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- Econonomics – general, micro/macro unification
- Welsh economics history
- Podolinski, Fredrick Soddy
- Importance of energy
  - diss2_beamer
  - motion charts

What do economists do?

- Attempt to model complex social systems – Macroeconomics – lots of equilibrium-based models
- Attempt to explain individual (consumer/firm) behaviour – Microeconomics
- Attempt to link them – microfoundations of macroeconomics, network systems with emergent behaviours, stochastic agent-based models

Similarities/dissimilarities with physics

- Use maths in several ways (physics envy?)
  - Theory – so use mostly the same algebras you do (especially linear), although so far no tensor algebra
  - Applied – since difficult to repeat experiments, have evolved a wide set of statistical methods
  - Simulation
- Use scientific methods, processes (publish, etc.)
- Share people – Fredrick Soddy, Wall Streen “quants”
- Narrow vein of thermodynamicists (Sergei Podolinski, Georgescu-Roegen) to whom economics is a thermodynamic system
- Must incorporate institutions and history
- Again, very little repeatability – difficult to “rewind” a macroeconomy since people are involved

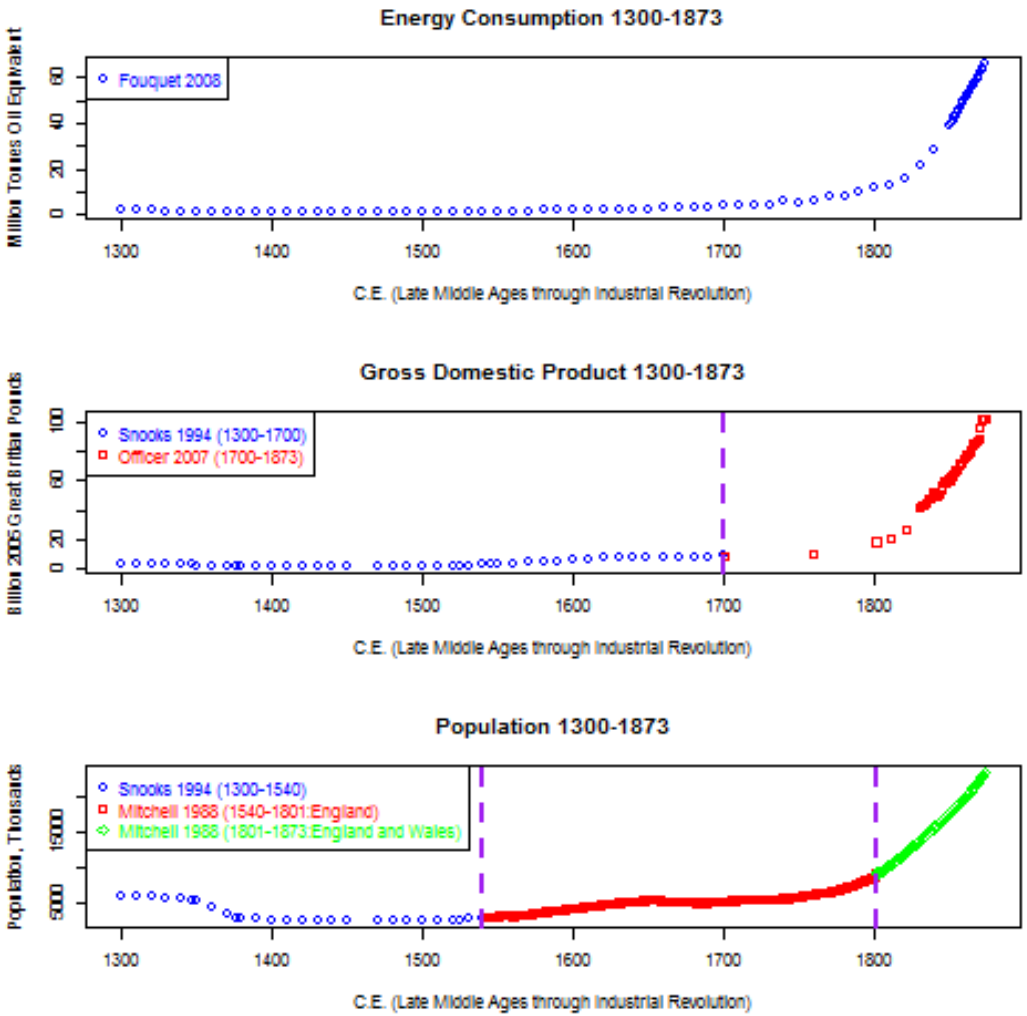
English Industrial Revolution, 1590 - 1876

