: These estimates are taken from Table IV in Becker and Woessmann (2009). Standard errors are in parentheses. The dependent variables are: an indicator for whether a county was a free imperial city, urban population per km², indicator for whether county had a university, and indicator for whether the county had a school.

Source: Steinsson (2020) based on Becker and Woessmann (2009).

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Source: Steinsson (2020) based on Becker and Woessmann (2009).

- Coefficients are small in magnitude.
- Imprecise estimate: fail to reject that $\beta = 0$.
- Claim: distance to Wittenberg is valid instrument.

Protestant prosperity: reduced-form

- Is instrument correlated with outcome (reduced-form)?
- Is distance to Wittenberg correlated with prosperity in 1870s?

$$\text{PROSP}_i = \alpha + \beta \text{DIST}_i + \mathbf{X}'_i \gamma + \varepsilon_i$$

- PROT_i : proxy for prosperity of county i in 1870s.
- DIST_i : distance to Wittenberg in km.
- \mathbf{X}_i : vector of control variables (share younger than 10, share Jews, share female, share born in municipality, household size, population size,...).
- ε_i : error term.

Protestant prosperity: reduced-form

Reduced-Form: Prosperity and Distance to Wittenberg

Dependent Variable:	Income Tax per capita	Log Teacher Income	Share Manuf. and Services
Distance to Wittenberg (in 100 km)	-6.0 (2.3)	-1.00 (0.48)	-0.78 (0.36)
Number of Observations	426	452	452

Notes: These estimates are produced using replication code and data provided by Ludger Woessmann. They are the reduced form estimates that correspond to the instrumental variables (IV) estimates presented in Table V of Becker and Woessmann (2009) except that I have included “% missing education info” as an additional control for consistency with the first stage reported in Table 2. Income tax per capita is measured in pfennig. Standard errors are in parentheses. The control variables included in the regression are: % age below 10, % Jews, % females, % born in municipality, % of Prussian origin, average household size, ln(population size), population growth from 1867-1871 in %, % missing education info, % blind, % deaf-mute, % insane.

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Source: Steinsson (2020) based on Becker and Woessmann (2009).

- Each 100km is associated with \downarrow income tax revenues of 6 pfennig.
- Precise estimate: clearly reject that $\beta = 0$.
- Magnitude:
 - s.d. in DIST = 150km. s.d. in INC = 70 pfennig.
 - \uparrow 1 s.d. DIST \implies \downarrow 0.13 s.d. INC (small-moderate).

Protestant prosperity: second-stage

- Second-stage (IV): impact of Protestantism on prosperity through distance to Wittenberg.
- If valid: IV not correlated with all other determinants of prosperity.
- As move away from Wittenberg, the only potential determinant of prosperity changing is share Protestantism.
- If prosperity changes as move away from Wittenberg, only due to changes in Protestantism.

Protestant prosperity: second-stage

- Causal chain:

$$\text{DIST on PROSP} = \text{DIST on PROT} \times \text{PROT on PROSP}$$

Protestant prosperity: second-stage

- Causal chain:

$$\text{DIST on PROSP} = \text{DIST on PROT} \times \text{PROT on PROSP}$$

- Second-stage is ratio of reduced-form to first-stage:

$$\text{PROT on PROSP} = \frac{\text{DIST on PROT}}{\text{DIST on PROSP}}$$

Protestant prosperity: second-stage

Second-Stage: Prosperity and Protestantism Through Distance to Wittenberg

Dependent Variable:	Income Tax per capita	Log Teacher Income	Share Manuf. and Services
Share Protestant	0.62 (0.24)	0.11 (0.05)	0.08 (0.04)
Number of Observations	426	452	452

Notes: These estimates are taken from Table V in Becker and Woessmann (2009). Income tax per capita is measured in pfennig. Coefficients in the second column are multiplied by 100. Standard errors are in parentheses. The control variables included in the regression are: % age below 10, % Jews, % females, % born in municipality, % of Prussian origin, average household size, ln(population size), population growth from 1867-1871 in %, % blind, % deaf-mute, % insane.

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Source: Steinsson (2020) based on Becker and Woessmann (2009).

- $\uparrow 10$ pp share Protestant $\implies \uparrow$ income tax revenues of 6.2 pfennig.
- Relatively precise estimate: reject that $\beta = 0$.
- Magnitude:
 - s.d. in PROT = 37%. s.d. in INC = 70 pfennig.
 - $\uparrow 1$ s.d. PROT $\implies \downarrow 0.33$ s.d. INC (moderate).

Protestant prosperity: mechanisms

- Was Weber right?
- Was it Protestant ethic and the spirit of capitalism?

Protestant prosperity: mechanisms

- Was Weber right?
- Was it Protestant ethic and the spirit of capitalism?
- Becker and Woessmann claim: through literacy.
 - Effect of Protestantism on literacy large.
 - Enough to explain effect of Protestantism on prosperity.

Protestant prosperity: mechanisms

Mechanisms: Literacy and Protestantism Through Distance to Wittenberg

Dependent Variable:	Share Literate
Share Protestant	0.19 (0.03)
Number of Observations	452

Notes: This IV estimate is taken from Table III in Becker and Woessmann (2009). Standard errors are in parentheses. The control variables included in the regression are: % age below 10, % Jews, % females, % born in municipality, % of Prussian origin, average household size, ln(population size), population growth from 1867-1871 in %, % blind, % deaf-mute, % insane, % missing education info.

Source: Steinsson (2020) based on Becker and Woessmann (2009).

Protestant prosperity: mechanisms

Mechanisms: Literacy and Protestantism Through Distance to Wittenberg

Dependent Variable:	Share Literate
Share Protestant	0.19 (0.03)
Number of Observations	452

Notes: This IV estimate is taken from Table III in Becker and Woessmann (2009). Standard errors are in parentheses. The control variables included in the regression are: % age below 10, % Jews, % females, % born in municipality, % of Prussian origin, average household size, $\ln(\text{population size})$, population growth from 1867-1871 in %, % blind, % deaf-mute, % insane, % missing education info.

Source: Steinsson (2020) based on Becker and Woessmann (2009).

- $\uparrow 10$ pp share Protestant $\implies \uparrow$ literacy of 2 pp.
- Relatively precise estimate: reject that $\beta = 0$.

Protestant prosperity: limits

- Claim: Protestantism \implies literacy \implies prosperity.

Protestant prosperity: limits

- Claim: Protestantism \implies literacy \implies prosperity.
- Empirical evidence:
 - Based on local differences in Protestantism and prosperity.
 - Unclear what are aggregate effects of Protestantism.

Protestant prosperity: limits

- Validity of instrument:
 - Evidence of printing press \implies Protestantism. [Rubin \(2014\)](#)
 - Evidence of printing press \implies prosperity *directly*. [Dittmar \(2011\)](#)
 \implies Threat to exogeneity of IV
 - Protestantism correlated with printing press, no effect on prosperity?

Protestant prosperity: limits

- Validity of instrument:
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 - Evidence of printing press \implies prosperity *directly*. [Dittmar \(2011\)](#)
 \implies Threat to exogeneity of IV
 - Protestantism correlated with printing press, no effect on prosperity?
- Controlling for distance to Mainz (printing press diffusion). [Steinsson \(2020\)](#)
 - First stage unchanged (DIST on PROT | PRINT).
 - IV weak and insignificant (PROT on PROSP through DIST | PRINT).

\implies Challenging to disentangle Protestantism, literacy, and growth!

Protestant prosperity: mechanisms

The diffusion of the movable type printing press

a: Cities with Printing in 1450



b: Cities with Printing in 1460



Source: Dittmar (2011).

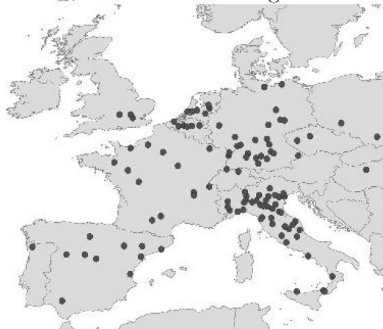
Protestant prosperity: mechanisms

The diffusion of the movable type printing press

c: Cities with Printing in 1470



d: Cities with Printing in 1480

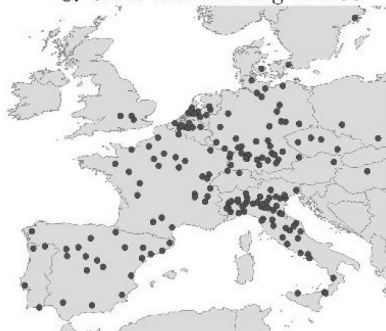


Source: Dittmar (2011).

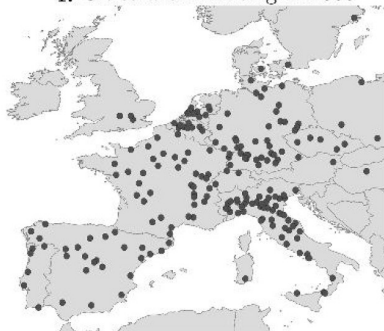
Protestant prosperity: mechanisms

The diffusion of the movable type printing press

e: Cities with Printing in 1490



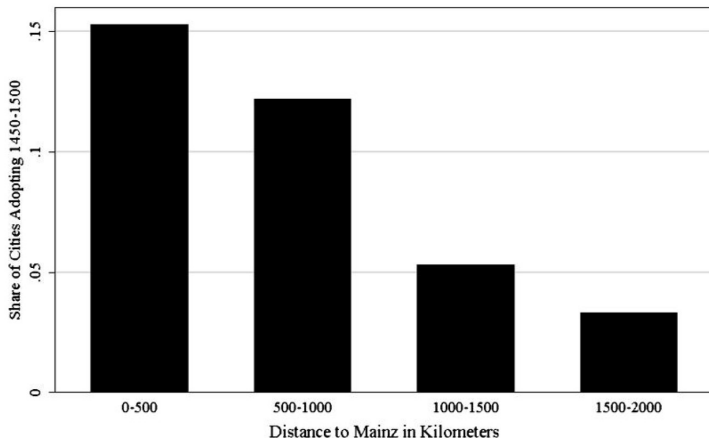
f: Cities with Printing in 1500



Source: Dittmar (2011).

Protestant prosperity: mechanisms

Distance from Mainz and adoption of the printing press, 1450–1500



Source: Dittmar (2011).

Protestant ethic: alternative interpretation

Kersting et al. (2021)

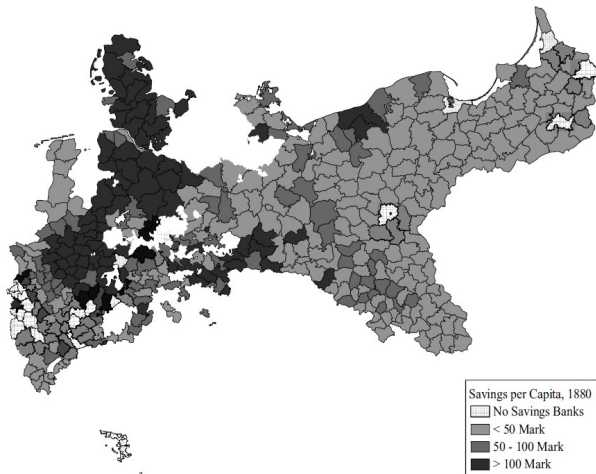
- The role of savings \implies accumulation of capital.
- The role of differences between ethnic groups as confounding factor.

Protestant ethic: data

- Sample: 434 counties of Prussia, dominant German State.
- Treatment: Protestant population share.
- Instrument: Protestant population share in 1624, residualized.
- Outcomes [Lehmann-Hasemeyer and Wahl \(2017\)](#):
 - Savings per capita (medium and lower income groups).
 - Number of saving banks.
- Years \simeq 1875, 1880, 1890, 1900, 1905.

Protestant ethic: data

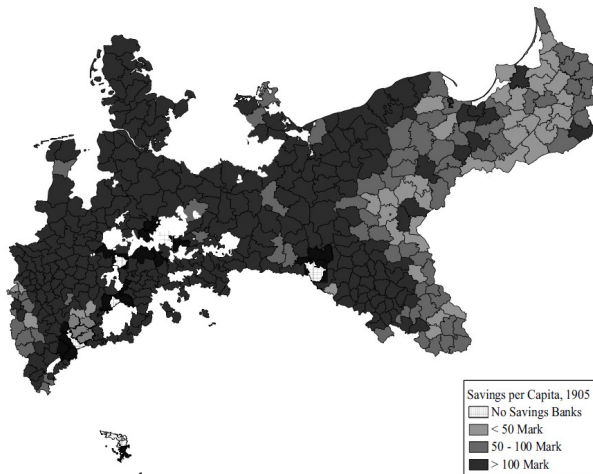
Savings per Capita, 1880



Source: Kersting et al (2020).

Protestant ethic: data

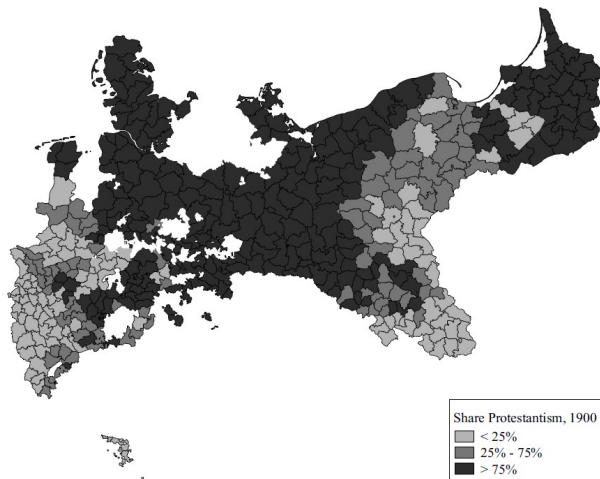
Savings per Capita, 1905



Source: Kersting et al (2020).

Protestant ethic: data

Protestantism, 1900



Source: Kersting et al (2020).

Protestant ethic: specification

- Baseline pooled OLS regression:

$$\text{Sav}_{it} = \alpha_1 + \beta_1 \text{Prot}_{it} + \mathbf{X}'_{it} \gamma_1 + \varepsilon_{1it}$$

- Sav_{it} : savings per capita in county i in year t .
- Prot_{it} : share of Protestants in county i .
- \mathbf{X}_{it} : vector of control variables (urban population, number of savings banks, household size, share of other religions).
- ε_{it} : error term.

Protestant ethic: instrument

- Idiosyncratic element of religious denomination as of 1624 (Peace of Westphalia). [Spenkuch \(2017\)](#)
- Regress Protestant 1624 at county level on predictors :
 - [Cantoni \(2012\)](#) Latitude, contribution to federal budget of Holy Roman Empire, distance to Wittenberg.
 - [Rubin \(2014\)](#) Existence of printing press.
- Use residuals as IV.
 - No reverse causality (200-year lag).
 - By construction, uncorrelated with factors affected by controls.

Savings per capita, 1875–1905

	(1)	(2)	(3)	(4)
Panel 1: OLS		Dep. Var. Savings per Capita		
Share Protestants	0.012 (0.079)	0.022 (0.102)	0.033 (0.081)	0.065 (0.103)
Income per capita			0.350*** (0.068)	0.316*** (0.072)
R^2	0.280	0.245	0.351	0.308
Panel 2: Second Stage		Dep. Var. Savings per Capita		
Share Protestants	-0.034 (0.101)	-0.029 (0.183)	-0.057 (0.110)	-0.064 (0.193)
Income per capita			0.342*** (0.072)	0.297** (0.084)
Panel 3: First Stage		Dep. Var. Protestantism		
Residual decision 1624	0.429*** (0.083)	0.288*** (0.048)	0.432*** (0.081)	0.294*** (0.045)
Income per capita			-0.109 (0.092)	-0.162* (0.080)
R^2	0.324	0.392	0.331	0.409
Including eastern provinces	Yes	No	Yes	No
Further controls	Yes	Yes	Yes	Yes
F-statistic excluded instruments	26.65	36.26	28.73	42.32
N	1,830	1,355	1,830	1,355

Source: Kersting et al (2020).

Effect of Protestantism on literacy, 1871

	(1)	(2)	(3)
Panel 1: OLS			
	Dep. Var. Literacy		
Share Protestants	0.057*** (0.009)	0.033** (0.013)	0.040*** (0.012)
Share German speaking			0.213*** (0.036)
R^2	0.610	0.431	0.735
Panel 2: Second Stage			
	Dep. Var. Literacy		
Share Protestants	0.030 (0.018)	0.031 (0.017)	0.020 (0.015)
Share German speaking			0.221*** (0.036)
Panel 3: First Stage			
	Dep. Var. Protestantism		
Residual decision 1624	46.088*** (4.227)	43.094*** (3.277)	45.369*** (2.866)
Share German speaking			0.327** (0.144)
R^2	0.474	0.599	0.489
Including eastern provinces	Yes	No	Yes
Further controls	Yes	Yes	Yes
F-statistic excluded instruments	246.34	172.95	250.58
N	378	280	378

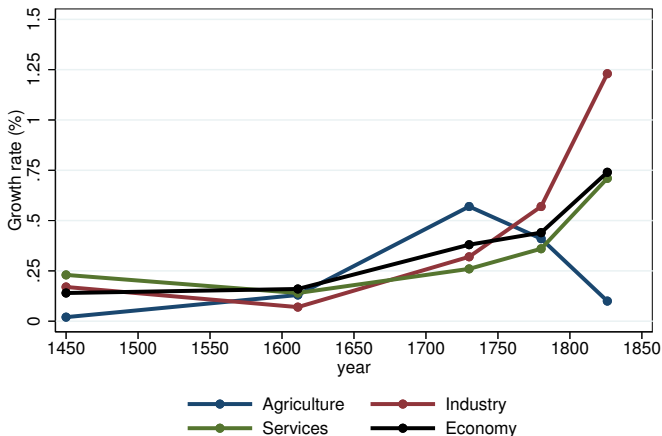
Source: Kersting et al (2020).

