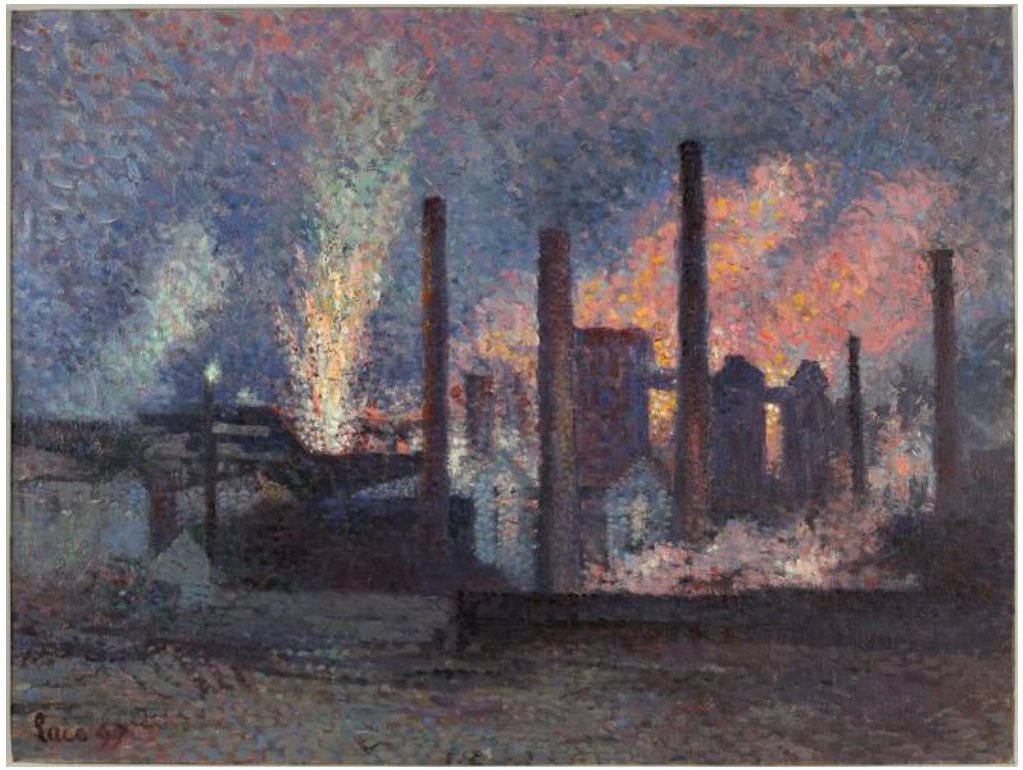
Above and beyond the industrial revolution: energy, pollution, and dark sides



Lionel Kesztenbaum (INED and PSE)

https://lionel-kesztenbaum.site.ined.fr/

Advanced Economic History

Session 3

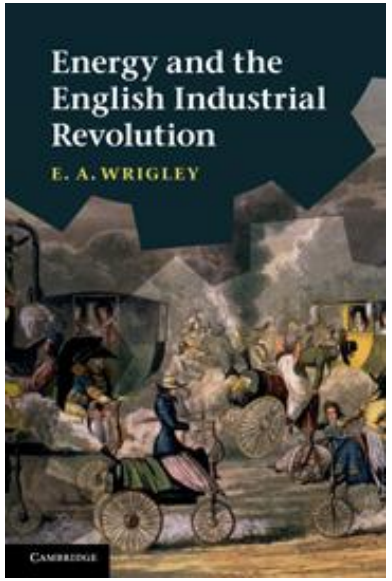
01/10/2025

Pictures: Maximilien Luce, Usines près de Charleroi (1897) & Félix Thiollier, Paysage de mine, les puits Chatelus à Saint-Etienne (1907-1912). Both from Musée d'Orsay.

Beyond the Industrial Revolution: debates and oppositions

- Need to relativize the very idea of the industrial revolution
  - More a continuous (but not linear!) process than a "Revolution".
  - A very masculine, simplified, heroic, western-centric story of the IR.
  - Bias of sources but, more generally, difficulties to express the complexity of IR.
- And elsewhere?
  - Geographic constraint: China vs Britain and the role of "ghost acres" (Pomeranz).
  - More broadly: was the economic development of the West fueled by the Rest? (see Denis Cogneau sessions next).
- And energy?
  - The role of coal and energy in the British development.
  - An energy revolution?
  - Another view of the IR: material flow analysis.
- The dark side of the industrial revolution
  - Human and social costs.
  - Environmental costs.

Feeding the industrial revolution: the role of energy

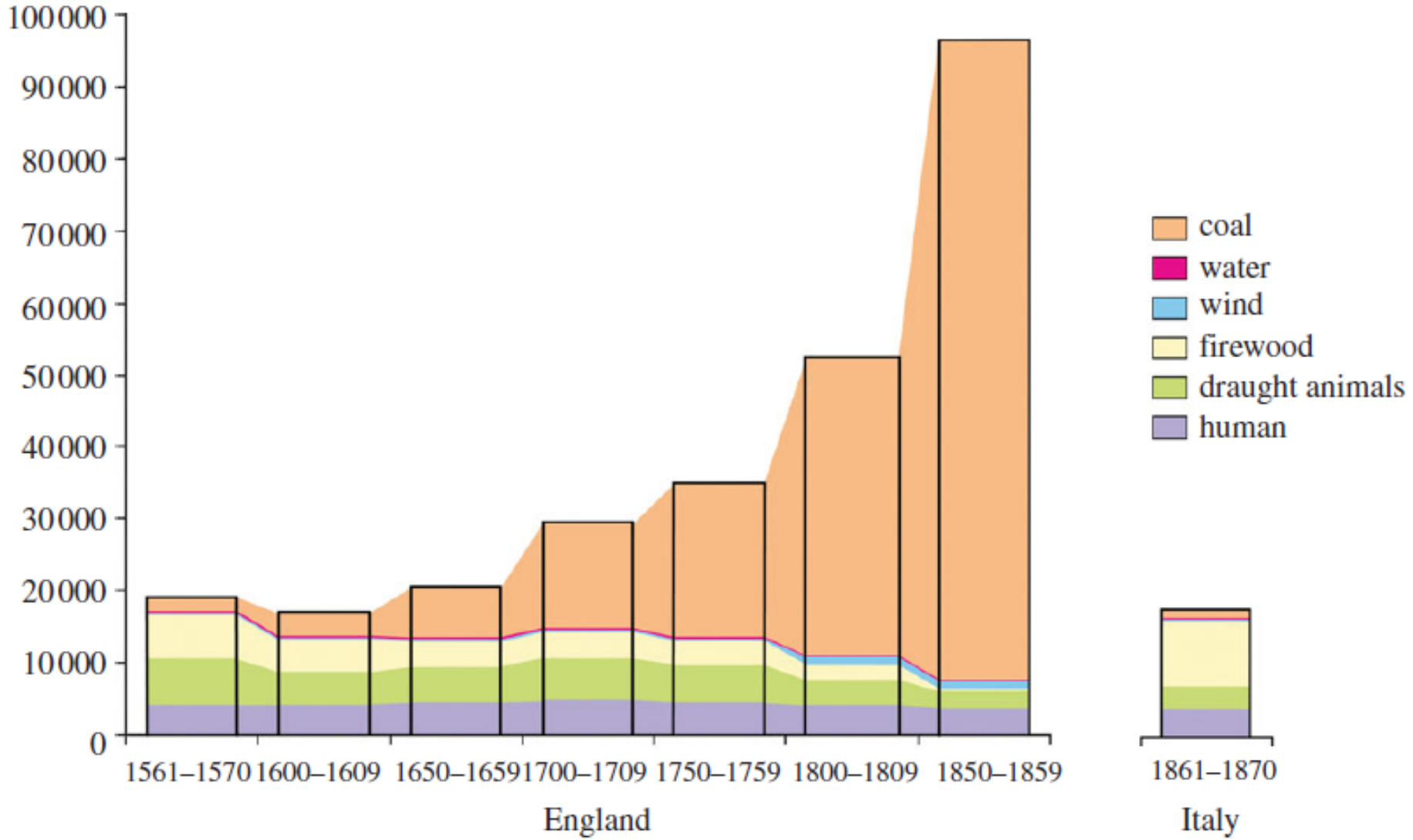


- A new paradigm? Change in the source of energy as motor of the IR.
- Tony Wrigley: sources of energy over the long run
  - 'The Supply of Raw Materials in the Industrial Revolution' (*EHR*, 1962).
  - *Energy and the English industrial revolution* (2010).
- From organic to mineral economies
  - Only one source of energy: harnessing the energy of the sun through photosynthesis.
  - Organic economies: ultimately all source of energy is land. Hence strong constraints.
  - Mineral economies take advantage of the accumulated result of photosynthesis: fossil fuels.
- A change of regime?
  - The energy supply is decisive to maintain momentum.
  - "Fungibles" vs "consumptibles" materials (renewable or not).