- Modern economic growth
- Unconstrained quantity of fossil carbon energy – an *energy* revolution led by a demand revolution
- Little statistical space for institutional or cultural events – except to explain structural breaks
- Framework applicable across time series, space, and time

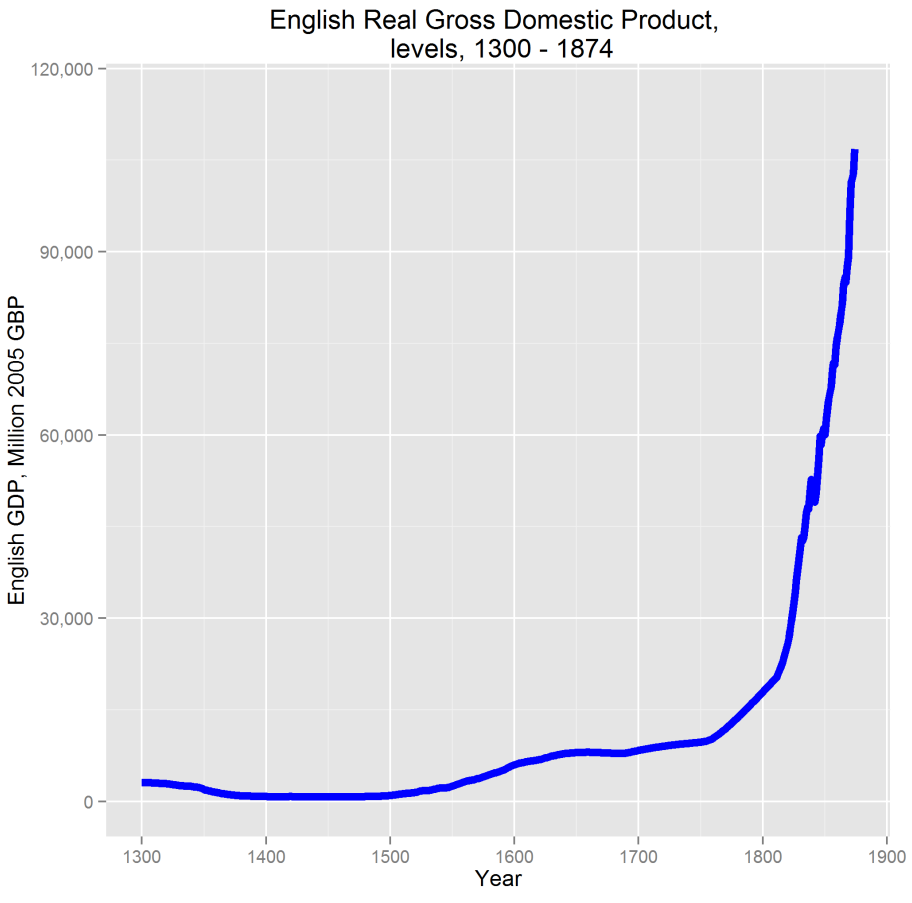
Taxonomy of EIR explanations