Topic 5

Directed technical change

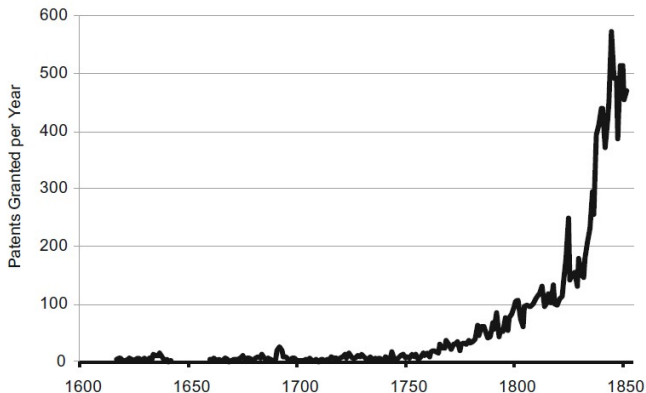
Productivity growth in Britain

Sectoral Annual Average Productivity Growth Rates in England (1381–1700) and Great Britain (1700–1870)



Source: Broadberry (2020) based on Broadberry et al. (2015).

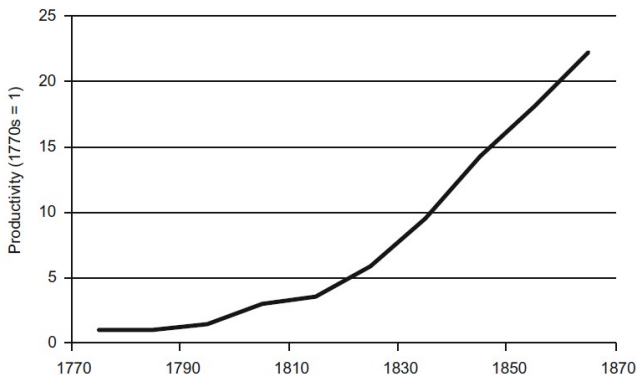
Patents per year in England (1660–1851)



Source: Clark (2014) based on Mitchell (1988).

Productivity growth in Britain

Cotton spinning and weaving productivity (1770–1869)



Source: Clark (2014) based on Harley (1998).

The cotton industry

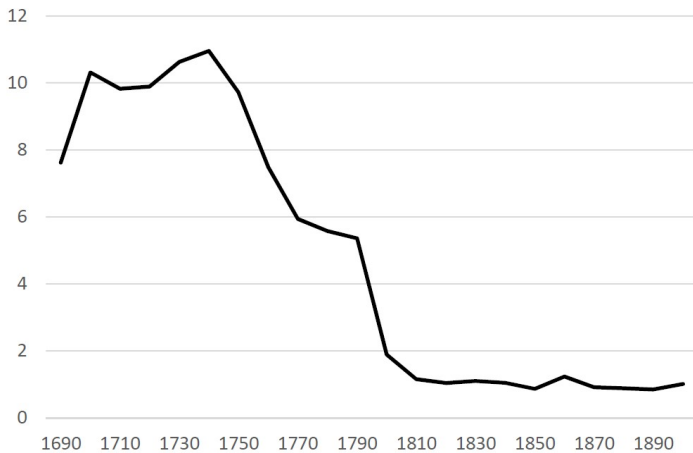
- The cotton industry epitomizes the IR in Britain.
 - Production growth: 7% per year 1770–1815.
 - Total factor productivity growth: 2.6% per year 1780–1860.
 - Accounted for 25% of British productivity growth 1780–1860.
 - Reduction in output price by factor 10 1750–1820.

The cotton industry

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 - Total factor productivity growth: 2.6% per year 1780–1860.
 - Accounted for 25% of British productivity growth 1780–1860.
 - Reduction in output price by factor 10 1750–1820.
- Most intensively mechanized sector.
 - Large decline in share of labor in value added.
 - Many inventions: Hargreave's, spinning jenny, Arkwright water frame, Cartwright loom, Withney cotton gin. . .
 - Biased technical change: save labor.

The cotton industry

Prices of cotton cloth relative to bread in England



Source: Steinssen (2020) based on Allen (2009).

The cotton industry

Real cost of cotton (16 count) in 1784 prices

	Hand Method 1760	24-Spindle Jenny 1775	Arkwright Mill 1784	Glasgow Mill 1836
Labor:				
Cleaning and Carding	7.00	7.00	2.69	0.16
Spinning	7.00	2.33	2.57	0.34
Reeling, bundling, etc.	0.47	0.47	2.19	0
Administrative	2.72	2.72	0.41	0.02
Total Labor	17.19	12.52	7.86	0.52
Materials:				
Raw Cotton	16.88	16.88	16.88	16.70
Other	0	0	1.20	0.53
Capital	0.93	1.88	2.00	0.47
Total Cost	35.00	31.28	27.94	18.22
Labor Share of Value Added	95%	87%	80%	53%

Source: Steinssen (2020) based on Allen (2009).

The cotton industry

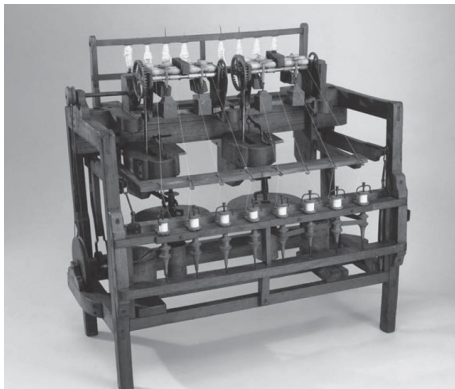
Hargreave's spinning jenny of 1770



Source: Allen (2009).

The cotton industry

Arkwright's water frame of 1775



Source: Allen (2009).

- Measuring innovation
- Technical change in cotton spinning
- The High Wages argument
- The Energy Revolution

Measuring innovation

Mokyr (1990)

- Effective characterization of patterns of technical change:
 - Microinventions: “small, incremental steps that improve, adapt and streamline existing techniques.”
 - Macroinventions: “inventions in which a radical new idea, without a clear precedent, emerges more or less ab nihilo.”

Mokyr (1990)

- Effective characterization of patterns of technical change:
 - Microinventions: “small, incremental steps that improve, adapt and streamline existing techniques.”
 - Macroinventions: “inventions in which a radical new idea, without a clear precedent, emerges more or less ab nihilo.”
- Traditional measurement of innovations:
 - Raw patent counts.
 - But do not take into account relative importance of underlying inventions.

⇒ “Patent statistics [in the IR period] do not permit to distinguish between radical and minor inventions”

Nuvolari et al. (2021)

- Composite indicator of quality for the 13,070 English patents 1700–1850.

Nuvolari et al. (2021)

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- Sources of the “Bibliographic Composite Index of patent quality”
 - Woodcroft’s *Reference Index* of 1855 on patents 1617–1852: counts number of times each patent mentioned in specialized publications, adjusted for time effects. [Nuvolari and Tartari \(2011\)](#)
⇒ Captures visibility of patents in contemporary engineering and legal literature.

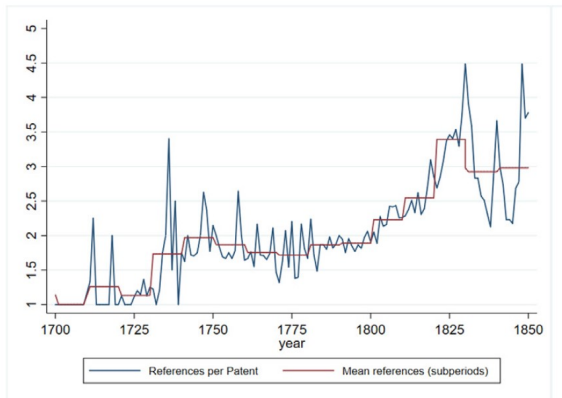
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 - Number of times patent mentioned in Schookler’s (1966) list of “important inventions.”
 - ⇒ Captures visibility of patents in modern reference books of history of science and technology.
 - Number of times patentee mentioned in large set of biographical dictionaries.
 - ⇒ Captures relative visibility of patentee in biographical dictionaries.

- Properties of the quality indicators:
 - Three indicators correlated, but in limited way.
 - Capture complementary dimensions of patent quality.
 - WRI: captures incremental innovations.
 - Two others: capture breakthrough innovations.

Measuring Innovation

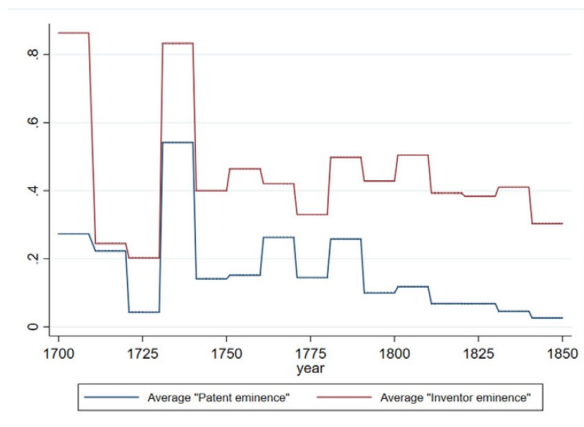
Average number of references per patents over time



(a) Average number of references per patents in Woodcroft (1862), yearly and by decade.

Measuring Innovation

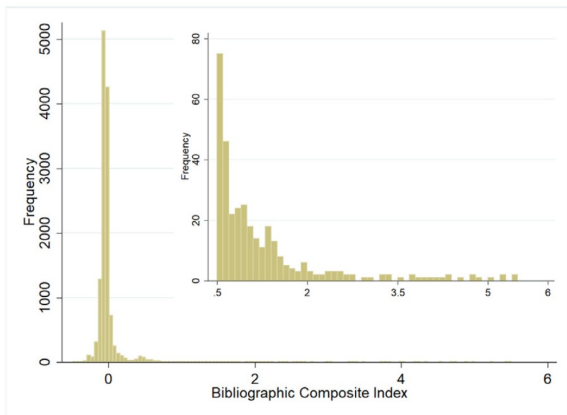
Average number of references per patents over time



(b) Average number of references per patents by decade.

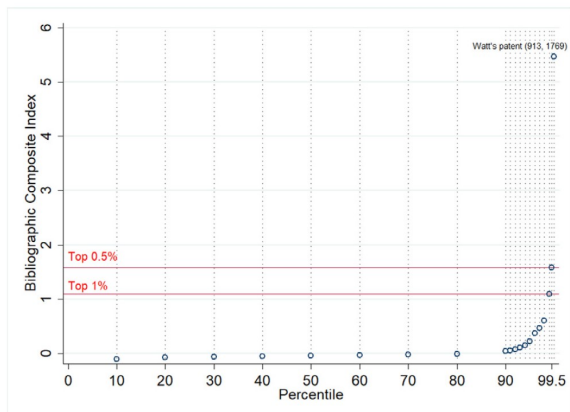
- Building the Bibliographic Composite Index (BCI):
 - Take into account time and sector correlated patterns.
 - Regress each indicator on time and sectoral indicators, extracting residuals.
 - Residuals capture share of variance due to intrinsic quality of patents.
 - Extract latent common factor for each patent.

Empirical distribution of the BCI



Source: Nuvolari et al. (2021).

Percentile plot of the BCI



Source: Nuvolari et al. (2021).

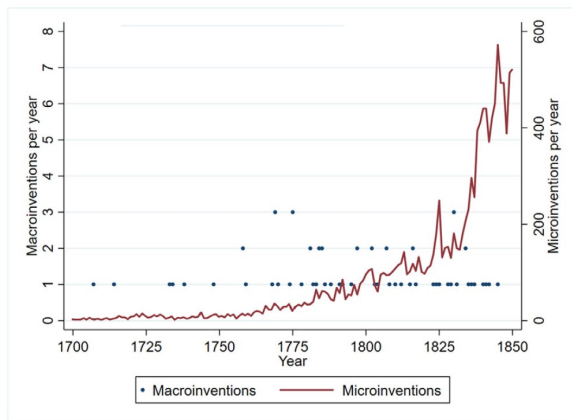
Patterns of innovation during the IR

- Hypothesis of Mokyr (1990):
 - Macroinventions are generated by a serendipitous search process.
 - Microinventions result of continuous and cumulative improvements, displaying temporal persistence.

Patterns of innovation during the IR

- Hypothesis of Mokyr (1990):
 - Macroinventions are generated by a serendipitous search process.
 - Microinventions result of continuous and cumulative improvements, displaying temporal persistence.
- Results confirm the hypothesis:
 - No time clustering of macroinventions (top 0.5% BCI).
 - Strong time clustering of microinventions (bottom 99.5% BCI).

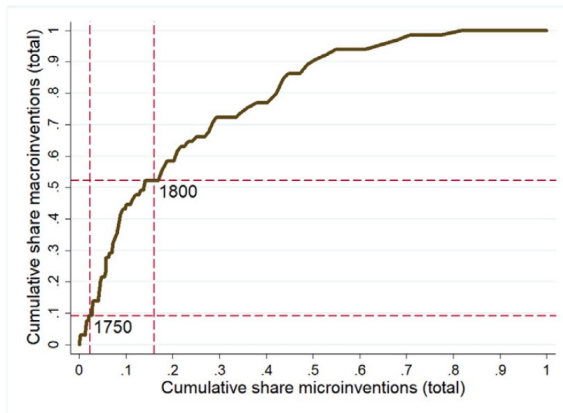
Number of inventions per year



Source: Nuvolari et al. (2021).

Measuring Innovation

Relative cumulative distribution of macro vs micro inventions

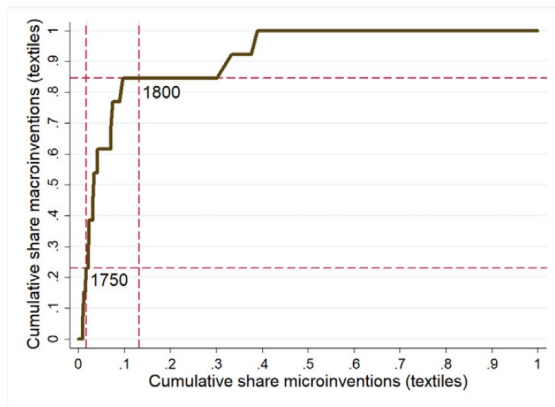


(a) All patents

Source: Nuvolari et al. (2021).

Measuring Innovation

Relative cumulative distribution of macro vs micro inventions



(b) Textile sector

Source: Nuvolari et al. (2021).

Technical change in cotton spinning

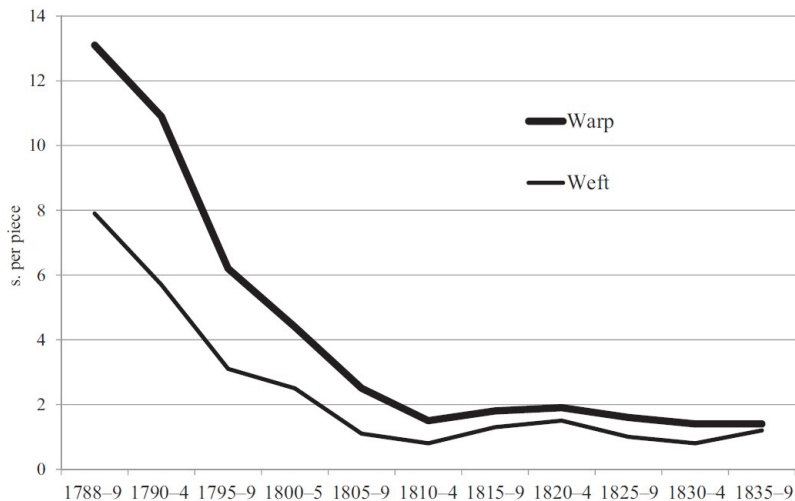
Technical change in cotton spinning

Maw et al. (2022)

- Textile and especially spinning: leading sector in IR.
- Early macro-inventions:
 - Hargreaves' spinning jenny mid-1760s.
 - Arkwright's water-frame late-1760s.
 - Crompton's mule in late-1770s.
- Initial productivity gains needed micro-inventions (improvements of macro-inventions) to sustain productivity growth after 1770s, especially from the 1780s to 1830s.

Technical change in cotton spinning

Yarn added-value, 1788–1839



Technical change in cotton spinning

Contemporary estimates of machine spindleage in the UK cotton industry (spindles, 000)

	<i>Jenny</i>		<i>Mule</i>		<i>Water-frame</i>		<i>Throstle</i>	<i>Total</i>
1784	283	(82%)	4	(1%)	60	(17%)	0	347
1787	1,605	(83%)	50	(3%)	286	(15%)	0	1,941
1789	1,400	(58%)	700	(29%)	310	(13%)	0	2,410
1811	156	(3%)	4,200	(90%)		311 (7%)		4,667
1845	0		13,000	(74%)	0		4,500 (26%)	17,500

Source: Maw et al. (2022).