The impact of coal in the IR

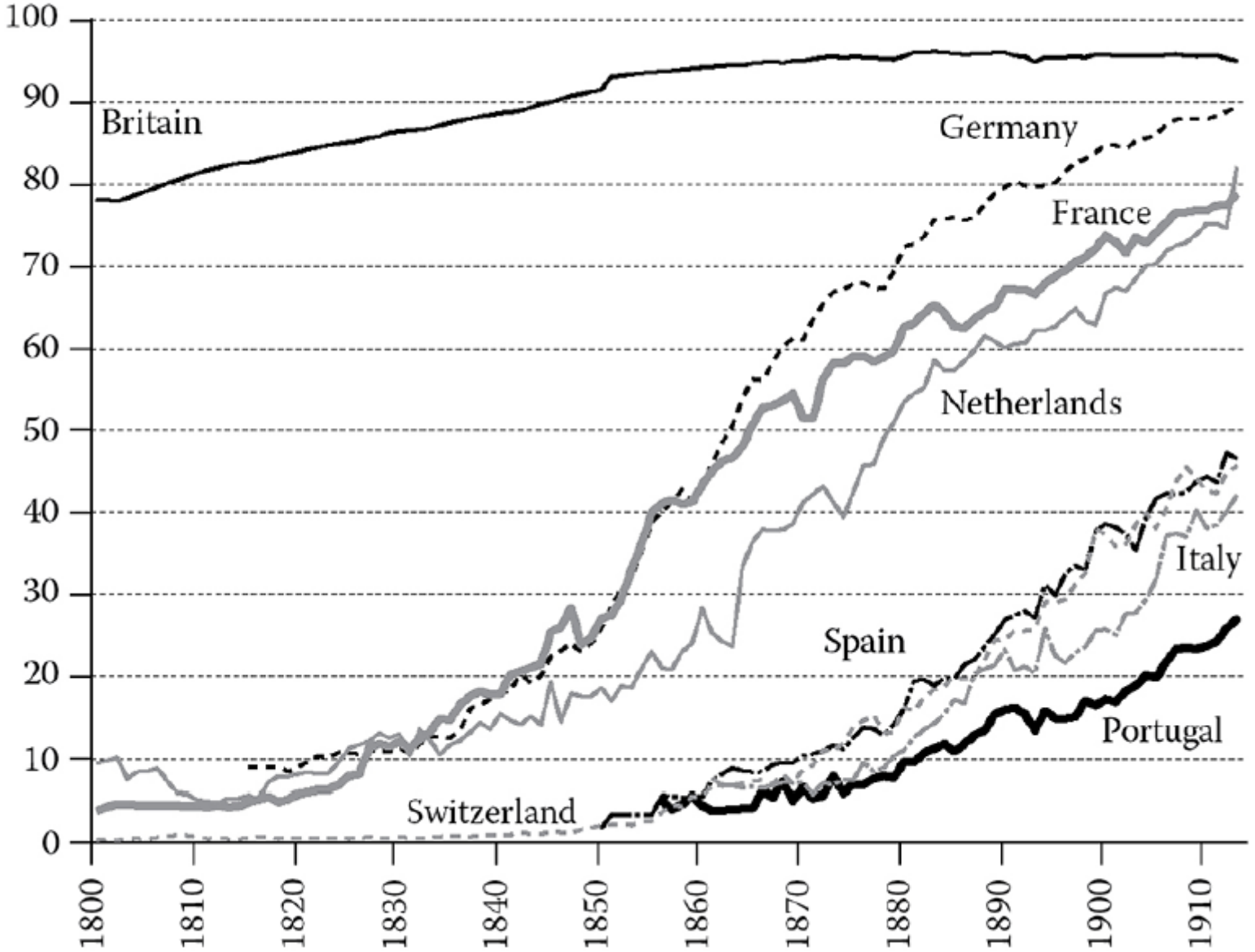
- Use of coal make up for wood that did not exist
  - 1750 = 4M acres (13% of England territory); 1800 = 11M acres (35%); 1850 = 48M acres (150%).
  - Fossil fuels being used as replacement for both heat and muscular energy.
- An energy revolution?
  - Increase in use of coal from rising demand in British cities.
  - Positive feedback loop between population growth, demand for coal, and technology (steam engine…).
  - Allows to break free from land constraints (domestic and abroad).
- From wood to coal
  - For heating (producing systems) to mechanical energy.
  - Symbiosis between coal extraction and use as source of mechanical energy.

Annual energy consumption per head (megajoules)



Wrigley, E. A. 2013. "Energy and the English Industrial Revolution." *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 371: 20110568.

The rise of coal (share in the energy mix, primary energy)



Fressoz J-B. *More and more and more. An all-consuming history of energy* Penguin.

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An energy revolution?

> "In my view the most important single issue on which to focus in trying to gain a clearer understanding of the industrial evolution is not how the period of more rapid growth began, but why it did not come to an end. All past experience appeared to justify the expectation that the very process of growth would set in train changes which would arrest and might well reverse the growth which had occurred."
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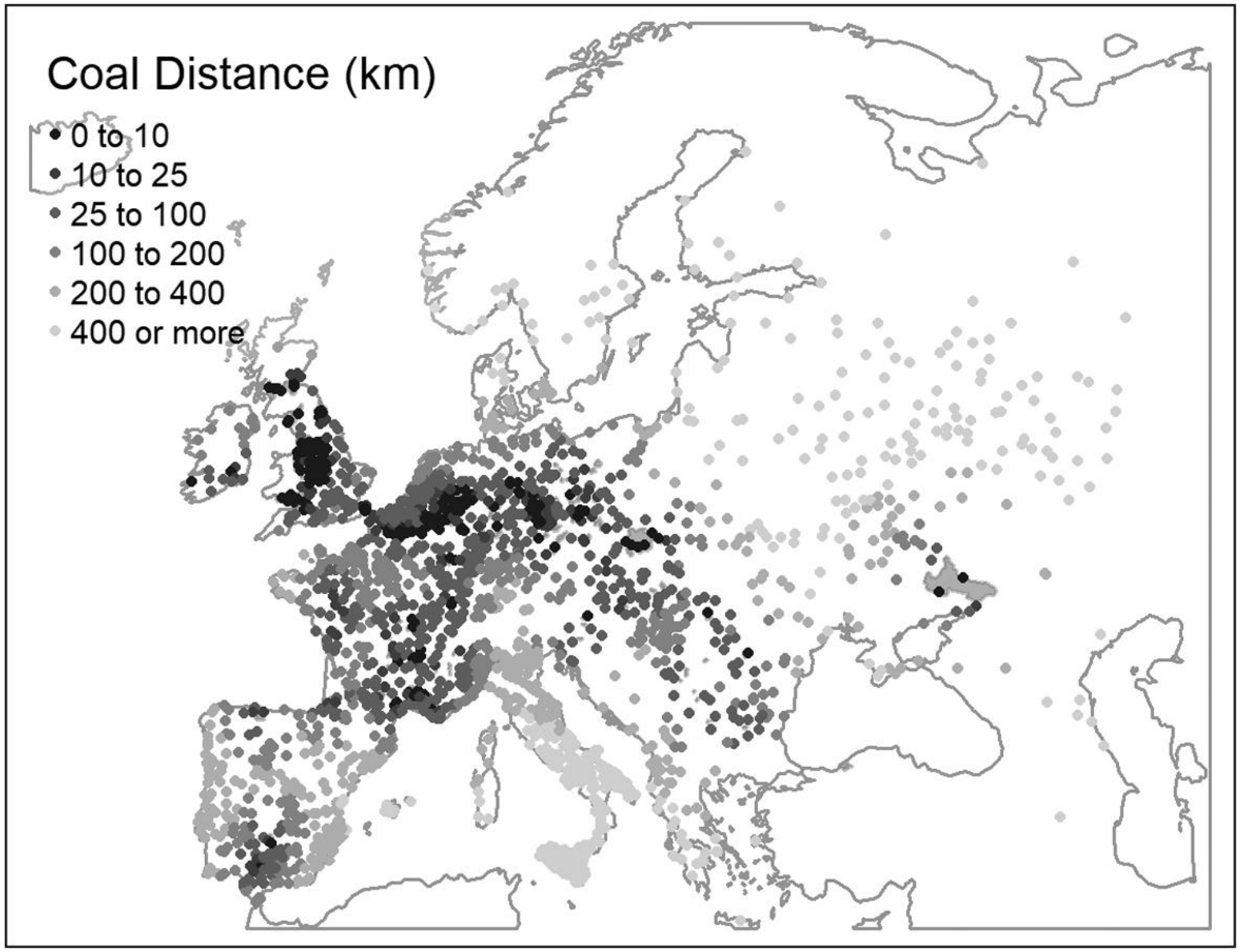
> Tony Wrigley (2010: 4)

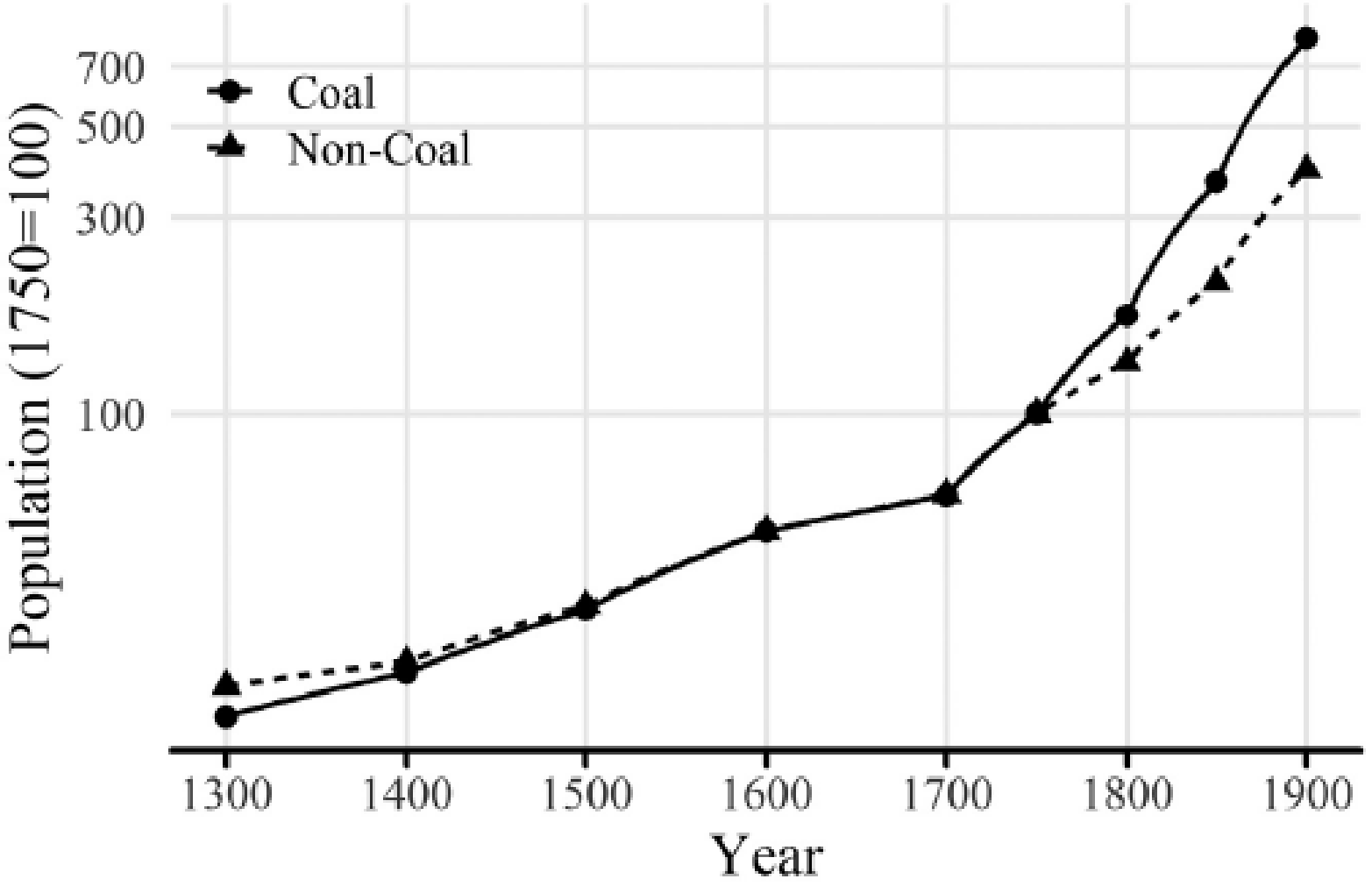
- Wrigley: coal was a necessary condition for IR
  - The rest does not matter, it's the new source of energy that makes the IR different.
  - Coal is not what makes the IR possible, but it is what sustained it: change of regime.
- Measuring the role of coal?
  - Exemple with Fernihough and O'Rourke (2021) Coal and the European industrial revolution, *EJ*.
  - Looking at a panel of European cities, 1300-1900.
  - Proxy for growth: population size. Link with closeness to a coal field + using IV (Carboniferous areas).
- But:
  - Probably a little too "natural" history. Centrality of coal for the IR was a choice (of whom? why?...).
  - Need to look at the social structure and political economy of energy adoption.

