Economic Development with unlimited supplies of energy: causes and consequences of industrial revolutons

Stephen C. Bannister
Department of Economics
University of Utah
Salt Lake City, Utah 84112, USA
801-581-7481
steve.bannister@econ.utah.edu

Acknowledgements:

My committee:

- Dr. Richard Fowles
- Dr. William Carlisle
- Dr. Thomas Maloney
- Dr. Rudi von Arnim
- Dr. Myron Evans
- Dr. Timothy Garrett
- Dr. John Watkins

My colleagues, students, and supporting friends

And the person who is not here . . .

I dedicate this dissertation to Dr. Stephen Reynolds, who cannot be here with us today

The great energy revolutions

Fire – more efficient human energy inputs – larger brains

Agriculture – surplus

European sail – global trade dominance

Coal – freedom from constrained heat energy inputs

Steam – removing muscle-power energy constraints

I will focus on the last two

Paper one – “What really happened in the English Industrial Revolution?”

Energy and GDP

Energy consumption patterns

Wood-to-coal, toward a theory

Muscle-to-steam, toward a theory

Energy and GDP – one “data generating process”

Period	Pearson Correlation Coefficient: energy and GDP
England 1300-1873	0.998
World 1980-2008	0.993

Table: Energy/GDP correlations – the case for energy revolutions as the historic driving force in economic history

Note that this implies that levels and growth of mean living standards depend on per-capita energy consumption.

Energy consumption matters

Year	England	China	Netherlands	India
1650[a]			0.63	
1820	0.61			
1840[a]			0.33	
1870	2.21			
1970[a]			8.07	0.33
1973		0.48		
1998[b]	6.56	1.18		
2008[b]	5.99	2.56	9.86	

Table: Per-Capita Primary Energy Consumption, annual Tonnes of Oil Equivalent. *Source:* Angus Maddison, [a]de Zeeuw, [b]US DOE EIA

Towards a theory of organic industrial revolutions

Two first energy revolutions: China 900 – 1200 (Northern Sung); England 1590 – 1700:[1]

$$\frac{\text{Marginal Product}_{\text{wood Joule}}}{\text{Price}_{\text{wood Joule}}} \ll \frac{\text{Marginal Product}_{\text{coal Joule}}}{\text{Price}_{\text{coal Joule}}} \quad (1)$$

Causal event – deforestation with increasing population leading to increased wood prices.

[1] This is intended to be didactic, not ideological, i.e. not supporting marginalism in general. Note that replacing neo-classical marginal pricing with more general average prices or prices of production will not affect this theory.

Towards a theory of organic industrial revolutions

Second energy revolution: England 1700 – 1873, but not in China:[2]

$$\frac{\text{Marginal Product}_{\text{labor Joule}}}{\text{Price}_{\text{labor Joule}}} \ll \frac{\text{Marginal Product}_{\text{steam Joule}}}{\text{Price}_{\text{steam Joule}}} \qquad (2)$$

In early-modern England the RHS of (2) was so large because of high wages and low coal prices, that it induced a major positive aggregate supply shock and large positive income effects.

China had low wages and, relatively, high energy prices, so failed to complete its natural industrial revolution.

[2]This is intended to be didactic, not ideological, i.e. not supporting marginalism in general. Note that replacing neo-classical marginal pricing with more general average prices or prices of production will not affect this theory.

Paper two – “China – The empire that did not bark”

A natural experiment

China’s institutional sufficiency

England had what China lacked

The case: China's institutional sufficiency (Peer Vries)