Technical change in cotton spinning

- Use newspaper advertisements 1780–1835 for information on early cotton-spinning machinery.
- Locations: Manchester, Blackburn, Leeds, Glasgow, Belfast, Derby, Nottingham, Preston.
- Total of 1,465 advertisements.
- Most common: public auctions (63%).
- Contains type of machine, average size, location.

Technical change in cotton spinning

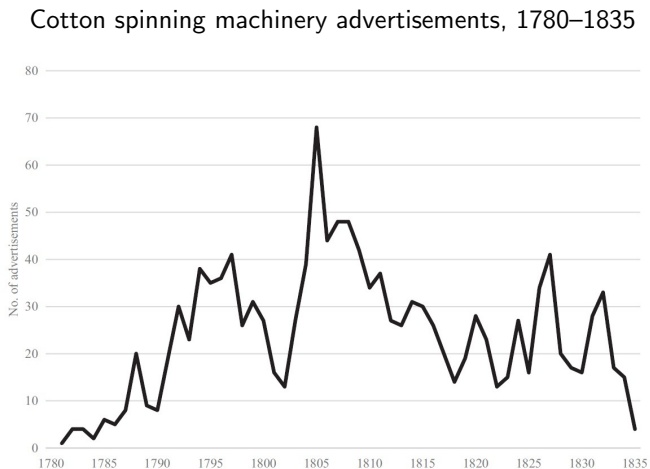
Example of advertisement for cotton-spinning machinery

b) *Manchester Mercury*, 8 Apr. 1788

A COTTON MILL.
To be SOLD by AUCTION,
By Order of the Assignees of SALISBURY, BARROW, CARR,
and Co. Bankrupts,
At Spencer's Tavern, in Manchester, in the County of Lan-
caster, on Tuesday the 15th Day of April, 1788, at Five
o'Clock in the Afternoon,
ALL that valuable COTTON MILL, situate at CHIR-
PINGTON, in the County of Lancaster, about 3 Miles from
Preston, in a populous Manufacturing Country, with the
Machinery in and belonging to the same, and the Messuage,
Cottages, Buildings, and about fourteen Acres of Land ad-
jacent thereto.
The Mill containing 23 Yards in Length, by 9 in Breadth,
with the Stream of Water, is held by Lease for a Term of
99 Years, (of which but few are expired) under the yearly
Rent of 4l.
The other Premises consisting of a Building adjoining to
the Mill, a Messuage in the Occupation of Mr. William
Carr, a Smithy, Barn, three Cottages inhabited, one other
Cottage nearly finished, four more Cottages built to the full
Floor, a Garden, and the fourteen Acres of Land, are held
by Lease for a Term of 99 Years, whereof three only are
expired, under the yearly Rent of 21l.
The Water-shaft is twenty-four Inches square, the Wheel
thirteen Feet and a half in Diameter, and five and a half in
Breadth on the Face; there are twenty Spinning Frames,
containing 1032 Spindles at work, and Machinery for six
more Frames, of forty-eight Spindles each; there are also
a proportionable Number of Carding, Roving, Drawing, and
other Machines, and the Mill and Machinery are in full
Work and good Condition.
For further Particulars enquire of Mr. John Whittenbury,
and Mr. Samuel Jackson, of Manchester aforesaid, the As-
signees of the said Bankrupt's Estate; or of Mr. Jones, of
the same Place, Attorney at Law.

Source: Maw et al. (2022).

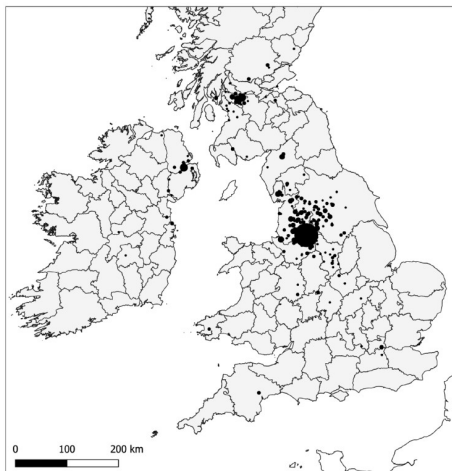
Technical change in cotton spinning



Source: Maw et al. (2022).

Technical change in cotton spinning

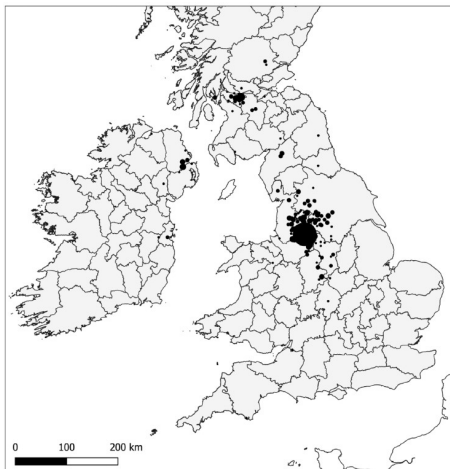
Advertisements for UK cotton-spinning machinery, by location, 1780—1811



Source: Maw et al. (2022).

Technical change in cotton spinning

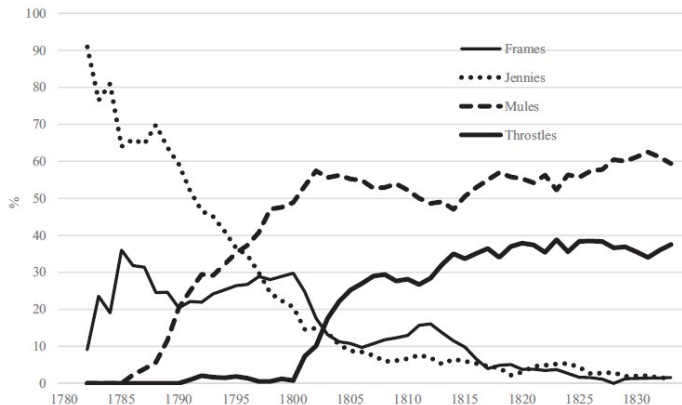
Advertisements for UK cotton-spinning machinery, by location, 1812—1835



Source: Maw et al. (2022).

Technical change in cotton spinning

Machinery advertisements by type of machine

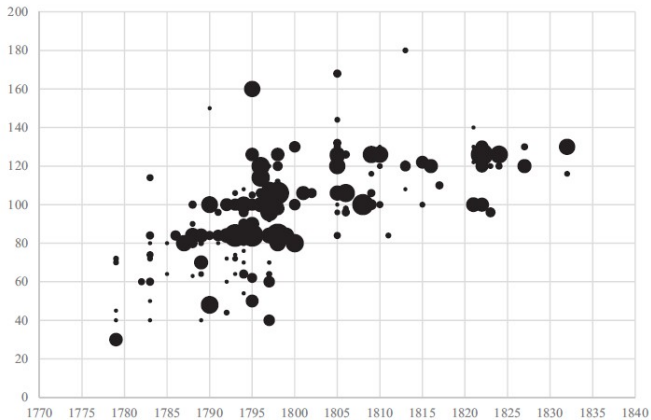


Source: Maw et al. (2022).

Technical change in cotton spinning

Size of advertised spinning machines (spindles)

a) Spinning jennies

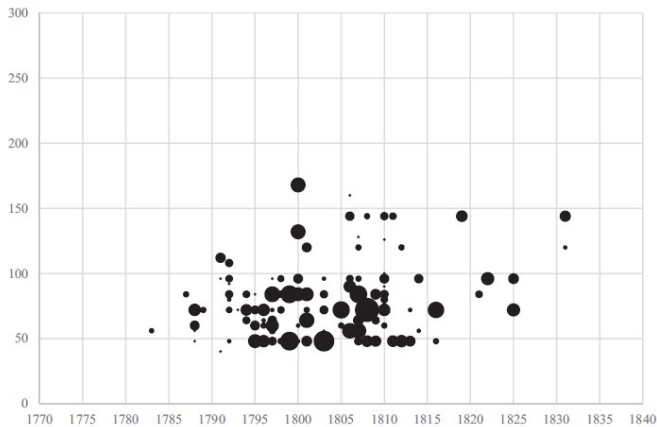


Source: Maw et al. (2022).

Technical change in cotton spinning

Size of advertised spinning machines (spindles)

b) Water-frames

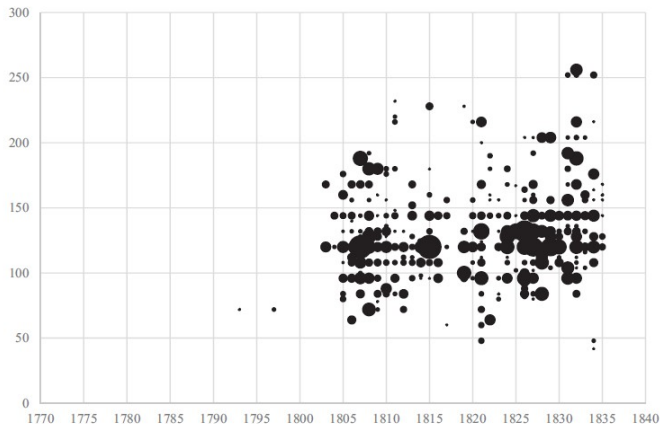


Source: Maw et al. (2022).

Technical change in cotton spinning

Size of advertised spinning machines (spindles)

c) Throstles

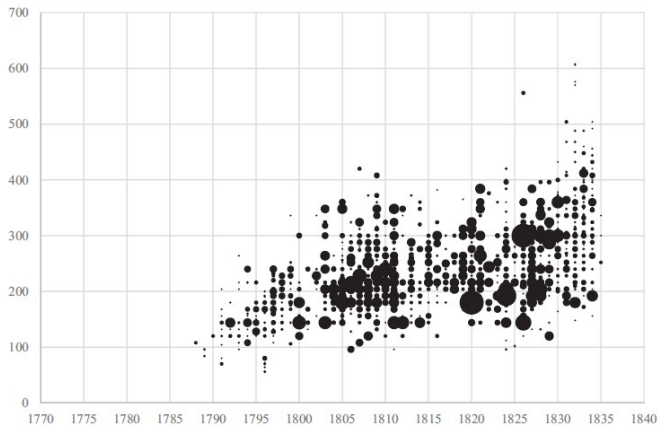


Source: Maw et al. (2022).

Technical change in cotton spinning

Size of advertised spinning machines (spindles)

d) Mules



Source: Maw et al. (2022).

Technical change in cotton spinning

Productivity indicators in cotton spinning, c. 1760—c. 1835

	<i>Spindles per machine</i>	<i>Spinners per machine</i>	<i>Spindles per spinner</i>	<i>Operatives per machine</i>	<i>Hanks spun per spindle, per day (and 'count')</i>		<i>Daily output per spinning machine (hanks)</i>	<i>Daily output per spinning machine (lbs)</i>	<i>Daily output per operative (hanks)</i>	<i>Change factor since 1760</i>
Hand spinning, 1760s	1	1	1	1	8	(16s)	8	0.5	8	
Spinning jenny, 1770s	16	1	16	1	1.6	(16s)	25.6	1.6	25.6	3.2
Water-frame, 1770s	48	1	48	1.5	1.6	(24s)	76.8	3.2	51.2	6.4
Hand mule, 1770s	48	1	48	1.5	1.25	(40s)	60	1.5	40	5
Spinning jenny, 1790s	93	1	93	1.5	1.2	(16s)	111.6	7	74.4	9.3
Water-frame, 1790s	69	1	69	1.5	2	(24s)	138	5.8	92	11.5
Hand mule, 1790s	169	1	169	1.5	1.25	(40s)	211.25	5.3	140.8	17.6
Throstle, early 1830s	142	0.67	213	0.84	4.5	(24s)	639	26.6	760.7	95.1
Power-assisted mule, early 1830s	298	0.5	596	1.08	3	(40s)	894	22.4	827.8	103.5

Source: Maw et al. (2022).

The High Wages argument

The high wages argument

Allen (2009)

- Institutions and culture (and literacy) played a role.
- Another crucial factor: relative factor prices in Britain?
 - Wages higher in Britain than elsewhere.
 - Energy prices lower in Britain than elsewhere

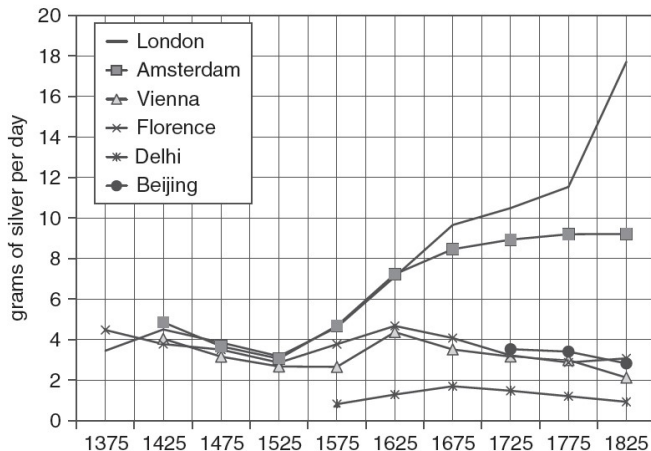
⇒ Incentives to produce labor-saving innovations, e.g., spinning jenny.

“The Industrial Revolution, in short, was invented in Britain in the XVIIIth century because it paid to invent it there, while it would not have been profitable to invent in other times and places.”

Allen (2009)

The high wages argument

Laborers' wages around the world, grams of silver per day



Source: Allen (2009).

The high wages argument

- Why would high cost of labor induce labor-saving innovations?

The high wages argument

- Why would high cost of labor induce labor-saving innovations?
- Innovation can be directed to factors of production that are expensive. [Acemoglu \(2002\)](#)
 - Depends on innovation possibilities frontier.
 - Cost and technical difficulty of innovation matters for direction of technical progress.
 - Skills availability matter.
 - Demand as well: affects profitability.

The high wages argument

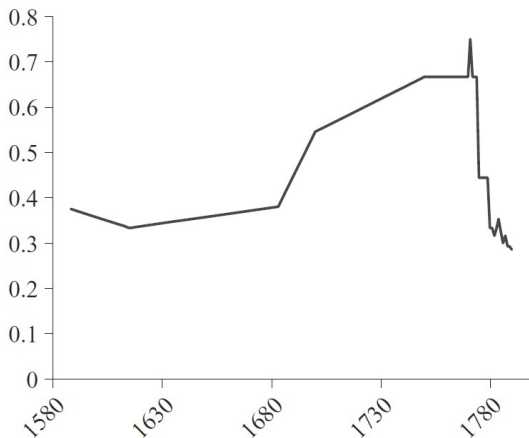
- Was Britain a high wage economy before industrialization?
- Allen highlights innovations in spinning, leading sector in IR:

“[I]t would not have paid to use spinning machines before the eighteenth century: hence, they were not invented earlier. The analysis of profitability turns on the history of women’s wages relative to the cost of spinning machinery’.” Allen (2009)

- Spinners’ high wages prompted innovations in textile industry.

The high wages argument

Earnings of a spinner relative to a building laborer



Source: Allen (2015).

The high wages argument

- Humphries and Scheinder (2018) “Spinning the Industrial Revolution” re-examine this thesis.
 - Essential labor input: hand spinners.
 - Necessary for Allen’s argument: costs of hand spinning rose late 17th–early 18th.
 - Measurement issues:
 - Mostly women and children: seldom appear in statistics.
 - Fragmented sources.
 - Nature of remuneration: piece rates.
- ⇒ Earnings estimates require productivity estimates.

The high wages argument

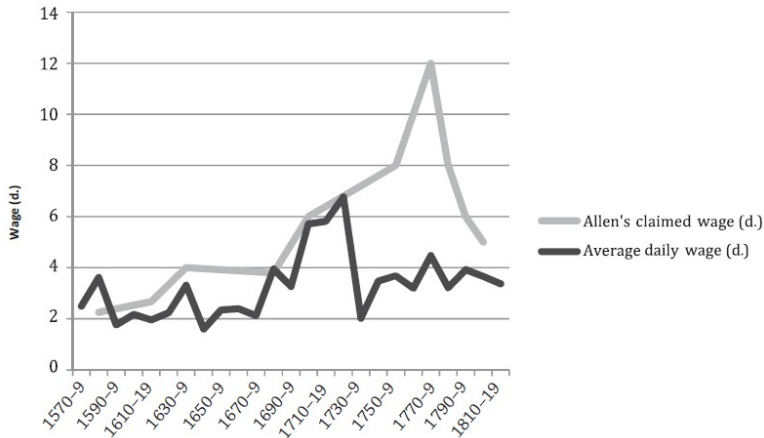
- [Humphries and Scheinder \(2018\)](#) criticize Allen's sources.
 - Allen's productivity estimates rely on one source. [Muldrew \(2012\)](#)
 - [Muldrew \(2012\)](#) based on biased observers (social commentators) and overestimate wages.