Distance between European cities and coal fields



Fernihough, Alan, and Kevin Hjortshøj O'Rourke. 2021. "Coal and the European Industrial Revolution." *The Economic Journal* 131 (635): 1135–49.

Distance between coal and population



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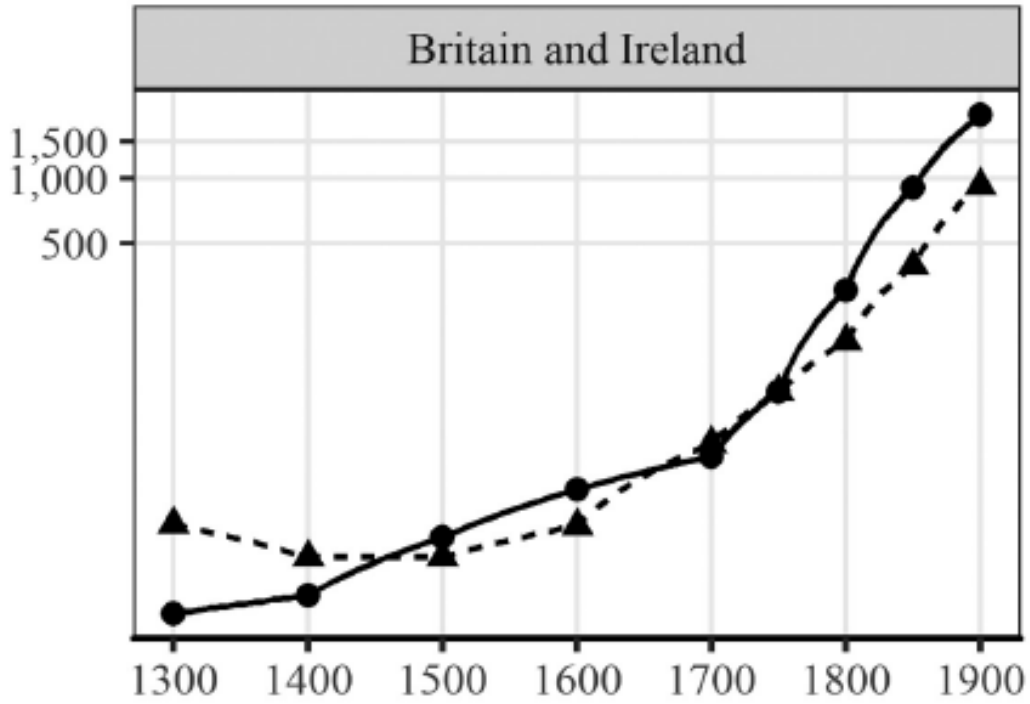

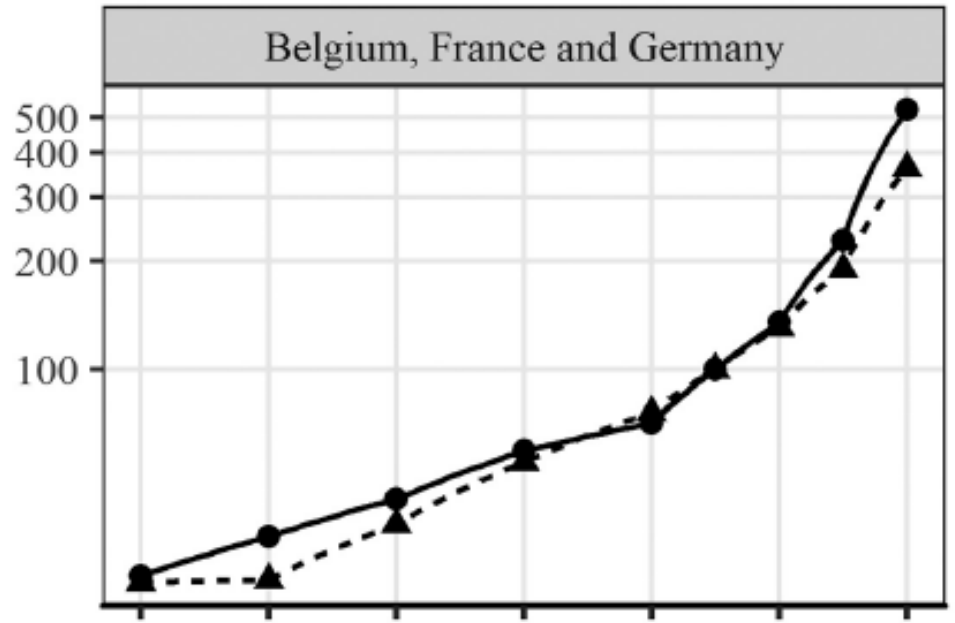

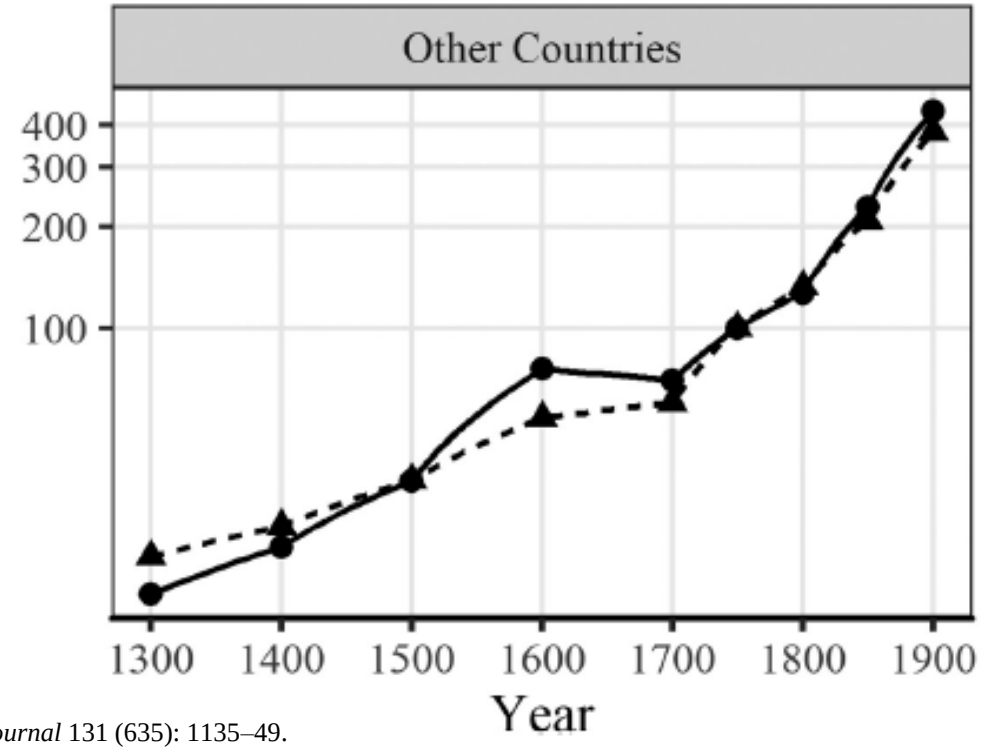

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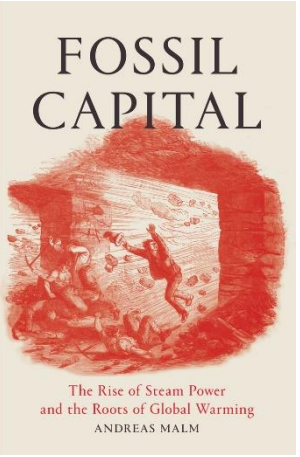
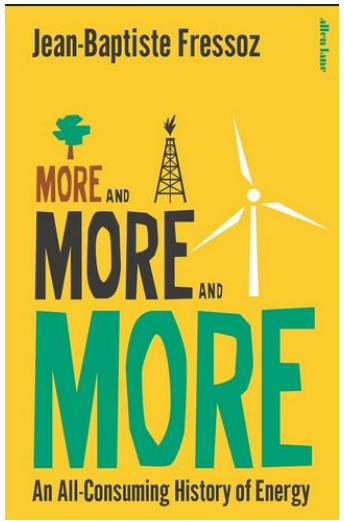
An alternative history: Water vs coal (Malm)



- Was economic growth possible without coal?
  - The steam engine was decisive in breaking the relationship to land.
  - There was always need (appetite) for more energy.
- What about water power?
  - Water power was the initial source of power for many industry (cotton in particular).
  - Its expansion stopped at the end of the 1820s when steam power took over.
  - The difference is that water need collective organization, cooperation and is less controllable.
  - What developed the use of steam engine was a choice by industrialist, in order to impose order on the labour force.
- Reintroducing inequality in the IR story
  - The steam engine triumphed because it allowed to create a controlled environment (the factory) independent of time and space constraints.
  - And as such it allows the exploitation of labour.
  - A less linear (/tautologic) view of the IR.
  - See also: Timothy Mitchell, *Carbon Democracy: Political Power in the Age of Oil*, 2011, Verso.