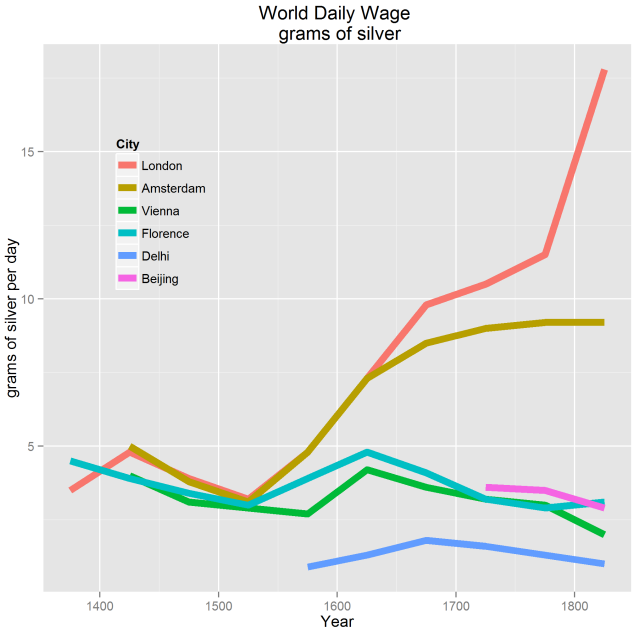
- "Qing China was not a poor and static society but enjoyed a standard of living that was comparable to Europe's right through the early 1800s."
- "Chinese markets were both 'much larger' and 'closer to Smith's model of perfect competition' than markets in Britain."
- "China's foreign trade was 'immense'."
- "Far from being "despotic," the Chinese Qing state was even less intrusive than Britain's: not only was the Chinese army 'comparatively small' but Britain had 'more than 30 times as many public servants per head of the population,' plus Chinese taxes seem to have been lower."
  China was "just as little, an 'open society' as Britain was'." [3]

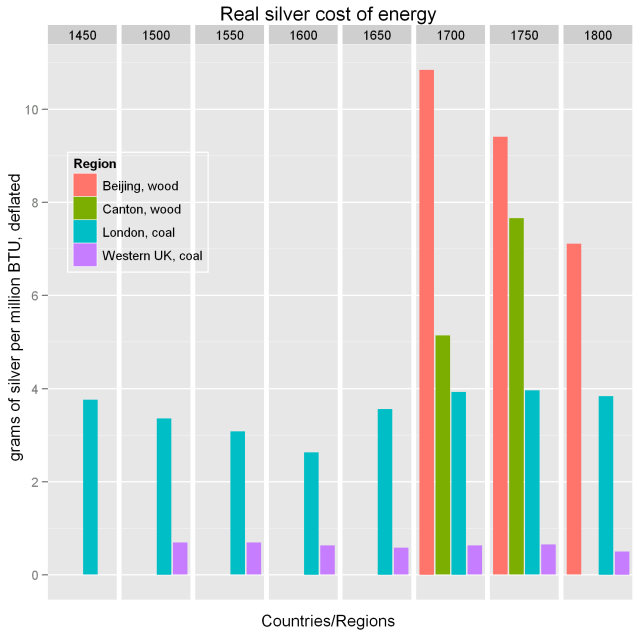
[3] Vries, Peer."Is California the Measure of All Things Global? A Rejoinder to Ricardo Duchesne, 'Peer Vries, the Great Divergence, and the California School: Who's in and Who's Out." World History Connected 2, no. 2 (May 2005). http://worldhistoryconnected.press.illinois.edu/2.2/vries.html.

The case: China's institutional sufficiency (Peer Vries)

- "Even if Weber were right about his claim that Confucianism had 'Weltanpassung' (adjustment to the world) as its ideal, in everyday practice the Chinese were, and are, permanently and intensively active in adapting the world to their will. If in doubt, just take a look at China's endless paddy fields. There was certainly nothing wrong with their rationality, work ethos, business acumen, love of profit, practical sense, or materialism."
- "As late as the end of the eighteenth century, China's agriculture per hectare still was much more productive than Britain's agriculture; in terms of productivity per labourer the differences between both countries or their core regions were minimal."
- "BUT . . . China's economy was not moving away from the Malthusian limitations of the old regime, and was not as ready to industrialize as England."
- Pomeranz and Wong (and others) support this point of view – essentially saying that Europe had no sufficiently different institutions from China to explain the history.