The high wages argument

- [Humphries and Scheinder \(2018\)](#) criticize Allen's sources.
 - Allen's productivity estimates rely on one source. [Muldrew \(2012\)](#)
 - [Muldrew \(2012\)](#) based on biased observers (social commentators) and overestimate wages.
 - [Humphries and Scheinder \(2018\)](#) improve measurement.
 - New data sources: records of putting-out networks, records of poor laws, spinning schools, farms accounts, diaries.
 - Suggests spinners did not have high or strongly growing wages.
 - Exception: 1720s, but too early to explain innovations of 1760s.
- ⇒ "The motivation for mechanization must be sought elsewhere"

The high wages argument

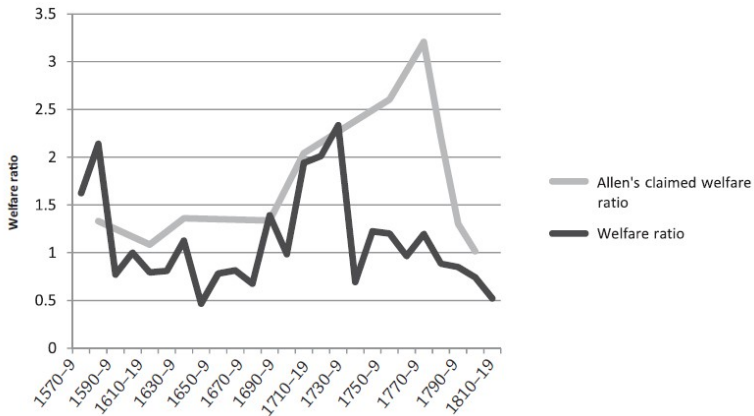
Nominal daily wages, decadal averages



Source: Humphries and Schneider (2018).

The high wages argument

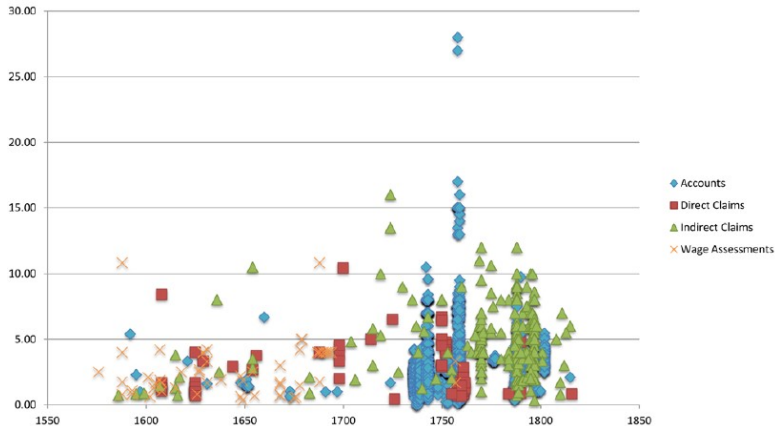
Welfare ratios, decadal averages



Source: Humphries and Schneider (2018).

The high wages argument

Daily wages by source type, nominal daily



Source: Humphries and Schneider (2018).

The high wages argument

- Allen (2019) “Spinning their wheels” re-examine the criticism.

The high wages argument

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- Criticism of Humphries-Schneider data:
 - Selection of spinning schools and poor laws data: individuals selected because of low productivity.
⇒ Bias toward low productivity and low wages of spinners.

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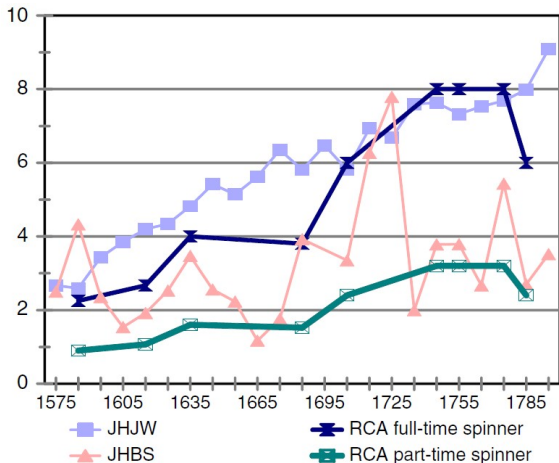
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⇒ This source might provide unreliable information.
- Allen’s data comparable to other series produced with wider coverage, showing wage growth.

⇒ “The data presented by Humphries and Schneider fail to sustain their critique of the ‘high wage’ explanation of the industrial revolution.”

The high wages argument

Spinners' earnings (pence per day)



Source: JHJW: Humphries and Weidsorf (2019); JHBS: Humphries and Schneider (2018); RCA: Allen (2015).

The high wages argument

- Humphries and Schneider (2020) “Losing the thread” respond to the rebuttal to the criticism of the original thesis.

The high wages argument

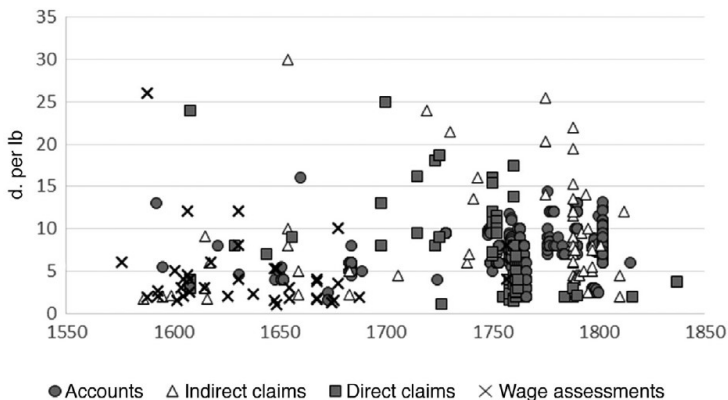
- [Humphries and Schneider \(2020\)](#) “Losing the thread” respond to the rebuttal to the criticism of the original thesis.
- Criticism of wage data used by Allen (low quality, small sample).
- Add 16 data sources, 1,700 observations less subject to biases. Find same results.

⇒ “Allen, rather than us, is spinning his wheels.”

⇒ “Allen has lost the thread of empirical evidence that connects economic historians to the subjects of their study.”

The high wages argument

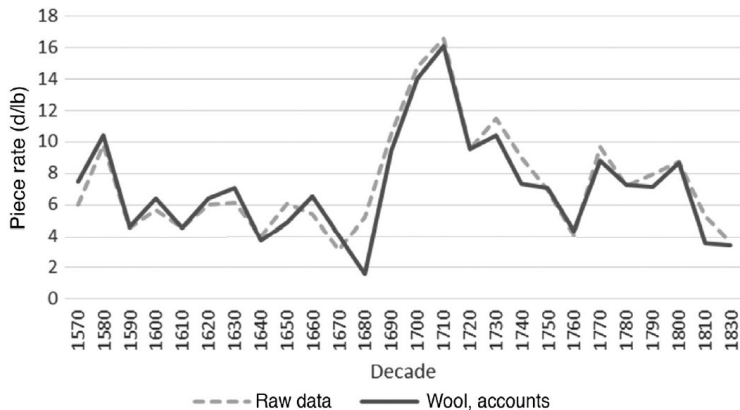
Piece rates by source type, nominal daily



Source: Humphries and Schneider (2020).

The high wages argument

Nominal piece rates from regression analysis



Source: Humphries and Schneider (2020).

The high wages argument

- Conversely, wages outside of Britain were perhaps not as low as claimed by Allen.
- Many evidence that wages relative to energy in France were high.
- E.g., Strasbourg wages. [Geloso \(2019\)](#)
 - Allen: London wages >> Paris wages 1650–1786.
 - Allen: gap with rest of France even bigger.
 - Geloso: rest of France was not much poorer.
 - Geloso: wages in France were not that low.

The high wages argument

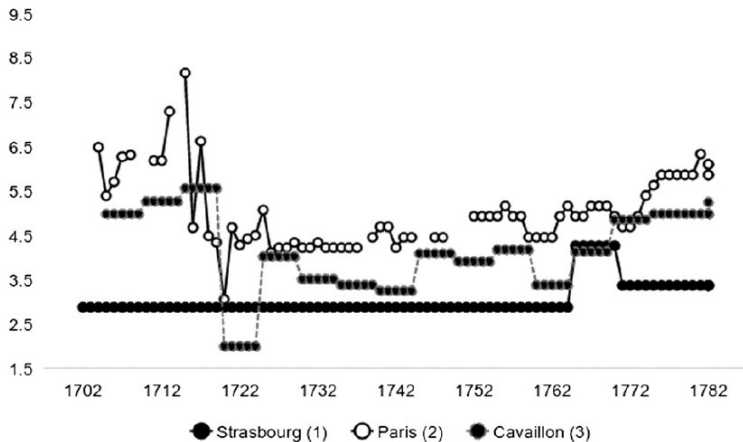
Real wages of Paris workers as a share of real wages of London workers

	UNADJUSTED FIGURES (1)	STEPHENSON ADJUSTMENT (2)
1650–1675	70.88%	88.60%
1675–1700	59.03%	73.78%
1700–1725	56.87%	71.08%
1725–1750	44.81%	56.01%
1750–1775	49.78%	62.22%
1775–1786	57.16%	71.45%

Source: Geloso (2019) based on Allen (2001) and Stephenson (2015).

The high wages argument

Wages in Paris, Strasbourg and Cavailon (grams of silver) 1702–1786



Source: Geloso (2019).

The high wages argument

Wages in Alsace for workers per day by season (grams of silver)

SEASON	OUVRIER	MOISONNEUR	FAUCHEUR	JOURNALIER	JOURNALIER	BATTEUR EN GRANGE	JOURNALIER	ALLEN'S DATA
	SUMMER	SUMMER	SUMMER	SUMMER	WINTER	WINTER	ANNUAL	SUMMER
1476-1500	4.95	4.89	4.64	3.96	3.51	2.89 ^a	3.74	3.96
1501-1525	4.50	3.60	5.22	3.74	2.52 ^a	2.55 ^a	3.13	3.67
1526-1550	4.05	5.08	4.95	5.09	3.24	3.33	4.17	3.82
1551-1575	5.63	4.46	3.82 ^a	4.59	2.61 ^a	2.39	3.60	3.47
1576-1600	5.54	4.29	3.67 ^a	3.87	2.51 ^a	2.54 ^a	3.19	3.40
1601-1625	6.17	4.19	3.85 ^a	4.37	2.63 ^a	2.48	3.50	4.49
1626-1650	9.32	8.15	6.98	8.46	4.77	4.82	6.62	4.78
1651-1675	8.78	6.30	5.63	5.31	3.51	3.65	4.41	-
1676-1700	6.06 ^a	5.27	4.54 ^a	5.27	3.10 ^a	3.29	4.19	-
1701-1725	6.91 ^a	5.99	5.17 ^a	6.27 ^a	3.53 ^a	3.60	4.90	2.88
1726-1750	4.50	4.83	3.6	5.01 ^a	3.06	3.51	4.03	2.88
1751-1775	4.50	5.09	4.36 ^a	4.50	3.60	3.51	4.05	3.31

^aInterpolated years.

Source: Geloso (2019).

The Energy Revolution

The Energy Revolution

- Before the Industrial Revolution, an ecological constraint:
 - Land was in fixed supply, no labor-saving technology.
⇒ Strong diminishing returns to labor.

The Energy Revolution

- Before the Industrial Revolution, an ecological constraint:
 - Land was in fixed supply, no labor-saving technology.
⇒ Strong diminishing returns to labor.
 - Production was extremely land intensive:
 - Food for humans and animals.
 - Heat: firewood.
 - Mechanical energy: animal power.
- ⇒ Increase production would require extra land.

The Energy Revolution

- The advent of steam engines powered by coal was a Revolution.
 - Relaxed the ecology constraint.
 - “Coal provided ‘ghost acres’ on a huge scale.” [Wrigley \(2010\)](#)
 - Enabled a shift from organic to energy-powered economy.
- ⇒ 30-fold ↑ in energy consumption during IR.

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 - Enabled a shift from organic to energy-powered economy.
- ⇒ 30-fold ↑ in energy consumption during IR.
- Coal became the main source of energy in Britain:
 - 1700: half of energy from coal.
 - 1850: 90% of energy from coal.

The Energy Revolution

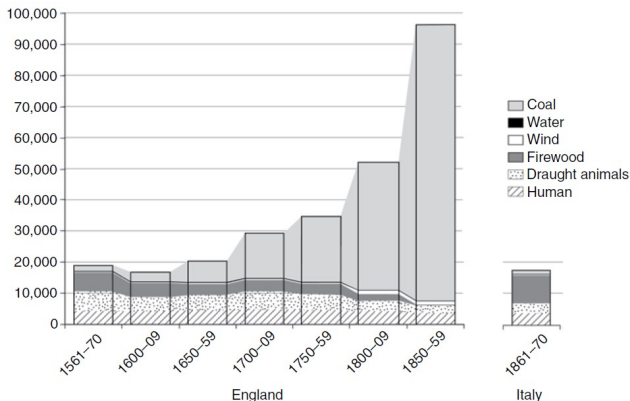
Coal production and energy consumption in England, Wales, and Scotland

	(1)	(2)	(3)	(4)	(5)
	1560s	1700-9	1750-9	1800-9	1850-9
Coal production ('000 tons)					
England	177	2,200	4,295	11,195	51,650
Wales	20	140	220	1,850	13,400
Scotland	30	300	715	2,000	9,000
Total	227	2,640	5,230	15,045	74,050
Energy consumption, England and Wales (petajoules)					
Draught					
animals	21.1	32.8	33.6	34.3	50.1
Population	14.9	27.3	29.7	41.8	67.8
Firewood	21.5	22.5	22.6	18.5	2.2
Wind	0.2	1.4	2.8	12.7	24.4
Water	0.6	1.0	1.3	1.1	1.7
Coal	6.9	84.0	140.8	408.7	1,689.1
Total	65.1	168.9	230.9	517.1	1,835.3
Total less coal	58.2	84.9	90.1	108.4	146.2

Source: Wrigley (2010).

The Energy Revolution

Annual energy consumption per head (megajoules) in England, Wales, and Italy



Source: Wrigley (2010).

The Energy Revolution

- Thomas Newcomen steam engine in 1712:
 - Primary usage: mine draining.
 - Based on scientific discoveries in 17th century.
 - Decade of experimentation and considerable expenses.
- Incentives for innovation:
 - High demand for energy due to London population growth (driven by international trade).
 - High price of wood vs coal.
 - Coal free where steam engine used.

The Energy Revolution

- Positive feedback loop between:
 - Population growth
 - Coal production
 - Steam engine innovation to improve efficiency
- ⇒ Innovations + coal availability kept energy prices low.

The Energy Revolution

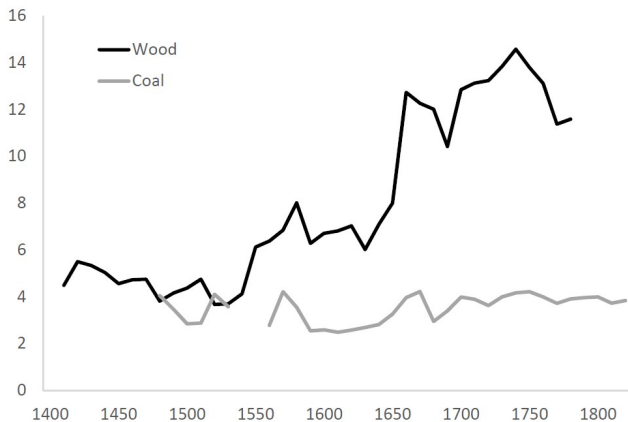
Urban population estimates for England and London

Population ('000s)						
	<i>c.1520</i>	<i>c.1600</i>	<i>c.1670</i>	<i>c.1700</i>	<i>c.1750</i>	<i>c.1800</i>
England	2,400	4,150	5,150	5,200	5,900	8,600
London	55	200	475	575	675	960
Other urban populations (5,000 or more inhabitants)	70	135	205	275	540	1,420
Total urban	125	335	680	850	1,215	2,380
Ten historic regional centres ^a	62	73		107	126	153
Urban populations as percentages of the national total						
London	2.25	4.75	9.25	11.00	11.50	11.25
Other urban	3.00	3.25	4.00	5.25	9.25	16.50
Total urban	5.25	8.00	13.25	16.25	20.75	27.75

Source: Wrigley (2010).

The Energy Revolution

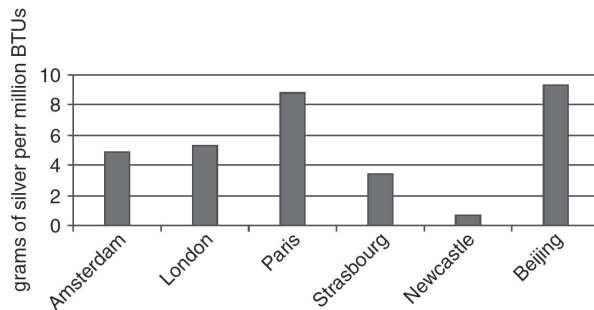
Real prices of wood and coal in London



Source: Steinsson (2020) based on Wrigley (2010).

The Energy Revolution

Prices of energy in the early 1700s



Source: Allen (2009).