The illusion of coal? (Fressoz)

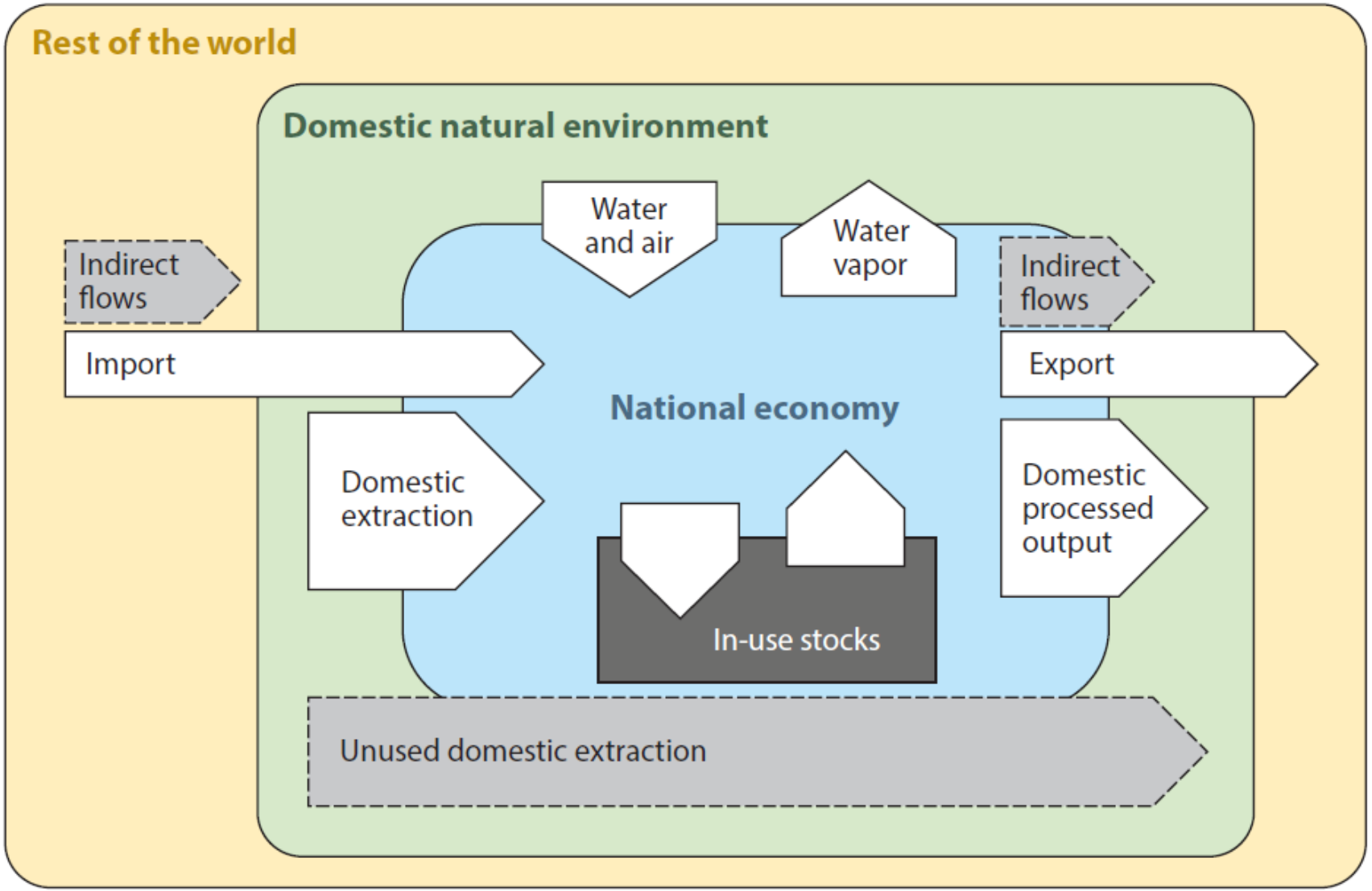


- Is there such a thing as a mineral economy?
  - Arrival of coal leads to increase (not decrease) of wood use (but for other uses).
  - For instance: role of timber as prop in the mines.
  - UK 1900s: around 4 million m3 of woods vs 3.6 for firewood in 1750.
- Additions and complementarities between energy sources
  - Steam engines would run on coal in Britain but on wood elsewhere; e.g., charcoal in Sweden until 1930s.
  - Example: railways, huge quantity of woods used for sleepers (20million m3 in the US), often burned in locomotives after use.
  - And the same is true for oil: primary material for oil extraction (derricks, tank, barges…).
- Need new ways to measure relationships between economics and nature
  - No clear transition between different sources of energy.
  - Accumulation of raw materials over time feed economic growth.

Material flows analysis: a material picture of the economy

- Accounting for resources used in the economic process
  - Aims at measuring the physical basis of human economies/societies.
  - A measurement in quantity (in weight) instead of measures in value.
  - Accounting is a tool to assess socio-economic metabolism (Robert Ayres & Allen Kneese).
- Categories
  - 70 detailed categories of materials ("Dairy products birds eggs and honey", "Copper ores concentrates and compounds"…)
  - Aggregated in 4 main groups:
    - Biomass.
    - Metals.
    - Non-metallic minerals.
    - Fossil energy carriers.
- Measures/indicators
  - DE = domestic extraction = materials extracted from national territory for direct use.
  - IM = imports = material input from trade & EX = exports = amounts of material exported.
  - PTB = physical trade balance = IM – EX.
  - DMI = direct material input = DE + IM.
  - DMC = domestic material consumption = DE + PTB.

Material flows analysis (simplified)



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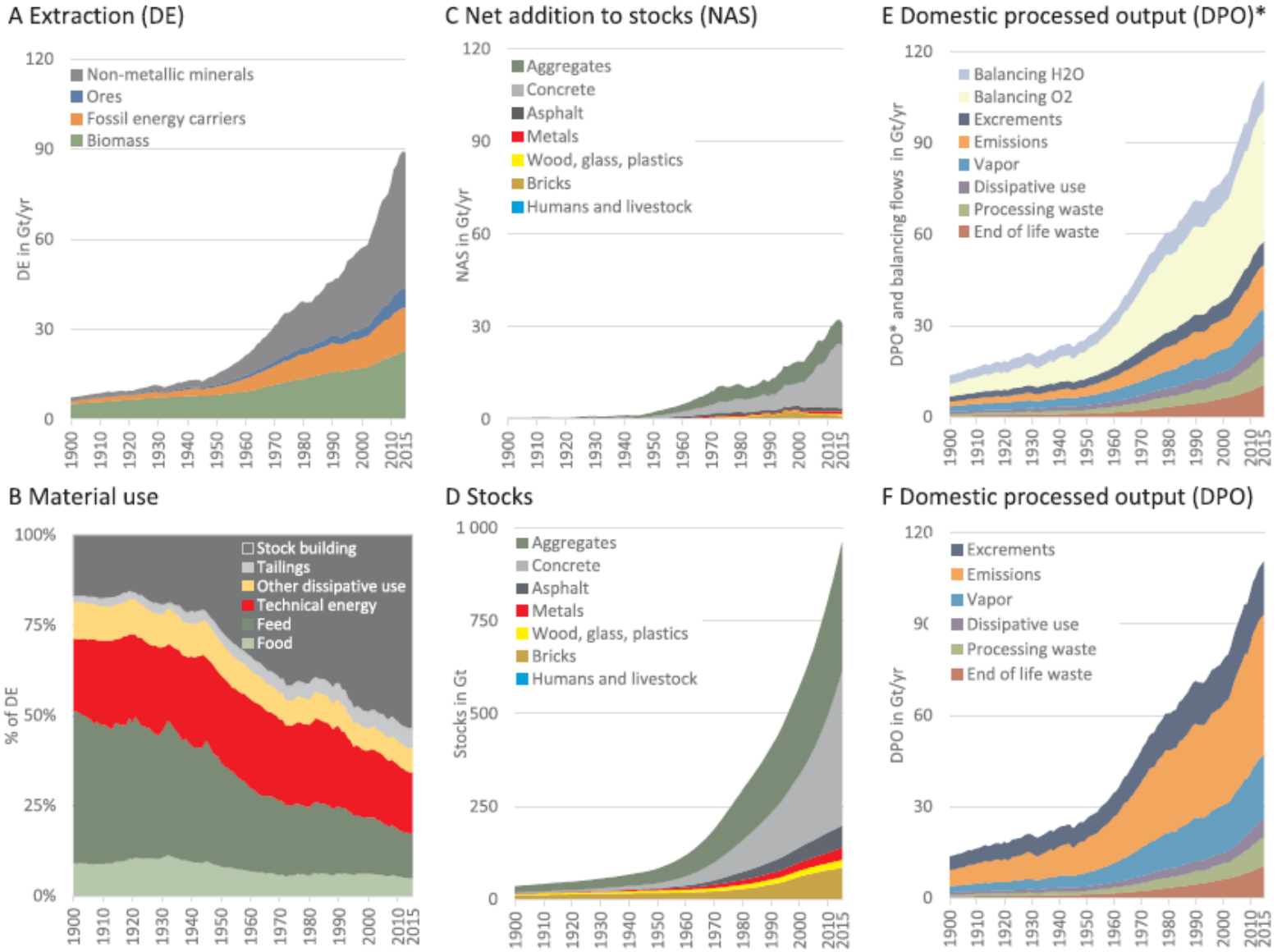
Material flows analysis: measurement and issues

- Difficulties and limitations of measurement
  - Using weight as a standard measure for very different things in nature.
  - Not everything is easy to measure (domestic less accurate than international).
  - Variations in time and space.
- Gives a rough view of the pressure on the physical (/natural) world
  - Can be used at many different levels: city, region, country, world…
  - Material productivity = GDP/DMC or Material intensity = DMC/GDP.
- Discussion
  - Allows to compute the use of non-domestic resources, such as "ghost acres".
  - A view in the long run helps understand how the IR unfolded…
  - … but also different paths of the IR.