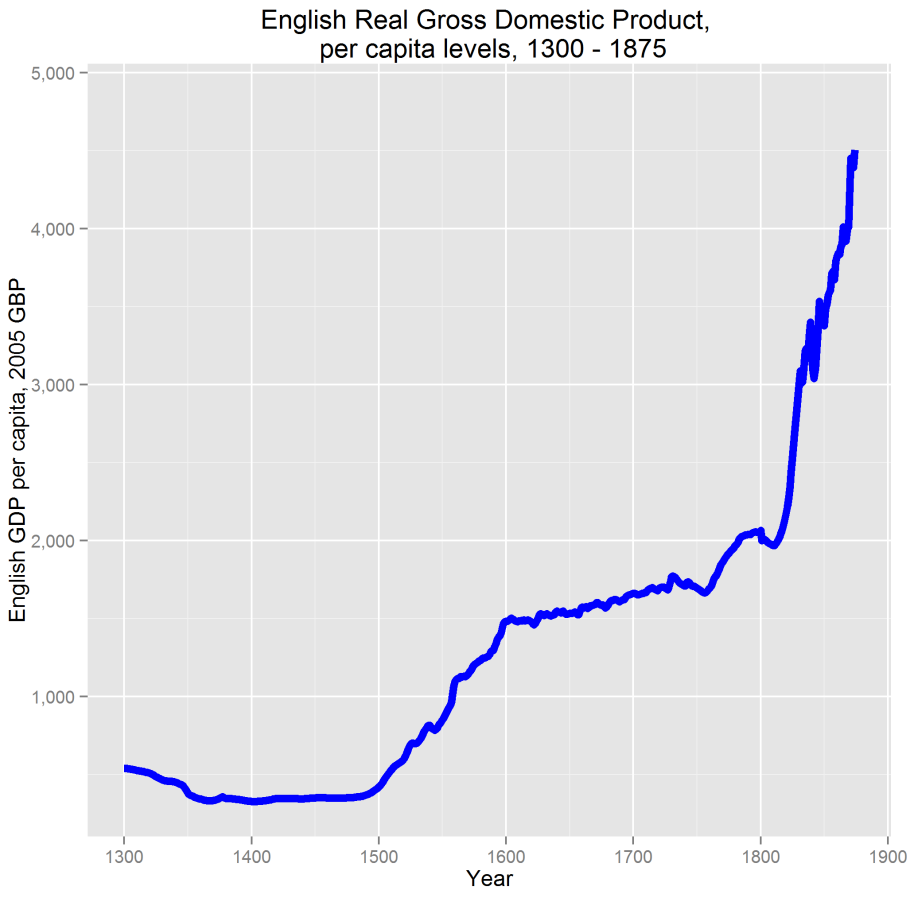
Label	Examples
English exceptionalists	Landes (1969), McCloskey (2010), Mokyr (1992,2010)
Partial culturalists	Cipolla (1966), Pomeranz (2001), Allen (2009)
Primarily energetic	Cottrell (1955), Wrigley (1988,2010), Malanima (2010)
Thermodynamicists	Georgescu-Roegen (1975), Ayres (2003), Garrett (2009)