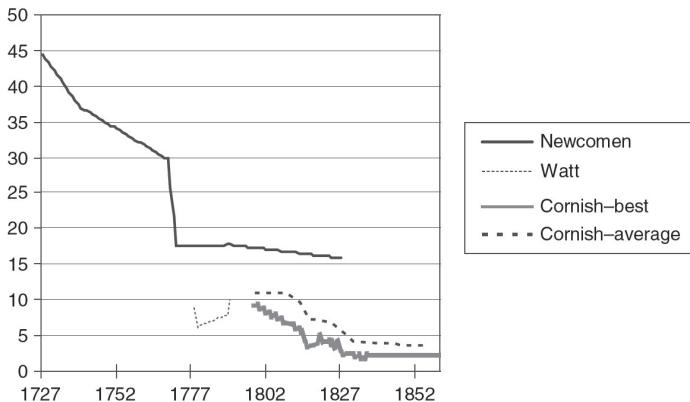
The Energy Revolution

- Steam engine innovations could be applied to other purposes (e.g., metallurgy).
- Switch from wood to coal induced tremendous innovation in building industry.
- Further incentives to improve steam engine (e.g., rotary engine for smooth motion).

⇒ Initiated general mechanization of British industry

The Energy Revolution

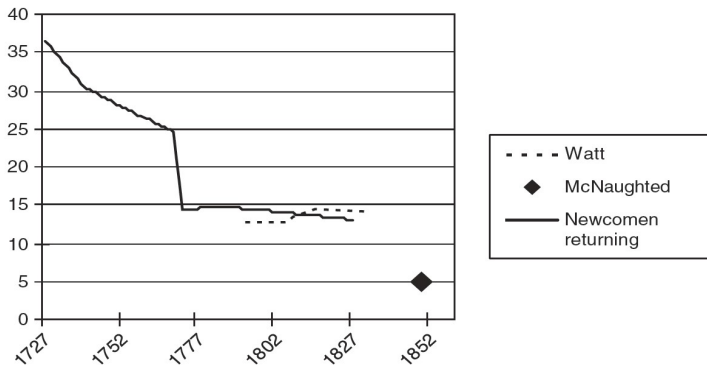
Coal consumption in pumping engines (pound of coal per horsepower-hour)



Source: Allen (2009).

The Energy Revolution

Coal consumption in rotary engines (pound of coal per horsepower-hour)



Source: Allen (2009).

The Energy Revolution

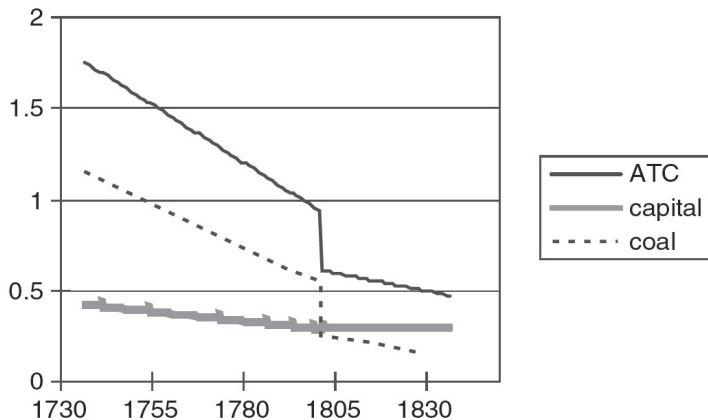
Stationary power sources in Great Britain

	1760	1800	1830	1870	1907
Steam	5,000	35,000	160,000	2,060,000	9,659,000
Water	70,000	120,000	160,000	230,000	178,000
Wind	10,000	15,000	20,000	10,000	5,000
Total	85,000	170,000	340,000	2,300,000	9,842,000

Source: Allen (2009).

The Energy Revolution

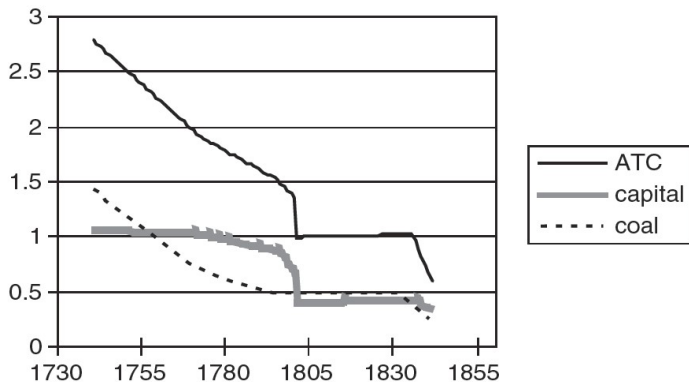
Pumping engine: cost per horsepower-hour



Source: Allen (2009).

The Energy Revolution

Rotary engine: cost per horsepower-hour



Source: Allen (2009).

The Energy Revolution

Capacity of stationary steam engines

	1760	1800	1840	1870
Britain	5	35	200	2,060
France		3	33	336
Prussia			7	391
Belgium			25	176
United States		0	40	1,491

Source: Allen (2009).

Conclusion

- Why did the Industrial Revolution occurred in Britain?
- Many potential answers, still uncertainties.
 - Institutions.
 - A culture of growth and literacy.
 - Availability of skills.
 - Directed technical change: high wages and cheap coal?
- Probably combination of all explanations.

Topic 6

Industrialization, urbanization, pollution, and health

Plan

- Urbanization and Mortality in Britain, 1800–1850 [Davenport \(2020\)](#)
- Pollution, mortality, and the Industrial Revolution in Britain, 1851–1861 [Beach and Hanlon \(2018\)](#)
- Temperature, disease, and death in London, 1866–1965. [Hanlon et al. \(2021\)](#)
- Pollution, city growth, and the Industrial Revolution in Britain, 1851–1911 [Hanlon \(2020\)](#)
- Cholera as sanity test of British cities, 1831–1866 [Davenport \(2021\)](#)
- Industrialization and health: paleopathological evidence [Soria \(2022\)](#)
- Dust Bowl migrants: environmental refugees and economic adaptation [Hornbeck \(2021\)](#)

Urbanization and Mortality in Britain, 1800–1850

Urbanization and Mortality in Britain

- Urban mortality penalty = common feature of Industrial Revolution in 19th century.
 - Urbanization and infectious diseases (unclean water + improper sewage disposal). [Kesztenbaum Rosenthal \(2011\)](#) [Alsan and Goldin \(2019\)](#)
 - Poor nutrition. [Fogel \(2004\)](#).
 - Air pollution. [Beach and Hanlon \(2018\)](#)

Urbanization and Mortality in Britain

Davenport (2020)

- Description of long-run historical relationship between urbanization and mortality.
- Focus on period 1830–1850.
- Increased mortality in rural and urban populations until 1870s.

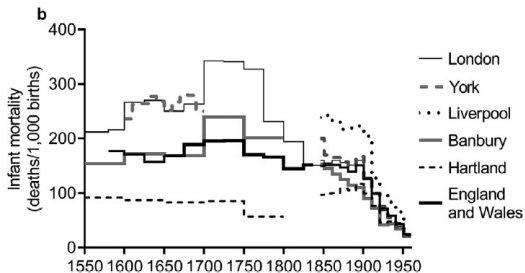
Urbanization and Mortality in Britain



Percentage of the population of England and Wales living in settlements of population 2,500 or more and life expectancy at birth

Source: Davenport (2020).

Urbanization and Mortality in Britain



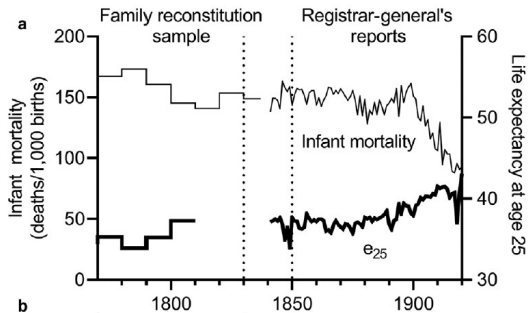
Infant mortality (deaths in the first year of life per 1,000 births)

Source: Davenport (2020).

Urbanization and Mortality in Britain

- England transformed from very lightly urbanized to world's first truly urban nation.
- By 1851 over half the population lived in settlements of 2,500 or more, peaking at around 80 per cent by the 1890s.
- No consistent relationship between urbanization and life expectancy in the aggregate.

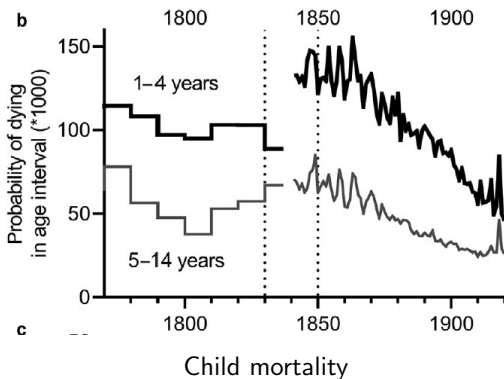
Urbanization and Mortality in Britain



Infant mortality and life expectancy at age 25

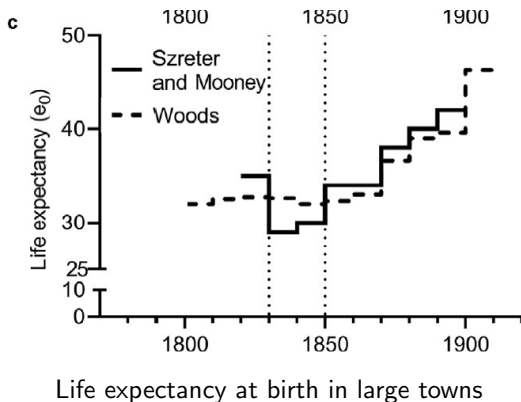
Source: Davenport (2020).

Urbanization and Mortality in Britain



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Urbanization and Mortality in Britain

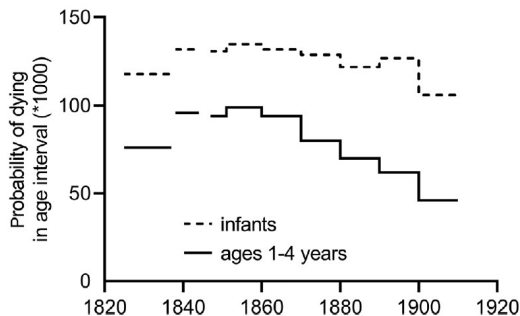


Source: Davenport (2020).

Urbanization and Mortality in Britain

- Focus on 1830–1850
- Three sources of data:
 - Parish family reconstitution data from Wrigley et al.
 - Mortality data from the Registrar General.
 - Decadal mortality rates after 1850.

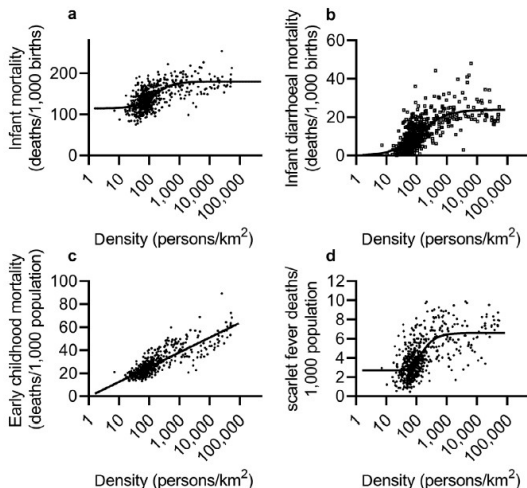
Urbanization and Mortality in Britain



Infant and early childhood mortality in reconstitution sample parishes and associated registration districts (unweighted means), 1825–1910

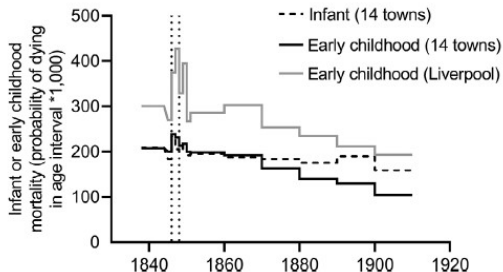
Source: Davenport (2020).

Urbanization and Mortality in Britain



Mortality in registration districts by population density, England and Wales, 1861–70

Urbanization and Mortality in Britain

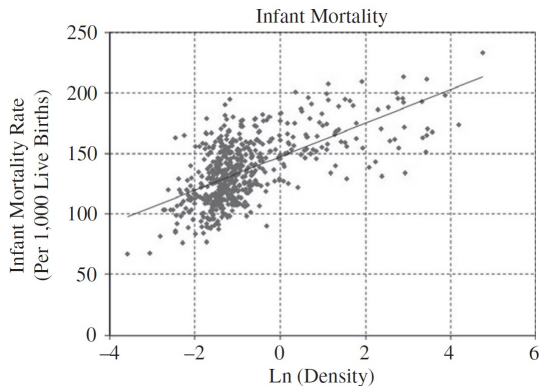


Infant and early childhood mortality in core registration districts of 14 large towns (unweighted means), and early childhood mortality in Liverpool, 1838–1910

Source: Davenport (2020).

Pollution, mortality, and the Industrial Revolution in Britain, 1851–1861

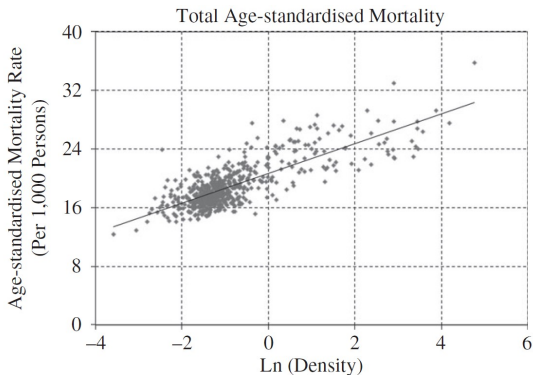
Pollution, Mortality, and the Industrial Revolution



Urban mortality penalty across districts in England and Wales in 1851–1860

Source: Beach and Hanlon (2018).

Pollution, Mortality, and the Industrial Revolution



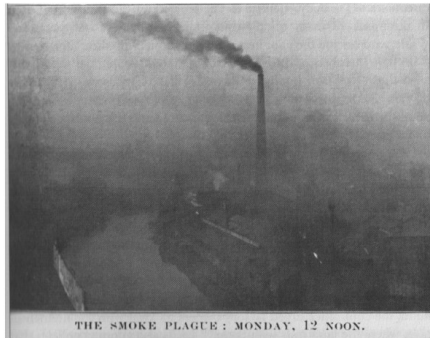
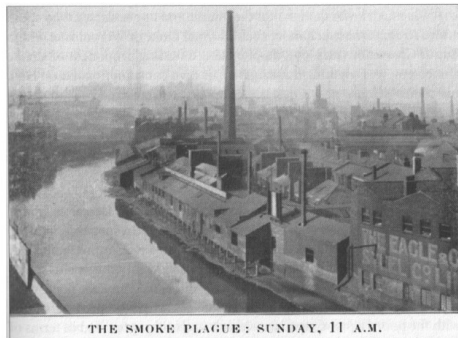
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 - Poor nutrition. [Fogel \(2004\)](#).
 - **Air pollution.** [Beach and Hanlon \(2018\)](#)

Pollution, Mortality, and the Industrial Revolution



Sheffield in 1920

Source: Hanlon (2020) from Richmond (1921).

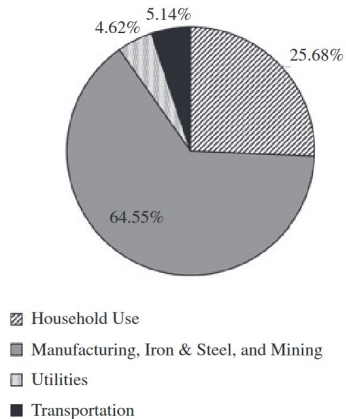
Pollution, Mortality, and the Industrial Revolution

Coal production and energy consumption in England, Wales, and Scotland

	(1)	(2)	(3)	(4)	(5)
	<i>1560s</i>	<i>1700-9</i>	<i>1750-9</i>	<i>1800-9</i>	<i>1850-9</i>
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Total less coal	58.2	84.9	90.1	108.4	146.2

Source: Wrigley (2010).

Pollution, Mortality, and the Industrial Revolution



Coal usage shares for the UK in 1855

Source: Hanlon (2018).

Pollution, Mortality, and the Industrial Revolution

- By mid-19th century, coal = main source of power.
- Pollution from burning coal exacerbated:
 - Coal burnt inefficiently \implies incomplete combustion \implies \uparrow pollution.
 - Coal burnt on-site at factories, located in urban areas.

Pollution, Mortality, and the Industrial Revolution

- By mid-19th century, coal = main source of power.
- Pollution from burning coal exacerbated:
 - Coal burnt inefficiently \implies incomplete combustion \implies \uparrow pollution.
 - Coal burnt on-site at factories, located in urban areas.
- Serious health implications of coal pollution (respiratory and cardiovascular diseases).
- Yet, little regulation (*laissez faire* ideology).

Pollution, Mortality, and the Industrial Revolution

- Mortality consequences of pollution at district level 1851–1861?
[Beach and Hanlon \(2018\)](#)

Pollution, Mortality, and the Industrial Revolution

- Mortality consequences of pollution at district level 1851–1861?
[Beach and Hanlon \(2018\)](#)
- Mortality data:
 - From report of the Registrar General (births, marriages, deaths).
 - Decade average 1851–1861 age and cause of death by district (581).
 - Primary outcome variable: infant mortality (deaths per 1,000 births).
 - Other outcomes: deaths across age categories net of accidents.
 - Control for population sorting of less healthy population:
 - NPR mortality: child not pollution related mortality.
 - Infant deaths from cholera, digestive disorders, smallpox, typhus.