The microeconomics of energy source substitution





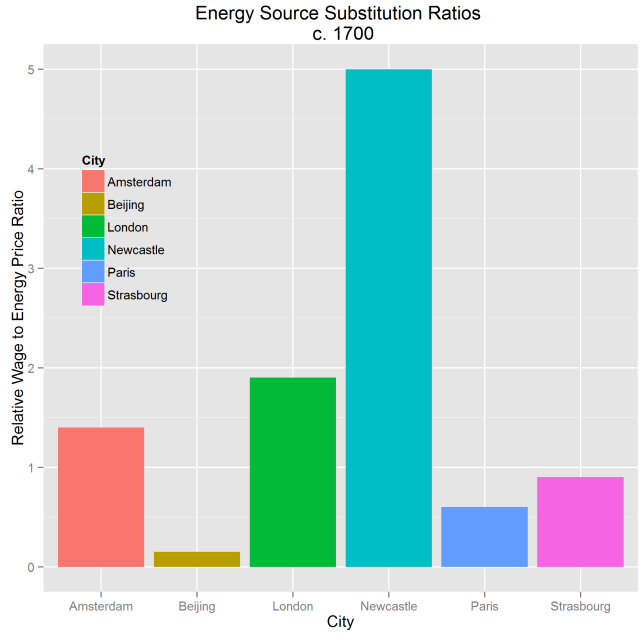


Figure: Robert Allen, world wage and energy costs

Paper three – “The rise and fall of industrial capitalism”

Whence industrial capitalism?

Derived demand for capital elicited supply

Accumulation drove the institution

The fall will be cause by a decline in aggregate demand

Towards a theory of industrial capitalism

All energy revolutions arose in a context of sufficient, ever increasing, effective aggregate demand.

First energy revolutions – wood to coal – were necessary for industrial capitalism, but not sufficient.

First energy revolutions generated large demand for capital – and supply appeared.

Second energy revolutions – muscle to steam – were sufficient.

The second energy revolution magnified the demand for, and supply of, capital. This was the economic change that spawned industrial capitalism.

Whence rising aggregate demand?