Global material use, 1900-2015



Krausmann, Fridolin, Christian Lauk, Willi Haas, and Dominik Wiedenhofe. 2018. From Resource Extraction to Outflows of Wastes and Emissions: The Socioeconomic Metabolism of the Global Economy, 1900–2015. *Global Environmental Change* 52: 131–140.

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Material flow analysis: the case of France

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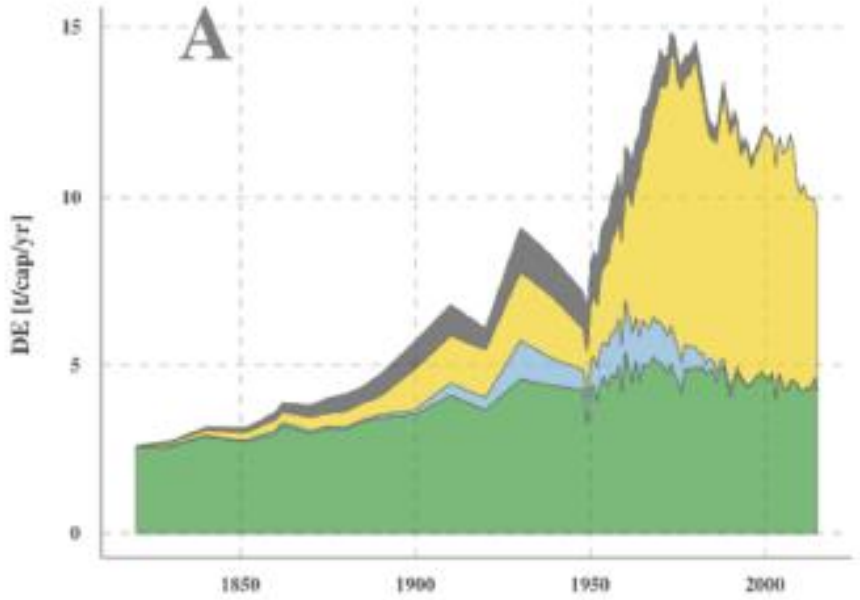
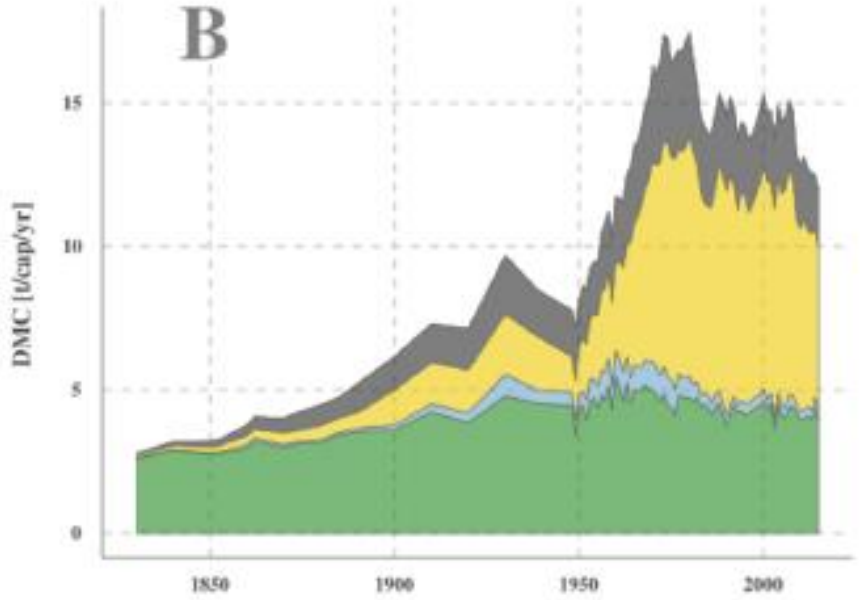
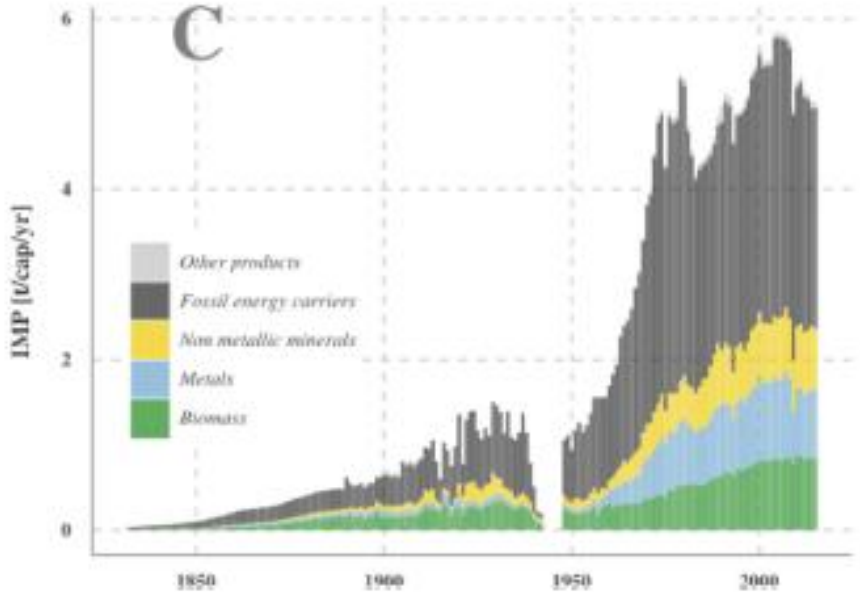
- Socio-metabolic transition: from agrarian to mineral economy
  - Rise of fossil fuels, in two moves: coal and then oil.
  - More progressive (and late) in France than UK or USA.
  - Specificity of France: strong dependency to external resources, for the whole period.
- A global and material history
  - How a country (France) is inserted in broader world systems.
  - History of material allows a different reading and understanding of the industrial revolution.
- Different path to development?
  - How to overcome the constraints of natural endowment.
  - MFA allows to see political decisions and their concrete impact on the economic system.

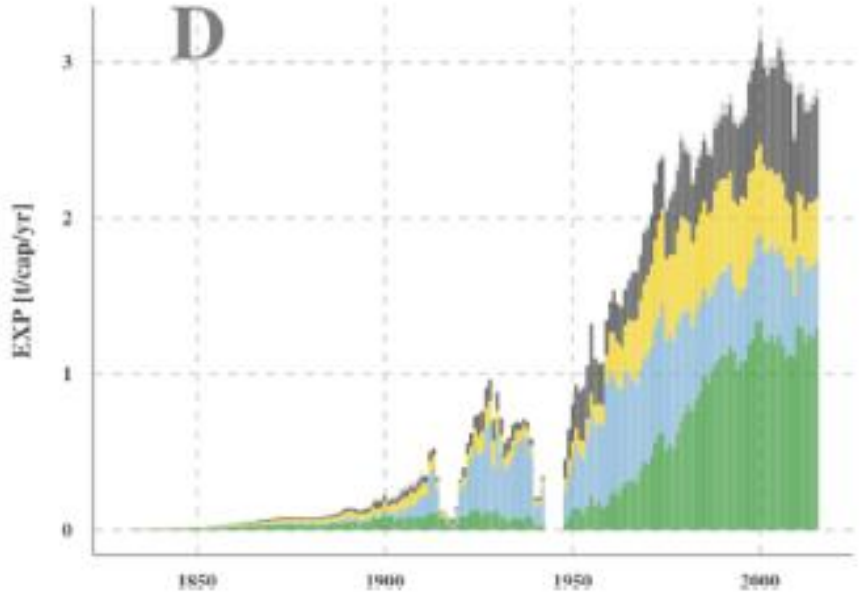
Material flows in France

(tonnes/capita/year)