Pollution, Mortality, and the Industrial Revolution

- Main challenge: no reliable pollution data.

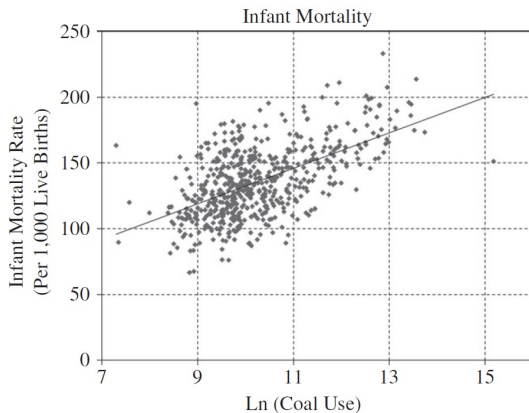
Pollution, Mortality, and the Industrial Revolution

- Main challenge: no reliable pollution data.
- Indirectly capture through local industrial coal use:
 - District-level employment by industry (26) in 1851.
 - Coal use per worker from Census of Manufacturers 1907.
 - Coal use intensity at district d level in year t :

$$\text{COAL}_{dt} = \rho_t \sum_i \theta_i L_{idt}$$

- L_{idt} : local employment industry i district t .
 - θ_i : coal use intensity in industry i .
 - ρ_t : efficiency gains in coal use (absorbed, one period).
- Assume stable relative coal intensity per worker across industries.

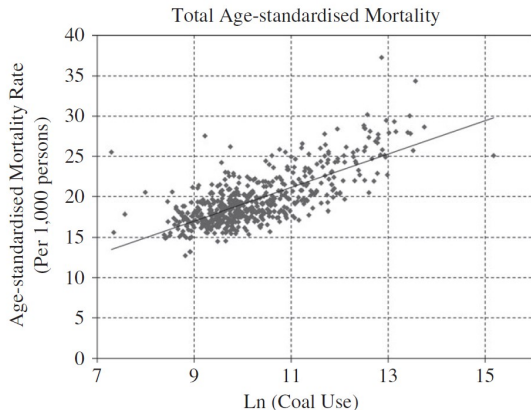
Pollution, Mortality, and the Industrial Revolution



Coal use and mortality in England and Wales in 1851–1860

Source: Beach and Hanlon (2018).

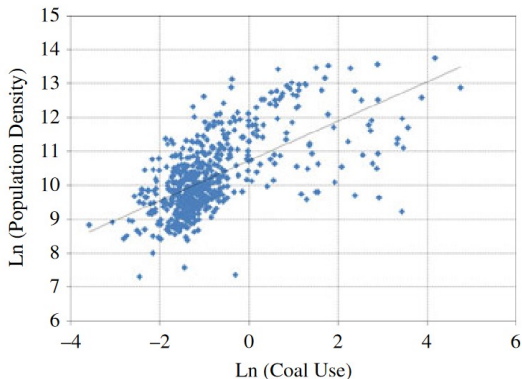
Pollution, Mortality, and the Industrial Revolution



Coal use and mortality in England and Wales in 1851–1860

Source: Beach and Hanlon (2018).

Pollution, Mortality, and the Industrial Revolution



Coal use and population density in England and Wales in 1851–1860

Source: Beach and Hanlon (2018).

Pollution, Mortality, and the Industrial Revolution

Coal Use per Worker



Population Density



Infant Mortality



Industrial coal use, population density, and mortality

Source: Beach and Hanlon (2018).

- Baseline specification

$$\text{IMR}_d = \alpha_0 + \alpha_1 \log(\text{DENSITY}_d) + \alpha_2 \log(\text{COAL}_d) + X_d \nabla + \varepsilon_d$$

- IMR_d : deaths children < 1 in district d / births (in 1,000s) 1851–60.
- DENSITY_d : population density in d in 1851.
- COAL_d : local industrial coal use in d .
- X_d : control variables (altitude, hilliness, FLFP, agricultural suitability, seaport indicator and tonnage).

Pollution, Mortality, and the Industrial Revolution

	DV: Infant mortality rate				
	(1)	(2)	(3)	(4)	(5)
Ln(Coal use)	15.09*** (1.358)			13.68*** (2.462)	10.92*** (2.328)
Ln(Population density)		16.55*** (1.440)	7.797*** (1.531)	5.255*** (1.432)	-1.351 (1.521)
Ln(District population)			8.503*** (1.421)	-2.465 (2.612)	-1.924 (2.393)
Child NPR mortality					1.500*** (0.170)
Other controls			Yes	Yes	Yes
Observations	581	581	581	581	581
R ²	0.324	0.390	0.498	0.530	0.621

Coal use, infant mortality, and the urban mortality penalty

Source: Beach and Hanlon (2018).

Pollution, Mortality, and the Industrial Revolution

- Interpretation (col. 4):
 - As population included, coal use interpreted as changes in intensity of district industrial coal use per person.
 - Strong correlation between local coal use and infant mortality.
 - Coal use explains 1/3 of urban mortality penalty.

Pollution, Mortality, and the Industrial Revolution

- Interpretation (col. 4):
 - As population included, coal use interpreted as changes in intensity of district industrial coal use per person.
 - Strong correlation between local coal use and infant mortality.
 - Coal use explains 1/3 of urban mortality penalty.
- Two concerns with col. 4:
 - OVB correlated with local coal use and infant mortality \implies robust to additional controls.
 - Sorting of less healthy population into more polluted areas \implies control for NPR mortality in col. 5.

Pollution, Mortality, and the Industrial Revolution

- Other patterns:
 - In cols. 2–3: population density correlated with infant mortality = urban mortality penalty.
 - Penalty remains after controlling for coal use (col. 4).
 - No penalty when controlling for NPR mortality (col. 5).

⇒ Coal use and NPR both explain infant urban mortality penalty.

Pollution, Mortality, and the Industrial Revolution

- Improve identification by exploiting wind patterns:
 - In Britain, wind from south and west toward north and east.
 - Upwind and downwind coal use for each district within 25 km.
 - Upwind vs downwind unlikely to affect health besides pollution.
 - Key statistics: difference between upwind and downwind coal effects (proximity to high coal affects other outcomes).
- Placebo tests: no differential relationship between coal use in upwind and downwind districts and other district characteristics

Pollution, Mortality, and the Industrial Revolution

	DV: Infant mortality rate				
	(1)	(2)	(3)	(4)	(5)
Ln(Coal use)	8.727*** (1.752)	8.441*** (1.867)	10.06*** (2.855)	13.63*** (2.722)	10.74*** (2.674)
Ln(Upwind coal)	1.694 (1.228)	2.849* (1.549)	2.638* (1.426)	1.424 (1.149)	1.907* (1.137)
Ln(Downwind coal)	-1.285 (1.070)	0.00599 (1.489)	-0.227 (1.362)	-1.420 (1.211)	-1.012 (1.173)
Ln(Population density)	9.983*** (1.486)	10.68*** (1.492)	10.85*** (1.608)	4.950*** (1.615)	-1.509 (1.546)
Ln(Nearby population)		Yes	Yes	Yes	Yes
Ln(District population)			Yes	Yes	Yes
Other controls				Yes	Yes
Child NPR mortality					Yes
Observations	422	422	422	422	422
R ²	0.463	0.467	0.467	0.566	0.664
Difference between downwind and upwind coefficients					
Coefficient difference	2.979	2.843	2.865	2.844	2.919
p-value	0.0602	0.0640	0.0614	0.0538	0.0426

Effect of coal use in upwind and downwind districts

Source: Beach and Hanlon (2018).

Pollution, Mortality, and the Industrial Revolution

	DV: Infant mortality rate		
	(1)	(2)	(3)
Ln(Coal use)	11.80*** (1.364)	12.45*** (2.480)	9.462*** (2.275)
Ln(Coal use) × hilliness	3.535*** (1.091)	3.783*** (0.961)	4.239*** (0.845)
Ln(Population density)	6.739*** (1.576)	5.618*** (1.434)	-1.129 (1.454)
Ln(District population)		-1.842 (2.543)	-1.210 (2.262)
Mean altitude	1.149 (1.730)	-0.737 (1.744)	0.768 (1.672)
Hilliness	-9.334*** (1.761)	-9.496*** (1.888)	-7.834*** (1.961)
Other controls		Yes	Yes
Child NPR mortality control			Yes
Observations	581	581	581
R ²	0.527	0.549	0.645

Effect of coal use interacted with hilly topography

Source: Beach and Hanlon (2018).

Pollution, Mortality, and the Industrial Revolution

- Use wind patterns to recover within-district effects of pollution.
 - Need estimate of how concentration of coal-based pollution diminishes with distance.
 - Use pollution dispersion modelling for $50\text{m} \times 50\text{m}$ cells across $20\text{km} \times 20\text{km}$ grid with smokestack at center.
 - Average concentration in district = 4 times downwind and 1.5 times in upwind.
- \uparrow log-point industrial coal use $\implies \uparrow$ 7–10 deaths per 1,000 live births.
- Little upward bias in baseline results.

Pollution, Mortality, and the Industrial Revolution

DV: Mortality rate in each age category (per 1,000 persons)									
Under 5	5-9	10-14	15-19	20-24	25-34	35-44	45-54	55-64	65 up
Coefficient on coal use in upwind districts									
0.681 (0.416)	0.102* (0.0547)	-0.0002 (0.0433)	0.0804 (0.0643)	0.168 (0.103)	0.0806 (0.0828)	-0.224** (0.112)	-0.173 (0.128)	-0.136 (0.170)	-0.161 (0.360)
Coefficient on coal use in downwind districts									
-0.756 (0.477)	-0.0188 (0.0595)	-0.0504 (0.0411)	-0.0782 (0.0741)	-0.0943 (0.0864)	-0.139* (0.0761)	-0.248* (0.128)	-0.200 (0.141)	-0.348** (0.173)	-0.403 (0.314)
Difference between upwind and downwind coefficients									
1.437	0.1208	0.0502	0.1586	0.2623	0.2196	0.024	0.027	0.212	0.242
F-test for significance of difference between upwind and downwind effects (F-stat & p-value)									
6.14 0.0136	2.71 0.1004	0.88 0.3495	4.8 0.029	5.62 0.0183	8.41 0.0039	0.05 0.8176	0.05 0.8284	1.28 0.2588	0.53 0.4652

Upwind vs downwind coal use effects by age group

Source: Beach and Hanlon (2018).

Temperature, disease, and death in London, 1866–1965

Temperature, Disease, and Death in London

- London had very high mortality rates in mid-19th century:
 - Mortality concentrated on infants and young children.
 - In 1860–1899: 158% died before age one.
 - In 1900–1910: 132% died before age one.
 - In 1920–1930: 66% died before age one.
- Causes of deaths:
 - In the 1870s, among all ages, most deaths due to infectious diseases: tuberculosis (14%), bronchitis (13%).
 - In the 1870s, among infants, most important category: digestive diseases (13%).

Temperature, Disease, and Death in London

- No consensus on reasons for decline in mortality after 1900.
 - Concentrated among infants, driven by reduction of digestive diseases.
 - Water filtration and sewer access occurred decades before.
 - Other factors that might have played a role:
 - Improvements in milk quality.
 - Better nutrition.
 - Improved maternal care.
 - Better housing.
- Explore the role of weather in contributing to mortality patterns in London.

Temperature, Disease, and Death in London

- Weekly mortality data in London:
 - From the Registrar General.
 - 300,000 mortality observations for 4,540 weeks, 1866–1965 (before air conditioning).
 - Deaths by cause and age group for whole city.
 - Consistent geographic area encompassing all modern Central London.
 - Aggregate death causes in consistent categories.

Temperature, Disease, and Death in London

- Weekly temperature data in London:
 - Data from Radcliffe Observatory in Oxford, 80km outside central London.
 - Single location throughout.
 - Provides weekly average maximum and minimum temperature.
 - Abstract from urban heat-island effects, potentially endogenous to city growth.
 - Complement with precipitation and humidity information.

Temperature, Disease, and Death in London

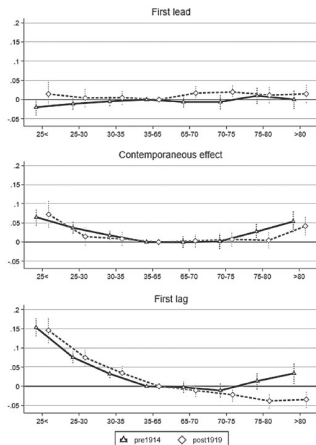
- Estimate relationship between unusually high or low temperature in a week on mortality in that week, and previous and subsequent weeks.
- Lead-lag regression model.
- Classify weeks into temperature bins with 35–65°F (1–18°C) as reference weeks.
 - < 25°F (–4°C).
 - 25–30°F (–4––1°C).
 - 30–35°F (–1–1°C).
 - 35–65°F (1–18°C).
 - 65–70°F (18–21°C).
 - 70–75°F (21–24°C).
 - 75–80°F (24–27°C).
 - >80°F (27°C).

Temperature, Disease, and Death in London

$$\log(y_{wt}) = \sum_{j=-m}^k \sum_{q=1, q \neq 4}^8 \alpha_j^q \text{TEMP}_{wt}^q[w = j] + \delta_w + \delta_t + X_{wt}\beta + \varepsilon_{wt}$$

- $\log(y_{wt})$: log infant deaths in week w of year t .
- TEMP_{wt}^q : set of indicators taking value 1 if weekly temperature is in q th bin, with $q = 4$ the reference bin.
- m leads, k lags.
- δ_w : week-of-the-year FE.
- δ_t : year FE.
- X_{wt} : week-by-year varying controls (precipitation, heavy fog).

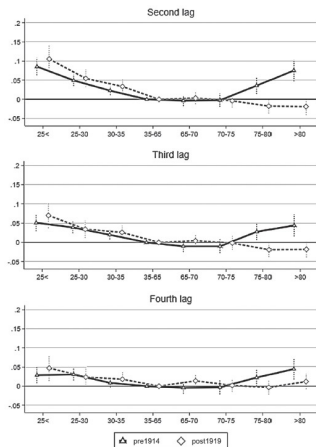
Temperature, Disease, and Death in London



Temperature and total mortality before and after WWI

Source: Hanlon et al. (2021).

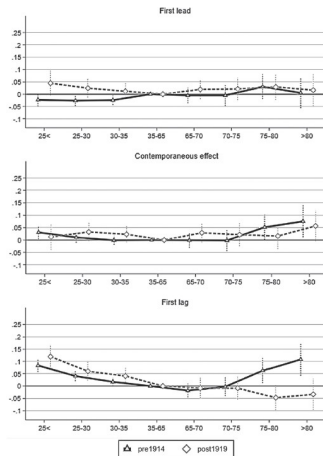
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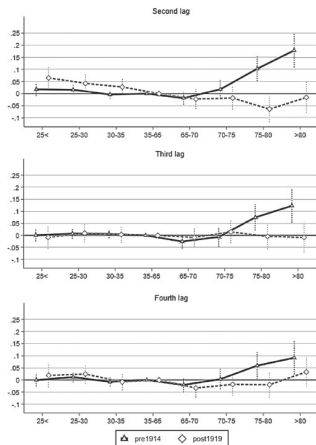
Temperature, Disease, and Death in London



Temperature and infant mortality before and after WWI

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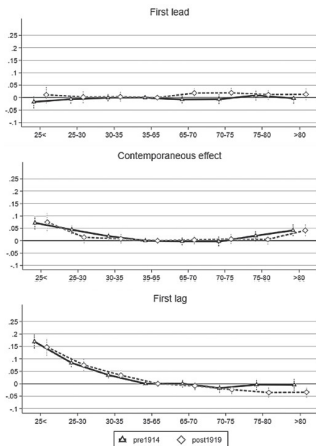
Temperature, Disease, and Death in London



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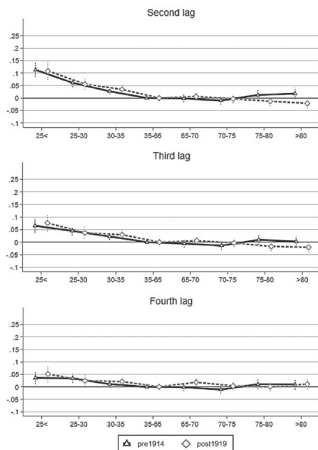
Temperature, Disease, and Death in London



Temperature and non-infant deaths before and after WWI

Source: Hanlon et al. (2021).

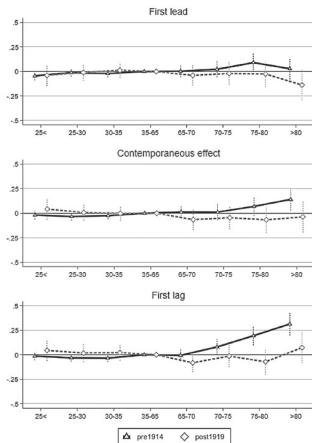
Temperature, Disease, and Death in London



Temperature and non-infant deaths before and after WWI

Source: Hanlon et al. (2021).