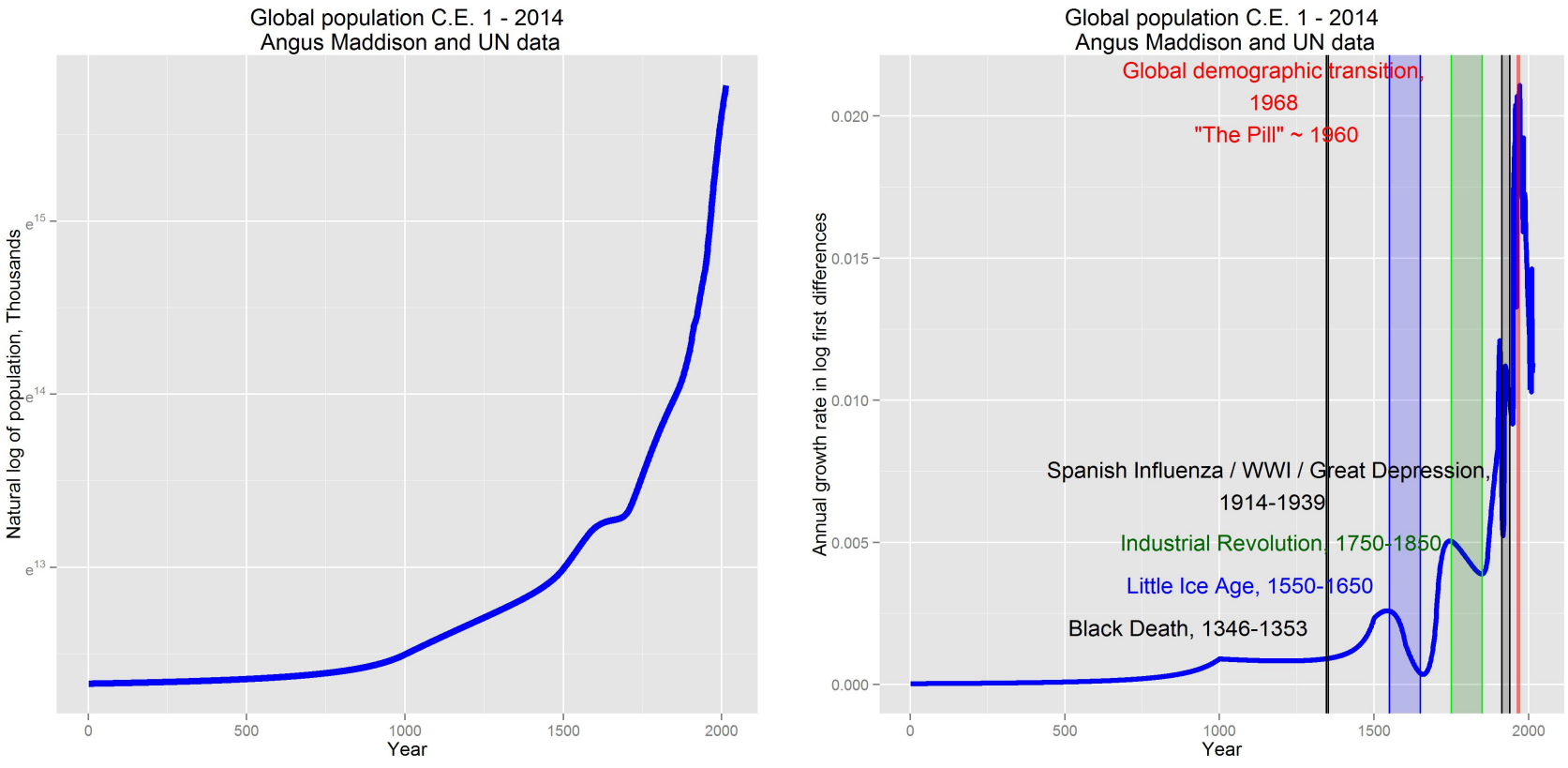


Figure: Angus Maddison and UN: log and log differences of global population levels

John Nef – the coal question

Nef, in “The Rise of the British Coal Industry” (v1, p.380) clearly claims that it was the high capital demand for extraction, production, and transportation infrastructure for using coal from deep (often flooded), distant, and centralized locations that was the root of industrial capitalism. Nef dates the start to the sixteenth century, and it accelerates from there.

Capital supply was from wealthy merchants and landowners, and does not seem to have been a constraint.

Paul Mantoux – the steam question

Mantoux, in “The Industrial Revolution in the Eighteenth Century” details with rich anecdotes the rise of machine industry – the replacement of muscle with steam power in highly centralized factories – and the demand for tangible capital investments that resulted.

As in Nef’s story, capital supply was from wealthy merchants and landowners, and does not seem to have been a constraint.

John Hartwell – The “natural experiment” of Sung China

“From about 750 to 1100, China experienced a series of economic changes roughly comparable to the subsequent patterns of European growth from the Crusades to the eve of the French Revolution . . . and the achievements of late sixteenth- and early seventeenth-century England, which John Nef terms an ‘early industrial revolution,’ were in many respects even exceeded by the impressive expansion of mining and manufacturing in eleventh-century China.” (1966, p.29) [4]

[4] Hartwell, Robert. “Markets, Technology, and the Structure of Enterprise in the Development of the Eleventh-Century Chinese Iron and Steel Industry.” The Journal of Economic History 26, no. 1 (March 1, 1966): 29-58.

John Hartwell – The “natural experiment” of Sung China

Demand for capital – the rise of the coal industry and iron and steel making.

Supply of capital – thirty six “wealthy families,” with merchant capitalism being at least a possible source for their accumulated capital.

Ruttan, Hayami – endogenous technology

Modern work arising from agricultural economics offers theories of technological and institutional change induced by changes in relative resource endowments and technology. This work is founded in microeconomics. Ruttan and Hayami have a good exposition. [5]

[5] Ruttan, Vernon W., and Yujiro Hayami. "Toward a Theory of Induced Institutional Innovation." Journal of Development Studies 20, no. 4 (1984): 203-223. doi:10.1080/00220388408421914.

Karl Marx – endogenous institutions

"The changes in the economic foundation lead sooner or later to the transformation of the whole immense superstructure. In studying such transformations it is always necessary to distinguish between the material transformation of the economic conditions of production, which can be determined with the precision of natural science, and the legal, political, religious, artistic or philosophic – in short, ideological forms in which men become conscious of this conflict and fight it out." [6]

[6] Marx, Karl. A Contribution to the Critique of Political Economy. Charles H. Kerr, 1904.

Summarizing

The very big picture

Summarizing

Rising population causes rising effective aggregate demand and deforestation.

Demand begets supply,
elicits endogenous technology, energy revolutions, and institutions,
causes a rise in demand for, and supply of, tangible capital,
and leads to, with accumulation, industrial capitalism.

The lifting of energy constraints raises productivity and living standards.

The Big Question for political economists: If population-driven rising aggregate demand "caused" the Industrial Revolution and elicited industrial capitalism, will population-driven falling aggregate demand cause the demise of industrial capitalism?