Author/time-span series of energy consumption, GDP, and population

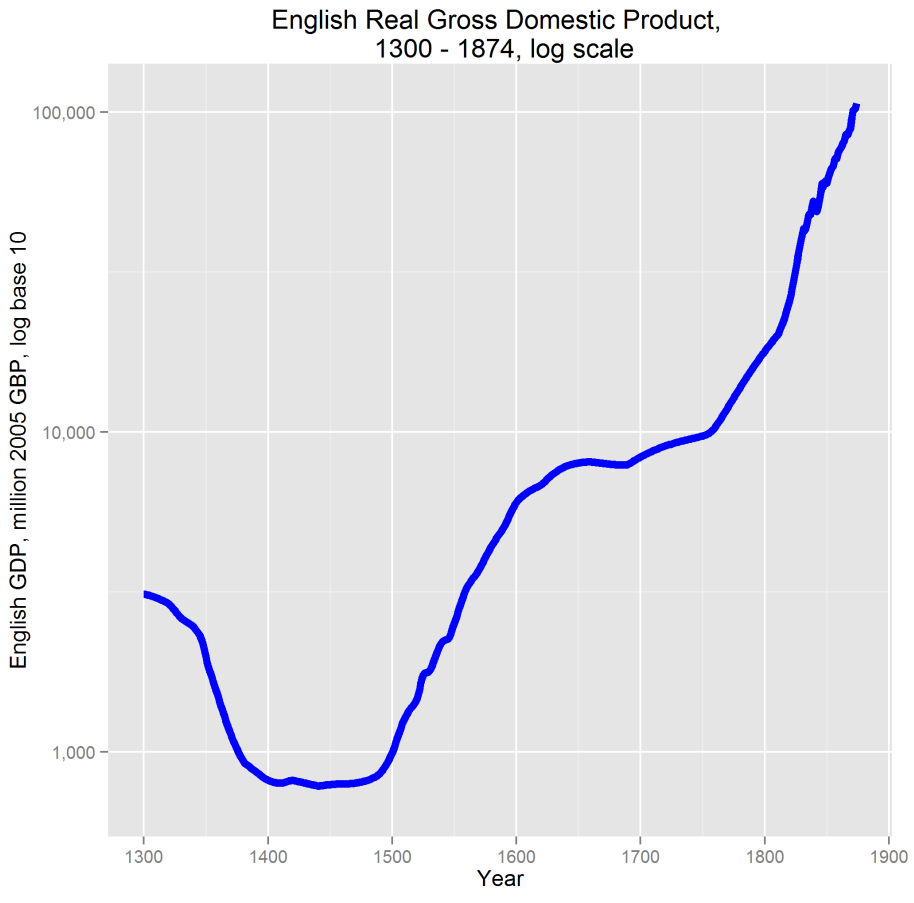


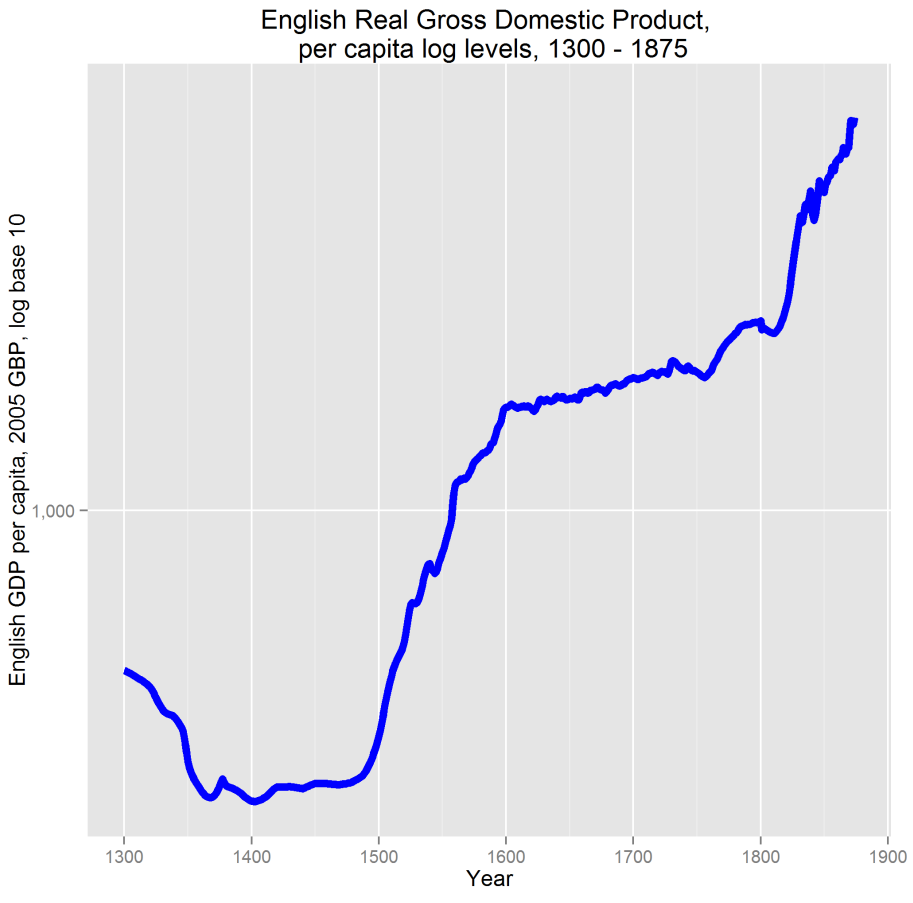
English real gross domestic product, levels and per–capita