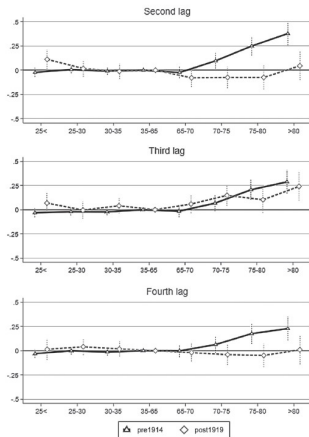
Temperature, Disease, and Death in London



Temperature and digestive mortality before and after WWI

Source: Hanlon et al. (2021).

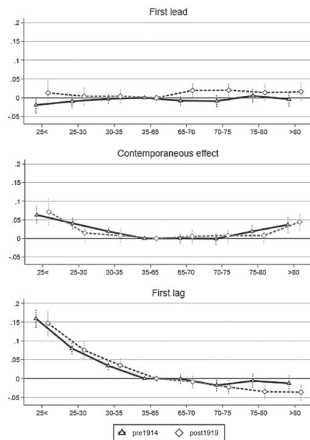
Temperature, Disease, and Death in London



Temperature and digestive mortality before and after WWI

Source: Hanlon et al. (2021).

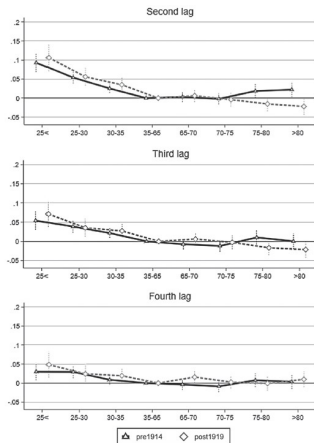
Temperature, Disease, and Death in London



Temperature and non-digestive mortality before and after WWI

Source: Hanlon et al. (2021).

Temperature, Disease, and Death in London



Temperature and non-digestive mortality before and after WWI

Source: Hanlon et al. (2021).

Temperature, Disease, and Death in London

- In late 19th and early 20th, both unusually cold and warm weather associated with elevated mortality.
 - Cold weather increased mortality among elderly, especially from respiratory-related diseases.
 - Warm weather increased mortality among infants and young children, especially from digestive diseases.
- After WWI:
 - Effects of warm weather disappeared.
 - Driven by reduction in infant deaths, especially those due to digestive diseases.
 - Impact of cold weather largely unchanged.

⇒ The disease environment mediates the mortality effects of temperature.

Pollution, city growth, and the Industrial Revolution in Britain, 1851–1911

Pollution, City Growth, and the Industrial Revolution

- How does industrial structure affect city growth?
 - +: job growth attracts population.
 - -: pollution deters population due to ↓ quality of amenities + ↓ productivity.

Pollution, City Growth, and the Industrial Revolution

- How does industrial structure affect city growth?
 - +: job growth attracts population.
 - -: pollution deters population due to ↓ quality of amenities + ↓ productivity.
- Assess impact of pollution on growth of British cities 1851–1911.
[Hanlon \(2020\)](#)

Pollution, City Growth, and the Industrial Revolution

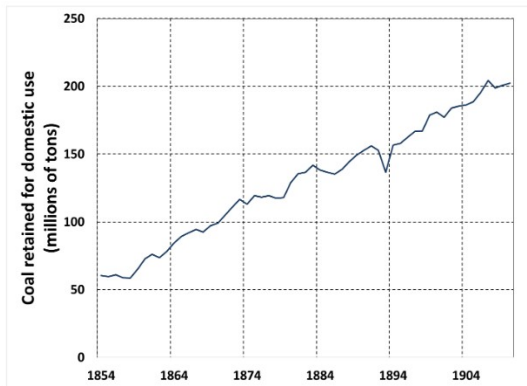
- How does industrial structure affect city growth?
 - +: job growth attracts population.
 - -: pollution deters population due to ↓ quality of amenities + ↓ productivity.
- Assess impact of pollution on growth of British cities 1851–1911.
[Hanlon \(2020\)](#)
 - Challenge 1. Pollution is one of many factors + effects take years: need high variation over multiple decades.
 - Challenge 2. No reliable pollution data: need proxy.
 - Challenge 3. Separate positive from negative effects: need empirical design.

Pollution, City Growth, and the Industrial Revolution

- On pollution context: remember Sheffield 1920.
- On migration context: British population highly mobile.
 - Large flows of population from rural areas, Ireland, Scotland, to English cities.
 - 1851–1881: 1/4 people changed county of residence; 1/2 changed town. [Long and Ferrie \(2003\)](#)
 - Primary driver of migration flows: search for work.

Pollution, City Growth, and the Industrial Revolution

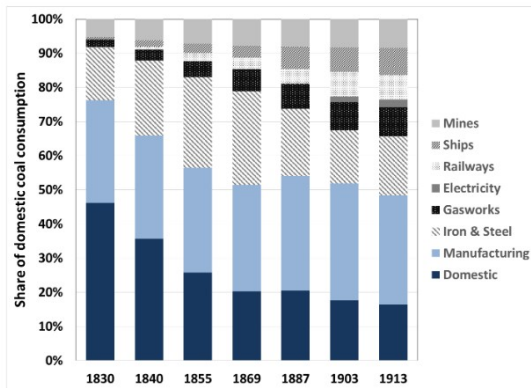
British coal consumption, 1854–1910



Source: Hanlon (2020) based on Mitchell (1988).

Pollution, City Growth, and the Industrial Revolution

British coal consumption by use, 1830–1913



Source: Hanlon (2020) based on Mitchell (1988).

Pollution, City Growth, and the Industrial Revolution

- Local industrial composition:
 - Occupations 1851–1911 for 31 largest cities from Census.
 - Series 1851–1911 for 26 broad industries.

Pollution, City Growth, and the Industrial Revolution

- Local industrial composition:
 - Occupations 1851–1911 for 31 largest cities from Census.
 - Series 1851–1911 for 26 broad industries.
- Coal intensity for each industry:
 - Coal use per worker and industry from Census of Production 1907.
 - Coal use intensity in city c in year t :

$$\text{COAL}_{ct} = \rho_t \sum_i \theta_i L_{ict}$$

- L_{ict} : local employment industry i city t .
- θ_i : coal use intensity in industry i .
- ρ_t : efficiency gains in coal use.

Pollution, City Growth, and the Industrial Revolution

English cities included in the study



Source: Hanlon (2020).

Pollution, City Growth, and the Industrial Revolution

Industry coal use per worker (tons per worker)

Industry	Coal/ worker
Earthenware, bricks, etc.	48.9
Metal and engine manufacturing*	43.7
Chemical and drug manufacturing	40.1
Mining	28.9
Oil, soap, etc. production	20.7
Brewing and beverage production	19.4
Leather, hair goods production	12.1
Food processing	12.0
Textile production	10.1
Paper and publishing	9.7
Shipbuilding	6.1
Wood furniture, etc., production	5.4
Vehicle production	2.6
Instruments, jewelry, etc.	2.0
Apparel	1.6
Tobacco products	1.1

Source: Hanlon (2020).

Pollution, City Growth, and the Industrial Revolution

- Estimating coal use effects city-industry employment growth:

$$\Delta \log(L_{ict}) = b_0 + b_1 \Delta \log(C_{ct}) + b_2 \Delta \log(L_{ct}) + \zeta_{it} + e_{ict}$$

- L_{ct} : overall city employment growth (negative congestion or positive agglomeration effects).
 - C_{ct} : city coal use (negative pollution or productivity effects).
 - ζ_{it} : industry-time fixed effects (absorb industry-specific productivity and demand shocks).
- Use log because linear relationship between pollution and employment in log.

Pollution, City Growth, and the Industrial Revolution

- Identification issue:
 - Changes in overall city employment and change in city coal use endogenously affected by city-industry employment growth.
 - Replace these terms with predicted values based on national-level trends and use deviations from predicted trends.

Pollution, City Growth, and the Industrial Revolution

- Overall city employment:

$$\Delta \log (\text{PrCityEMP}_{ct}) = \log \left(\sum_{j \neq i} L_{jct-\tau} \times \text{GR}_{j-ct,t-\tau} \right) - \log \left(\sum_{j \neq i} L_{jct-\tau} \right)$$

- $\text{GR}_{i-ct,t-\tau}$: growth rate of industry i in all cities other than c , from $t - \tau$ to t .
- $\Delta \log (\text{PrCityEMP}_{ct})$: expected growth in employment in all other local industries, given national industry growth rates and initial industrial composition of the city.
- When studying industry i , it is dropped from the measure.

Pollution, City Growth, and the Industrial Revolution

- City coal use:

$$\begin{aligned} \Delta \log(\text{PredCoal}_{ct}) &= \log \left(\sum_{j \neq i} L_{jct-\tau} \times \text{GR}_{j-ct,t-\tau} \times \theta_j \right) \\ &\quad - \log \left(\sum_{j \neq i} L_{jct-\tau} \times \theta_j \right) \end{aligned}$$

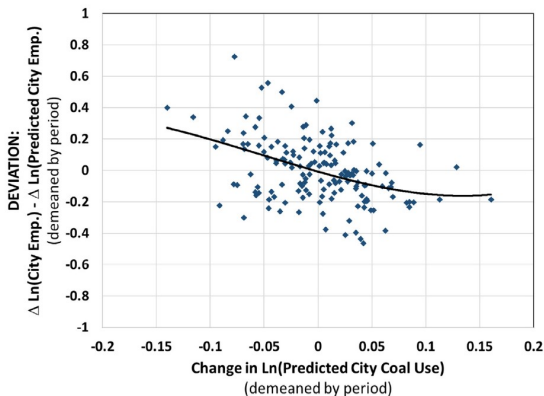
- Difference due only to variation in coal intensity of industries θ_j .

Pollution, City Growth, and the Industrial Revolution

$$\text{DEVIATION} = \Delta \log (\text{CityEMP}_{ct}) - \Delta \log (\text{PrCityEMP}_{ct})$$

- DEVIATION: difference between actual change in city employment and expected change given city's initial industrial structure and industry growth rates in all other cities.
- Captures extent to which employment growth of city performs relative to predictions based on national industry growth rates.

Pollution, City Growth, and the Industrial Revolution



Deviation vs predicted change in city coal use (over 2 decades)

- In cities where expect rising coal use, city employment growth systematically underperforms.

Pollution, City Growth, and the Industrial Revolution

- Estimating coal use effects city-industry employment growth:

$$\Delta \log (L_{ict}) = b_0 + b_1 \Delta \log (\text{PrCoal}_{ct}) + b_2 \Delta \log (\text{PrCityEmp}_{ct}) + \zeta_{it} + e_{ict}$$

- Predicted employment picks up direct effects of employment growth in other industries in city c on employment growth of i due to congestion or agglomeration.
- b_1 captures additional impact generated when this employment growth occurs in more coal-intensive industries.
- b_1 is the impact of a rise in local industrial coal use holding constant overall local employment level.
- b_2 is the impact of increase in local employment holding fixed level of local industrial coal use.

Pollution, City Growth, and the Industrial Revolution

Difference:	DV: $\Delta \ln$ of city industry employment					
	All industries			Manufacturing industries		
	One decade (1)	Two decades (2)	Three decades (3)	One decade (4)	Two decades (5)	Three decades (6)
$\Delta \ln(\text{PredCoal})$	-0.611 (0.621)	-1.987*** (0.732)	-3.016*** (0.803)	-0.444 (0.685)	-2.218*** (0.632)	-3.257*** (0.813)
$\Delta \ln(\text{PrCityEMP})$	-0.536 (0.586)	0.392 (0.757)	1.362* (0.826)	-0.725 (0.528)	0.383 (0.553)	1.172* (0.692)
Ind.-time effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,809	4,012	3,208	2,773	2,312	1,849
R^2	0.259	0.355	0.429	0.246	0.336	0.403

Baseline city industry regression results

Source: Hanlon (2020).

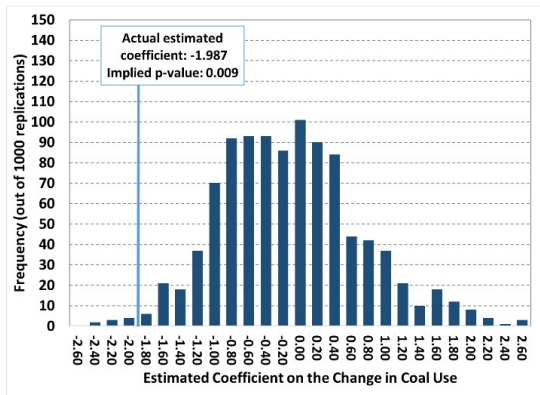
Pollution, City Growth, and the Industrial Revolution

DV: Δ Log of city-industry employment (two decade differences)						
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \ln(\text{PredCoal})$		-2.485** (1.001)	-2.485** (1.005)		-2.130** (1.011)	-1.886** (0.956)
$\Delta \ln(\text{PrCityEMP})$	-0.944 (0.733)	0.676 (1.045)	0.678 (1.153)	-1.487*** (0.485)	0.360 (0.952)	-0.248 (0.917)
Lagged $\Delta \ln(\text{PredCoal})$	-0.484 (0.448)	0.0261 (0.464)	0.0308 (0.743)			
Lagged $\Delta \ln(\text{PrCityEMP})$			-0.00654 (0.888)			
Leading $\Delta \ln(\text{PredCoal})$				0.0381 (0.677)	0.368 (0.596)	-0.630 (0.775)
Leading $\Delta \ln(\text{PrCityEMP})$						1.843*** (0.702)
Ind.-time effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,400	2,400	2,400	2,400	2,400	2,400
R-squared	0.328	0.342	0.342	0.355	0.360	0.364

City-industry regression results with previous or future changes in predicted coal use

Source: Hanlon (2020).

Pollution, City Growth, and the Industrial Revolution



Histogram of permutation results and estimate from true data

- Permutation exercise: random reassignment of coal use across 26 industries 1,000 times and re-estimate.

Pollution, City Growth, and the Industrial Revolution

DV: $\Delta \ln$ of city employment in analysis industries (two decade differences)						
	City employment in analysis industries		Total city working population		Total city population	
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \ln(PrWorkpop_{ct})$	0.955 (0.666)	0.433 (0.726)	0.756 (0.664)	0.0795 (0.724)	0.385 (0.624)	-0.229 (0.730)
$\Delta \ln(PrCoal_{ct})$	-1.457** (0.657)	-1.655** (0.670)	-1.352** (0.650)	-1.400** (0.665)	-0.986 (0.633)	-1.055 (0.686)
Time effects	Yes	Yes	Yes	Yes	Yes	Yes
Other controls		Yes		Yes		Yes
Observations	155	155	155	155	155	155
R^2	0.067	0.202	0.084	0.208	0.099	0.213

City-level regression results

Source: Hanlon (2020).

Pollution, City Growth, and the Industrial Revolution

- Consumer disamenities or productivity effects?
 - Need location-specific wage, rent, and price data.
 - Available for 51 cities in 1905 report of Board of Trade.
- Results:
 - Coal has small negative impact on quality of life.
 - Impact of coal seems larger through productivity effects.

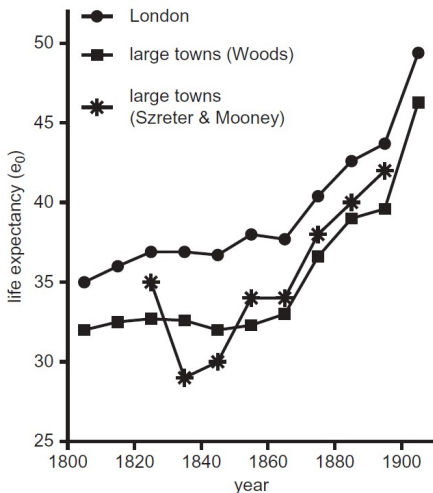
Cholera as a sanity test of British cities, 1831–1866

Cholera as a sanity test of British cities

Davenport et al (2019)

- Emergence of new industrial towns in Britain in 1760–1850.
- Life expectancy grows 1750–1820 but stagnates in 1820–1870.
- Is this due to urbanization and worsening conditions northern industrial towns?
 - Inefficient water supplies and sewage systems
 - Epidemiology: massive arrival of population from low mortality to high mortality areas

Cholera as a sanity test of British cities



Estimates of urban life expectancies at birth in England and Wales

Cholera as a sanity test of British cities

- Data quality issue:
 - Lack of data on mortality rates
 - Lack of data on water quality in urban centers
- Davenport et al (2019) collect new data on water quality and urban mortality patterns.

Cholera as a sanity test of British cities

- Urbanization as a vector of infectious diseases (waterborne diseases):
 - Urbanization generates massive problem of waste disposal.
 - Waste contains pathogens that spread through faecal-oral transmission (cholera, dysentery, typhoid).
 - Transmission can occur via contamination of water supplies or during food preparation when hand-washing and domestic hygiene lack.
- Important to assess the impact of improvements in water supply on health and mortality.