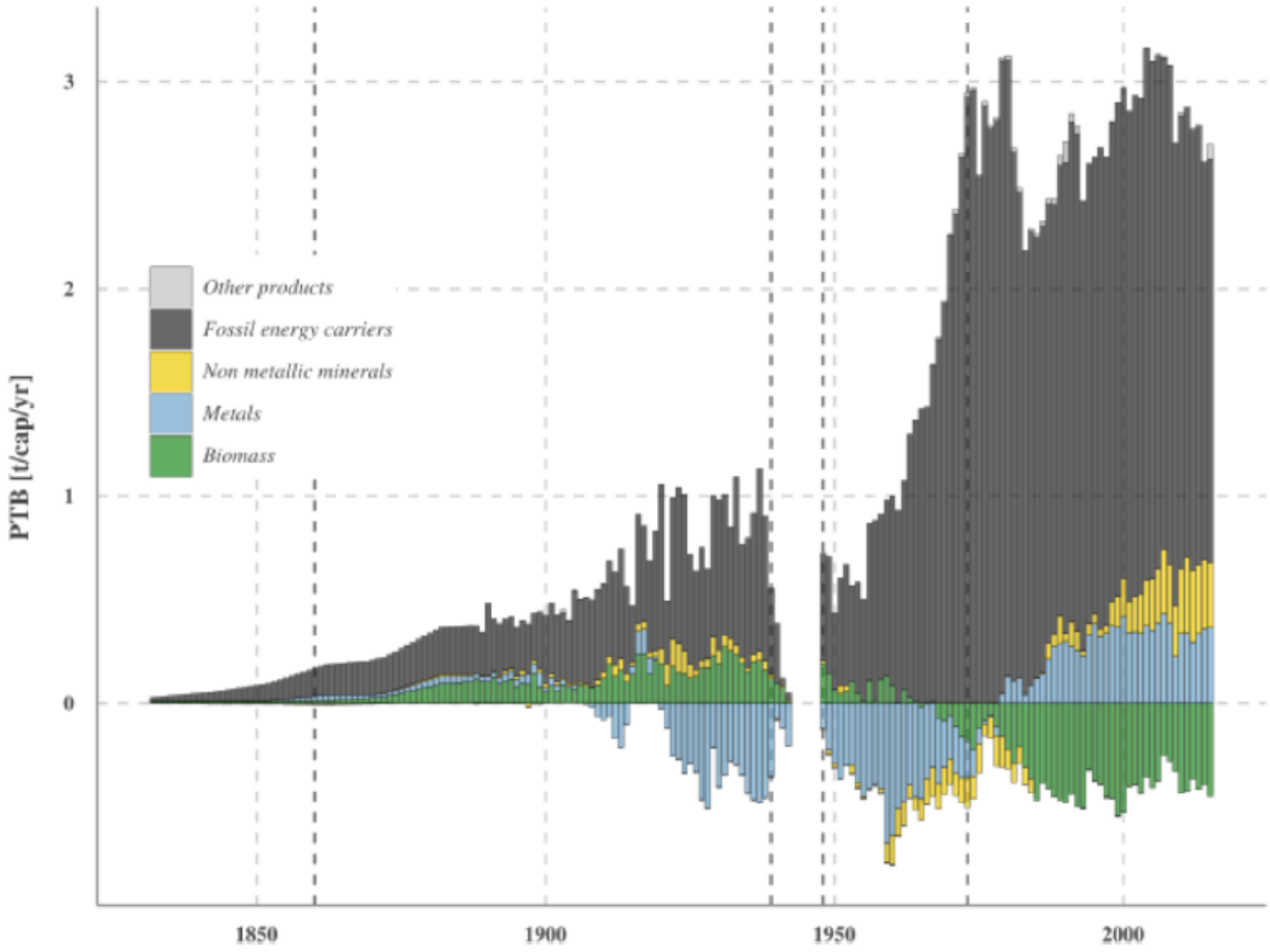






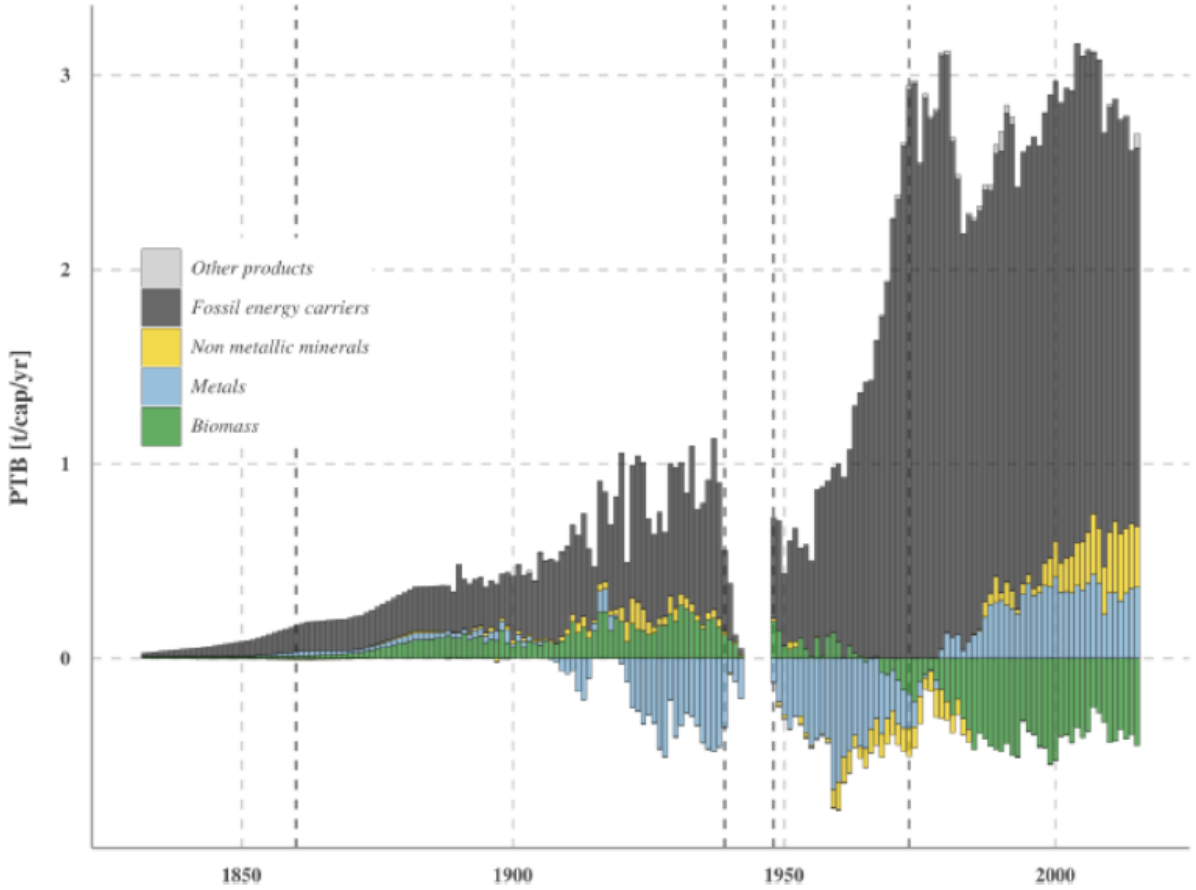


Physical trade balance

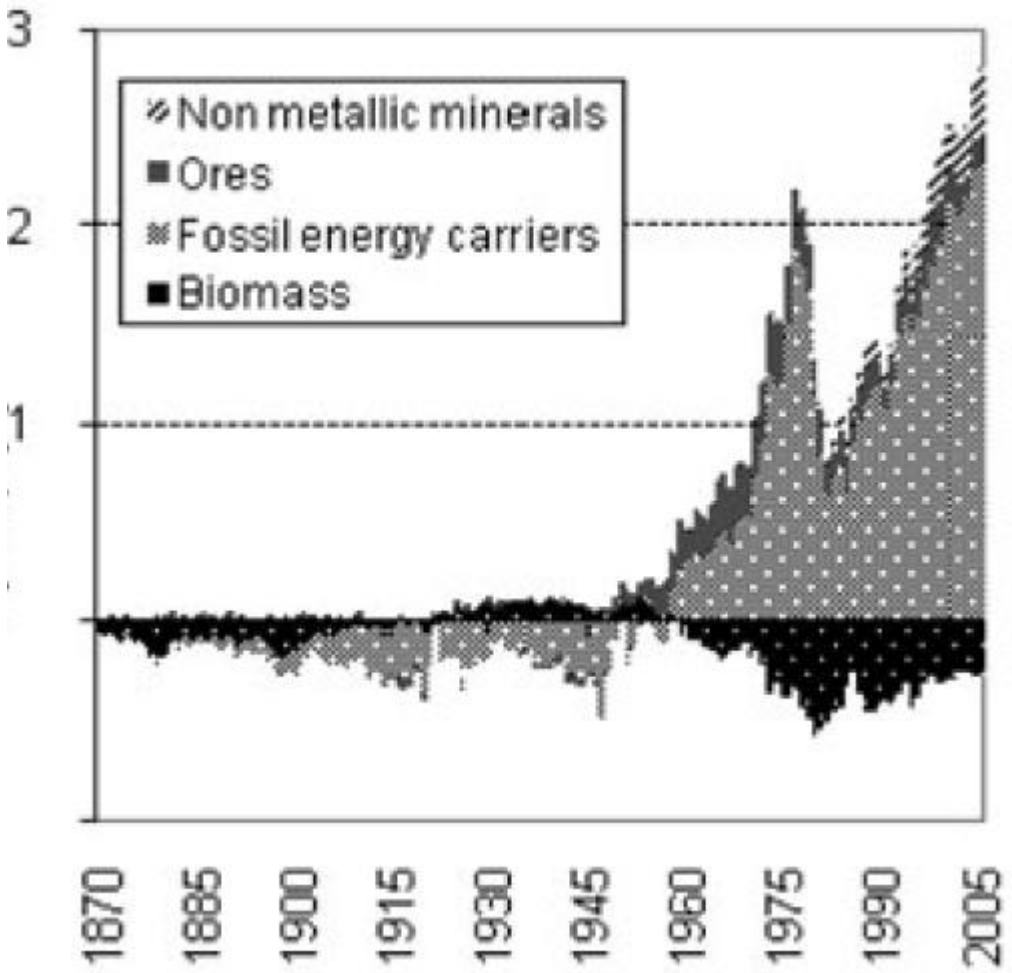


Physical trade balance

FRANCE



USA



From agrarian (/biotic) to mineral (/industrial) economy

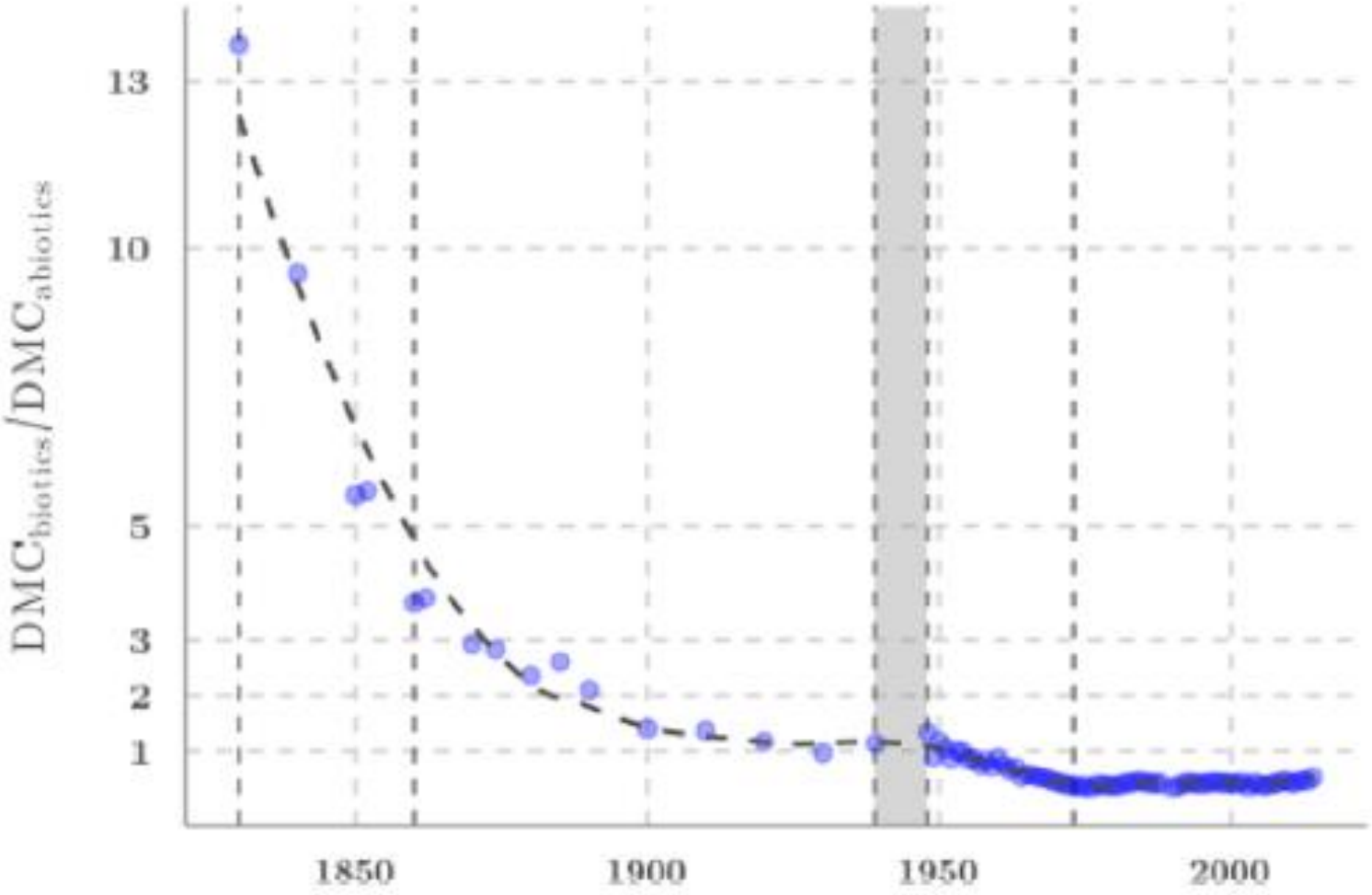


Fig. 5. Ratio biotic DMC/abiotic DMC.

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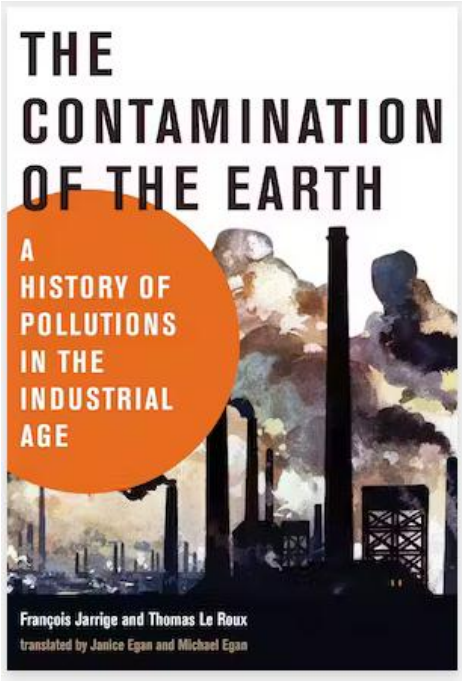
“The dark side of progress”: of pollution and destruction

- Environmental history
  - A political origin: William Cronon, Roderick Nash, Donald Worster…
  - An urban origin: Martin Melosi, Joël Tarr…
  - Link with history of climate (Le Roy Ladurie…).



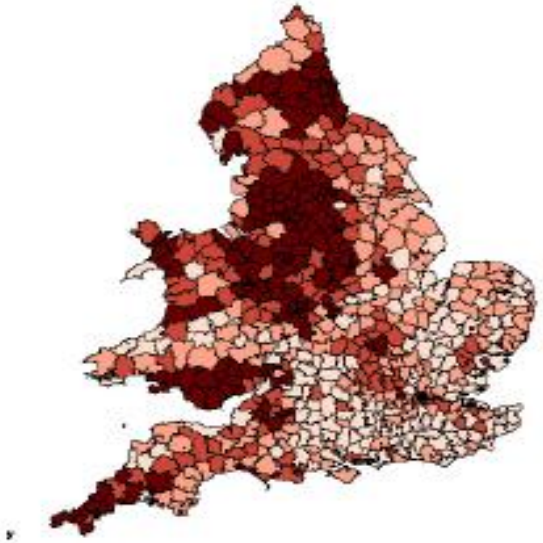
- The industrial revolution as a history of pollution
  - Industrialization caused large pollution issues.
  - Specificity of the industrial age: pollution is observed but deemed necessary.
  - Link between pollution and modernity is the key transformation.
  - Rise of expertise, often to promote and defend pollution.
  - Better technology (for limiting pollution) is offset by general growth.
  - Huge heterogeneity of pollutions, but also responses to it.

And from economic history? The example of Britain

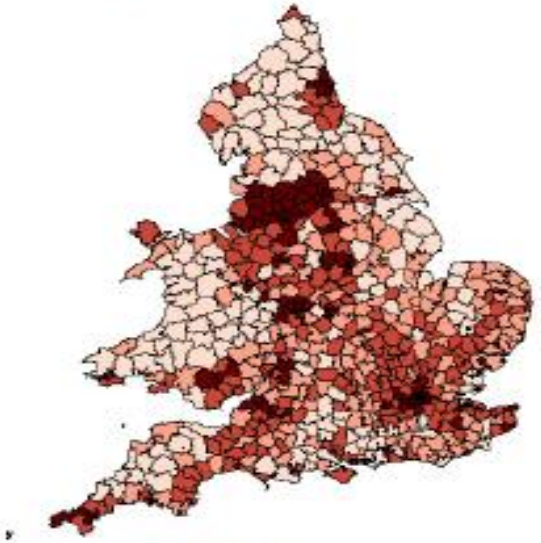
- Huge increase in coal consumption during 19th century… meaning huge increase in air pollution.
  - An important issue for cities (and London especially).
  - Effects of air pollution on mortality, on city growth...
- Coal pollution and health (Bailey, Hatton, and Inwood 2018)
  - Negative effect of coal intensity in a district and adult height.
  - Study at the city level, using an estimation of coal per workers across industries.
  - Indirect measure; source of variation: industrial structure between cities.
- Effect of coal pollution on mortality (Beach and Hanlon 2017)
  - Comparing cities according to coal use but also down/upwind.
  - Strong effect on infant mortality.
- Effect of coal pollution on city growth (Hanlon 2020)
  - Amenity channel: cities are less attractive.
  - Pollution channel: workers in these cities are less productive.