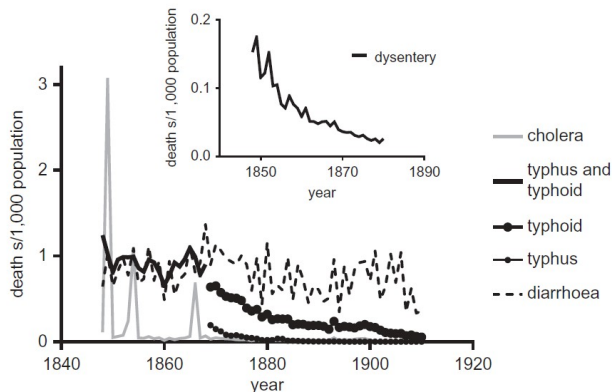
Cholera as a sanity test of British cities

Table 1. Pathogens with faecal-oral transmission routes¹

Pathogen	Mortality (% of cases)	Waterborne outbreaks (% of all outbreaks)
<i>Vibrio cholerae</i> , classical biotype [Asiatic cholera]	15.7	83.3
<i>Shigella dysenteriae</i> type 1 [dysentery]	7.5	80.0
<i>Salmonella typhi</i> [typhoid]	5.8	74.0
<i>Vibrio cholera</i> , el tor biotype	1.44	50.0
<i>Shigella flexneri</i>	1.32	48.3
<i>Shigella sonnei</i>	0.65	27.8
Enterotoxigenic <i>E. coli</i>	<0.1	20.0
<i>Campylobacter jejuni</i>	<0.1	10.7
Non-typhoid salmonella	<0.1	1.6

Pathogens with faecal-oral transmission routes

Cholera as a sanity test of British cities

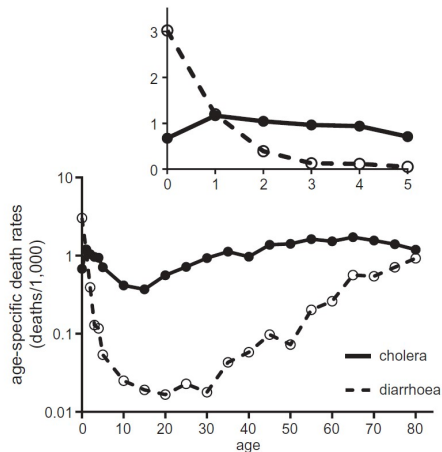


Crude death rates attributed to diseases with faecal-oral transmission pathways, and typhus, England and Wales, 1848–1911

Cholera as a sanity test of British cities

- Cholera as a test of water purity 1831–1866
 - Cholera is preeminently waterborne disease, so good proxy for water quality.
 - Epidemics of cholera well documented.
 - Highly lethal with distinctive symptoms, affecting all ages and groups.
- Issues with cholera outbreaks as a proxy of water quality:
 - Depends on transmission and thus size and connectedness of populations.
 - Mostly deaths are reported, and cases without deaths are under-reported (only see tip of iceberg).

Cholera as a sanity test of British cities



Age-specific mortality attributed to cholera and to diarrhoea, males, England and Wales, 1849.

Cholera as a sanity test of British cities

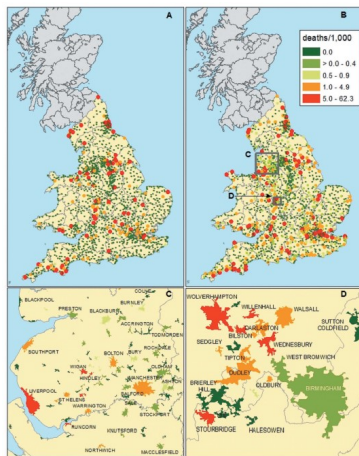
- Focus on first cholera epidemics (1832, 1849, 1854, 1866) when little knowledge of the disease and no policy for water quality.
 - 1832: reports from the Board of Health with places with cholera cases, deaths, and dates.
 - 1849: reports of the Registrar-General, General Board of Health, and Royal College of Physicians with sub-district information.
- Also collect data on baseline population, mortality rates, urban growth rates, transportation networks, waterways, ports (for connectedness measures).
- Assess relationship between size or growth rate of urban settlements and cholera mortality (high vs low).

Cholera as a sanity test of British cities

epidemic	England and Wales	London	Scotland
1831–32	21,882	5,275	9,592
1848–49	53,293	14,137	6,857
1853–54	20,097	10,738	6,848
1866	14,378	5,596	1,270

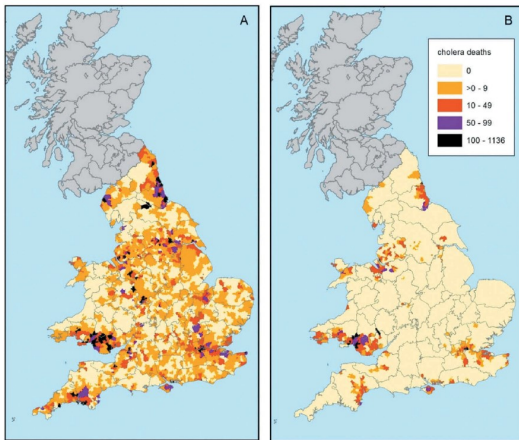
Cholera deaths reported by epidemic

Cholera as a sanity test of British cities



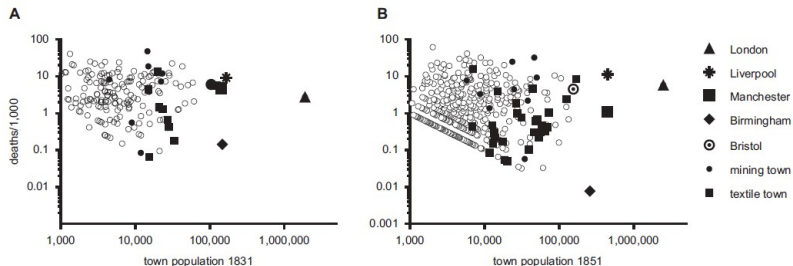
Crude cholera mortality in towns, 1831-2 (a) and 1848-9 (b-d).

Cholera as a sanity test of British cities



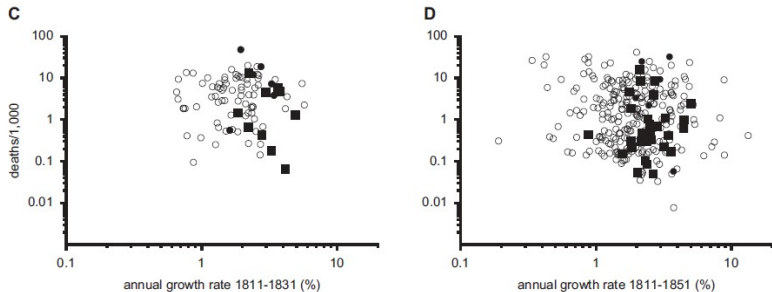
cholera deaths in registration sub-districts, 1848–1849 and 1866

Cholera as a sanity test of British cities



Crude cholera mortality (cholera deaths per 1,000 population) by population of towns or population growth rates in 1831–1832 (panels a,c) and 1848–1849 (panels b,d).

Cholera as a sanity test of British cities



Crude cholera mortality (cholera deaths per 1,000 population) by population of towns or population growth rates in 1831–1832 (panels a,c) and 1848–1849 (panels b,d).

Cholera as a sanity test of British cities

- Results of the empirical analysis:
 - No association between cholera outbreak and:
 - Population growth.
 - Turnpike roads, railway stations, canals.
 - Mines and coal proximity.
 - Positive association between cholera outbreak and:
 - Absolute population size.
 - Seaports and navigable rivers.
- Cholera mortality not particularly focused on northern industrializing or manufacturing towns.
- If Cholera is a good proxy, water supplies improved after 1850.

Industrialization and health: paleopathological evidence

Paleopathological evidence

Soria (2022)

- Measuring health implications of industrialization is challenging.
- Evidence from paleopathology (study of malignancy from bones).
- Exposure to exogenous carcinogens (pollution) induce malignancy.
- Bone metastases can be seen on bones.
- Compare 8973 bones from medieval period (1066–1547) to 4748 bones from industrial period (1700–1890).

Paleopathological evidence

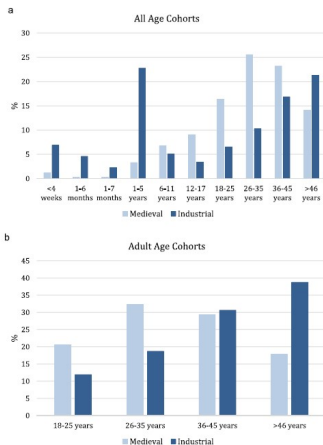
- Potential issues with measuring health through bones:
 - Bone metastases increase with age so need to consider age at death.
 - Preservation higher depending on soil quality, bone size, type, age, etc (eg male and young adults better preserved).
 - Some malignancies can increase bone fragility.
 - Remains affected by archaeological process (excavation methods, measurement instruments, etc).
- This might result in skewed sex ratios and age-at-death profiles compared to total population.

Paleopathological evidence



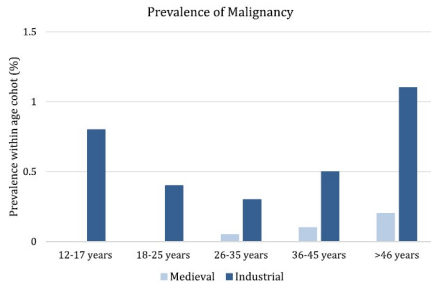
Map of cemetery locations

Paleopathological evidence



Comparison of age-at-death data for the medieval and industrial samples.

Paleopathological evidence



Prevalence of malignant disease in adolescents, young adults, young middle adults, older middle adults and mature adults for medieval and industrial time periods.

Paleopathological evidence

Time period	Males			Females		
	Cases of malignancy (n)	Total (N)	Crude prevalence (%)	Cases of malignancy (n)	Total (N)	Crude prevalence (%)
Medieval	5	3962	0.13	0	2616	0.00
Industrial	9	1319	0.68	7	1084	0.65
Both periods	14	5281	0.27	7	3700	0.19

Prevalence of malignancy in males and females for the medieval and industrial samples.

Dust Bowl migrants: environmental refugees and economic adaptation

Dust Bowl Migrants



The American Dust Bowl of the 1930s

Dust Bowl Migrants

- The American Dust Bowl of the 1930s:
 - Late 19th century, agricultural production expanded on American Plains, with native grasslands plowed up for crops.
 - But severe drought during the 1930s \implies loss ground cover.
 - Farmland susceptible to self-perpetuating dust storms (wind erosion).
 - By the 1940s, many Plain areas had cumulatively lost more than 75% of original topsoil.
 - Led to \downarrow agricultural land values and migration (during Great Depression). [Hornbeck \(2012\)](#)

Dust Bowl Migrants

Hornbeck (2021)

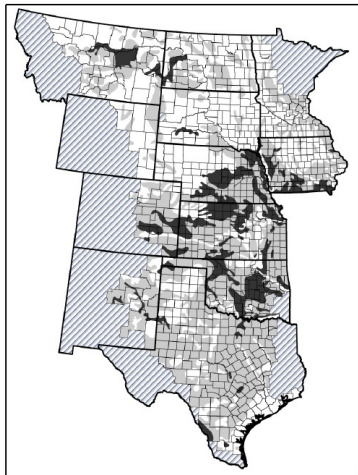
- How did migration respond to environmental collapse and associated economic upheaval?

Dust Bowl Migrants

Hornbeck (2021)

- How did migration respond to environmental collapse and associated economic upheaval?
- Challenge: identify Dust Bowl migrants separately from other migrants moving due to:
 - The Great Depression.
 - New Deal policies.
 - Agricultural mechanization.
 - Broader drought.

Dust Bowl Migrants



The 843 Plains counties, shaded by erosion level

Source: Hornbeck (2021). Map of low (< 25% topsoil lost), medium (25%–75%), or high (> 75%).

Dust Bowl Migrants: Data

- Study characteristics of Dust Bowl migrants using the full 1940 census:
 - County of residence 1940 and 1935.
 - Age, gender, education, farm status in 1935, birth state.
 - Sample selection: 25–55 in 1935 (50 million).

Dust Bowl Migrants: Data

- Study characteristics of Dust Bowl migrants using the full 1940 census:
 - County of residence 1940 and 1935.
 - Age, gender, education, farm status in 1935, birth state.
 - Sample selection: 25–55 in 1935 (50 million).
- Migration rate in county c :
 - Numerator: movers from county c to other counties from 1935 to 1940.
 - Denominator: People in 1940 reporting living in c in 1935 (recall error of 1935 location).
- Census of Agriculture (1910–1930): acres of farmland, cropland share, rural population, farms per acre, farm size, cattle per acre...

Dust Bowl Migrants: Empirical Strategy

- Estimate relative impact of Dust Bowl erosion on migration rates from Plains counties:

$$Y_c = \beta_1 H_c \beta_2 M_c + \alpha_s + \theta X_c + \varepsilon_c$$

- Y_c : migration rate for county c .
 - H_c : fraction of county in high-erosion area.
 - M_c : fraction of county in medium-erosion area.
 - α_s : state FE.
 - X_c : county characteristics in 1910, 1920, 1930.
- Identification from comparing more-eroded counties to less-eroded counties within same state with similar pre-1930s characteristics.

Dust Bowl Migrants: Empirical Strategy

- Estimate average differences between Plains migrants and non-migrants:

$$Y_{ic} = \beta \text{Migrant}_i + \gamma_c + \varepsilon_{ic}$$

- Y_{ic} : individual characteristic of individual i in c .
 - Migrant_i : indicator for having moved from a Plains county in 1945 to different county in 1940.
 - γ_c : county FE.
-
- When county FE 1935: β is average difference between Plains migrants and non-migrants from their old origin counties.
 - When county FE 1940: β is average difference between Plains migrants and natives in their new destination counties through U.S. (in-selection).

Dust Bowl Migrants: Empirical Strategy

- Estimate how Dust Bowl erosion induced different migrants:

$$Y_{ic} = \beta_1 H_c \times \text{Migrant}_i + \beta_2 M_c \times \text{Migrant}_i \\ + \alpha_s \times \text{Migrant}_i + \theta X_c \times \text{Migrant}_i + \gamma_c + \varepsilon_{ic}$$

- β s indicate how selection of Plains migrants from high-erosion and medium-erosion counties is different than selection of Plains migrants from low-erosion counties.

Dust Bowl Migrants: Results

	All Plains Counties (1)	Relative to Low Erosion Counties:	
		High-Erosion Counties (2)	Medium-Erosion Counties (3)
Panel A. Migration To All Counties			
Migration Percent	17.05 [5.19]	3.05 (0.64)	1.86 (0.46)
Panel B. Migration Beyond 200 Miles			
Migration Percent	7.19 [3.82]	2.57 (0.56)	1.38 (0.33)
Panel C. Migration Within 200 Miles			
Migration Percent	9.86 [3.41]	0.47 (0.38)	0.47 (0.28)

Estimated Migration From 1935 to 1940, by Original County Erosion Level

Source: Hornbeck (2021).

Dust Bowl Migrants: Results

Outcome:	Migrants to All Counties		
	Migrants from All Plains Counties (1)	Relative to Low-Erosion: Migrants from High-Erosion Counties (2)	Migrants from Med-Erosion Counties (3)
Years of Education			
Men	1.11 (0.06)	-0.51 (0.13)	-0.37 (0.10)
Women	1.02 (0.05)	-0.44 (0.13)	-0.37 (0.10)
Percent Living in Birth State in 1935	-8.47 (0.64)	2.63 (1.35)	1.92 (1.02)
Percent Living on a Farm in 1935	-9.79 (0.68)	1.34 (1.40)	0.93 (0.98)
Age	-2.95 (0.04)	0.08 (0.14)	-0.10 (0.10)
Percent Male	3.65 (0.21)	-0.32 (0.40)	-0.45 (0.32)

Estimated Out-selection of Migrants, by Original County Erosion Level

Source: Hornbeck (2021).

Dust Bowl Migrants: Results

Outcome:	Migrants to All Counties		
	Relative to Low-Erosion:		
	Migrants from All Plains Counties (1)	Migrants from High-Erosion Counties (2)	Migrants from Med-Erosion Counties (3)
Percent Living on a Farm			
in 1935	0.81 (1.74)	3.22 (1.31)	2.03 (0.99)
in 1940	-5.01 (0.70)	0.98 (0.79)	0.82 (0.64)
Years of Education			
Men	1.14 (0.15)	-0.35 (0.17)	-0.28 (0.09)
Women	1.12 (0.15)	-0.26 (0.14)	-0.29 (0.08)
Log Income in 1939			
Men	-0.017 (0.039)	-0.078 (0.029)	-0.071 (0.017)
Women	-0.156 (0.047)	-0.073 (0.040)	-0.044 (0.021)
Log Income in 1939, Skill-Adjusted			
Men	-0.093 (0.025)	-0.050 (0.022)	-0.049 (0.013)
Women	-0.214 (0.028)	-0.052 (0.024)	-0.031 (0.018)
Weeks Worked			
Men	-2.16 (0.25)	-0.14 (0.29)	-0.01 (0.19)
Women	-0.48 (0.30)	0.25 (0.42)	0.47 (0.26)

Estimated In-selection of Migrants, by Original County Erosion Level

Source: Hornbeck (2021).

Dust Bowl Migrants: Results

- Substantial migration response to Dust Bowl.
- While general migrants were positively selected, Dust Bowl migrants were negatively selected.
- Dust Bowl migrants pushed by environmental collapse rather than pulled to economic opportunities.
- Dust Bowl migrants struggled economically in 1939, relative to native, especially from more eroded areas.