Coal use, density, and mortality

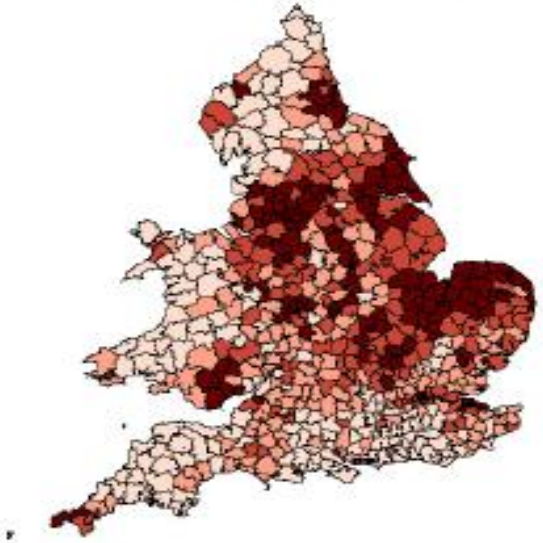
Coal use per worker



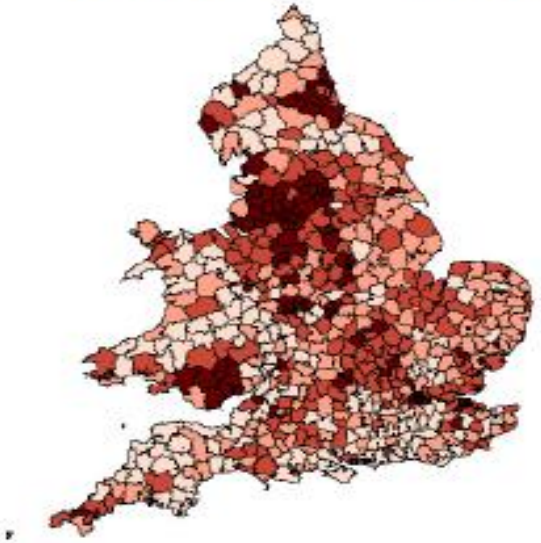
Population density



Infant mortality rate

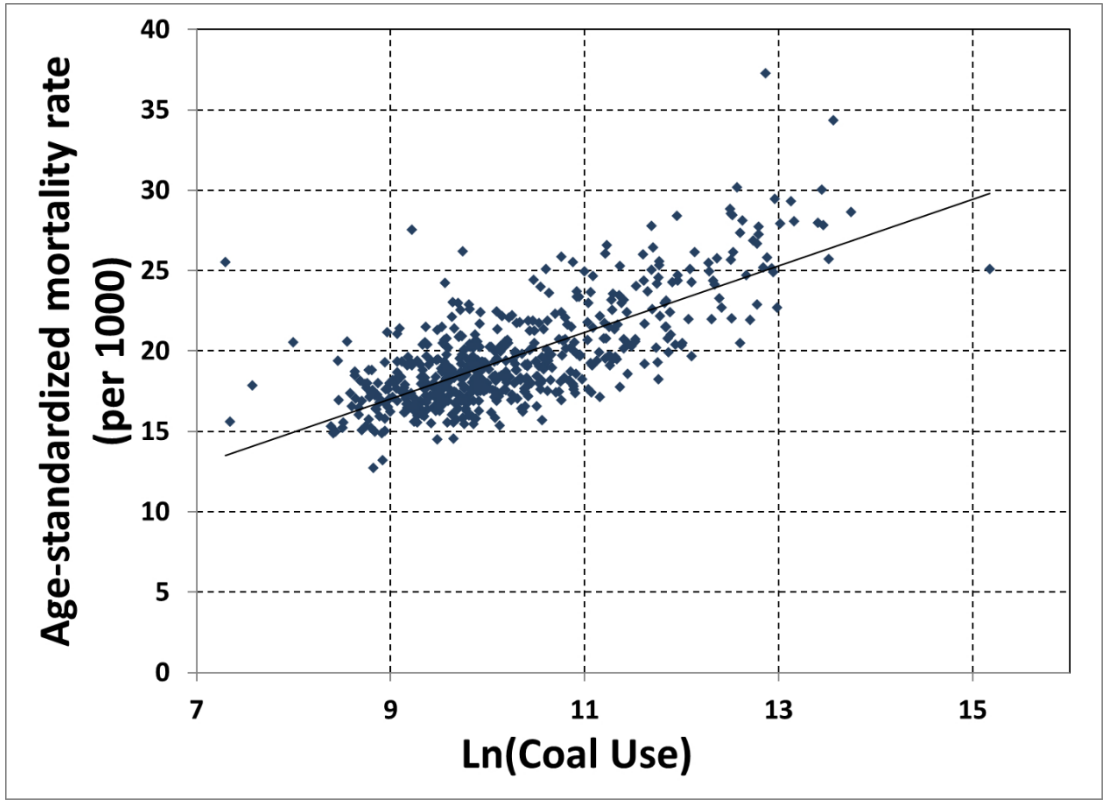


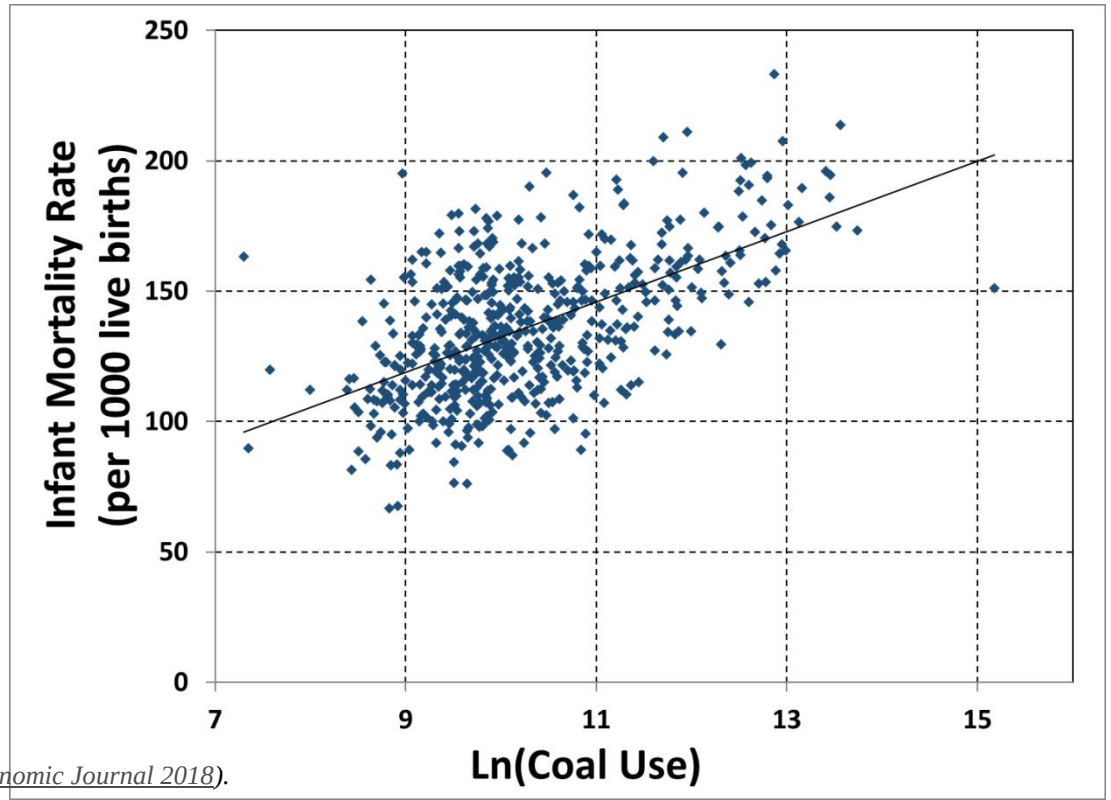
All-age mortality (age-standardized)



Beach, Brian, and W. Walker Hanlon. 2016. Coal Smoke and Mortality in an Early Industrial Economy, WP (later *The Economic Journal 2018*).

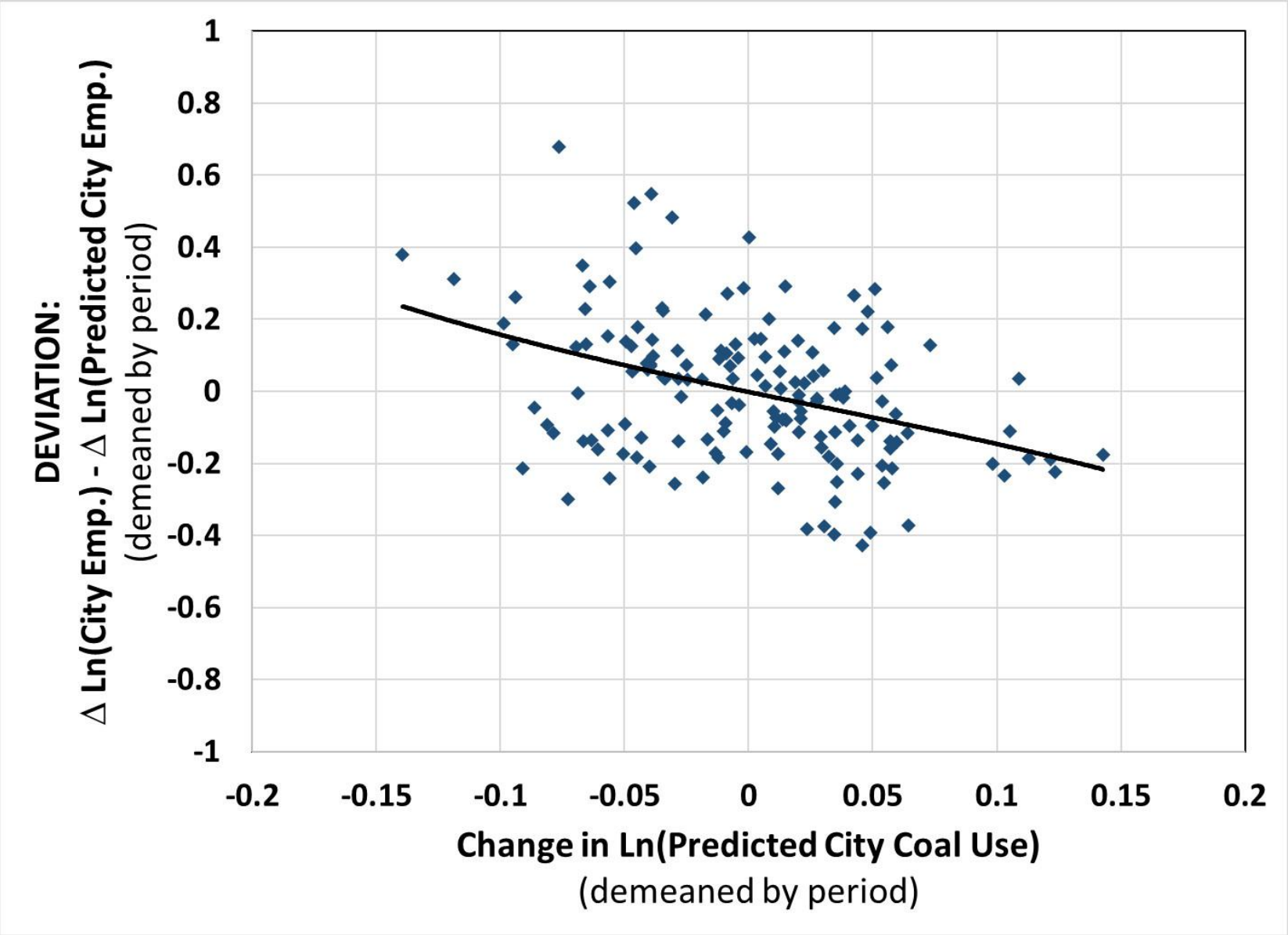
Coal use and mortality





Beach, Brian, and W. Walker Hanlon. 2016. Coal Smoke and Mortality in an Early Industrial Economy, WP (later *The Economic Journal 2018*).

City growth and coal use



Beach, Brian, and W. Walker Hanlon. 2016. Coal Smoke and Mortality in an Early Industrial Economy, WP (later *The Economic Journal 2018*).

And from economic history? The example of Britain

- Huge increase in coal consumption during 19th century… meaning huge increase in air pollution.
  - An important issue for cities (and London especially).
  - Effects of air pollution on mortality, on city growth...
- Coal pollution and health (Bailey, Hatton, and Inwood 2018)
  - Negative effect of coal intensity in a district and adult height.
  - Study at the city level, using an estimation of coal per workers across industries.
  - Indirect measure; source of variation: industrial structure between cities.
- Effect of coal pollution on mortality (Beach and Hanlon 2017)
  - Comparing cities according to coal use but also down/upwind.
  - Strong effect on infant mortality.
- Effect of coal pollution on city growth (Hanlon 2020)
  - Amenity channel: cities are less attractive.
  - Pollution channel: workers in these cities are less productive.

Concluding remarks: conflicting or complementary view of the IR

- Why Britain first? What explains the Industrial Revolution?
  - Institutions? Industrious revolution? Technology? Probably a mix (with a touch of luck).
  - Material vs technological view of the IR share the same general view of economic motivations.
  - Looking at the energy side modify the perception of the revolution.
- A less linear history of economic growth
  - And also less Western-centered, less male-centered, etc.
  - More continuity than transition, more rebuttals than triumphs.
  - Understanding (or at least highlighting) alternative trajectories.
- Better understand the broader social change related to the IR (for lack of a better concept?)
  - History allows to make visible social and power relations behind economic growth.
  - For instance: on environment and energy, e.g., Ecologically unequal exchange (Hornborg).