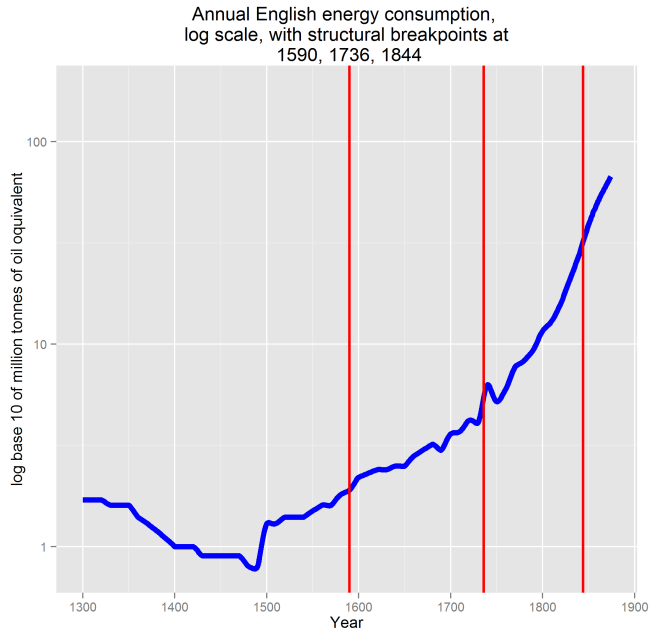


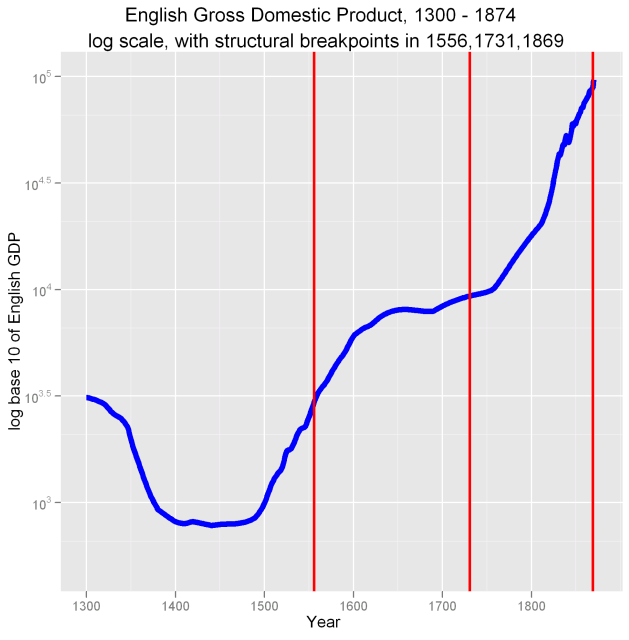
English real gross domestic product, log levels and log per–capita

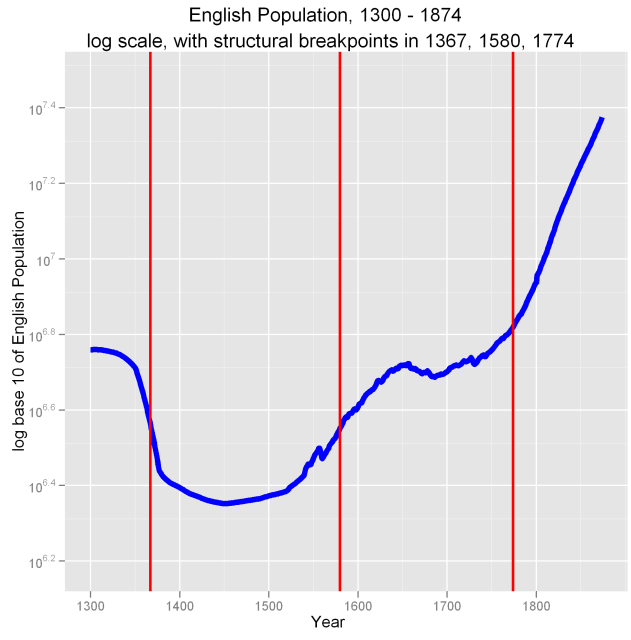




Structural break comparison



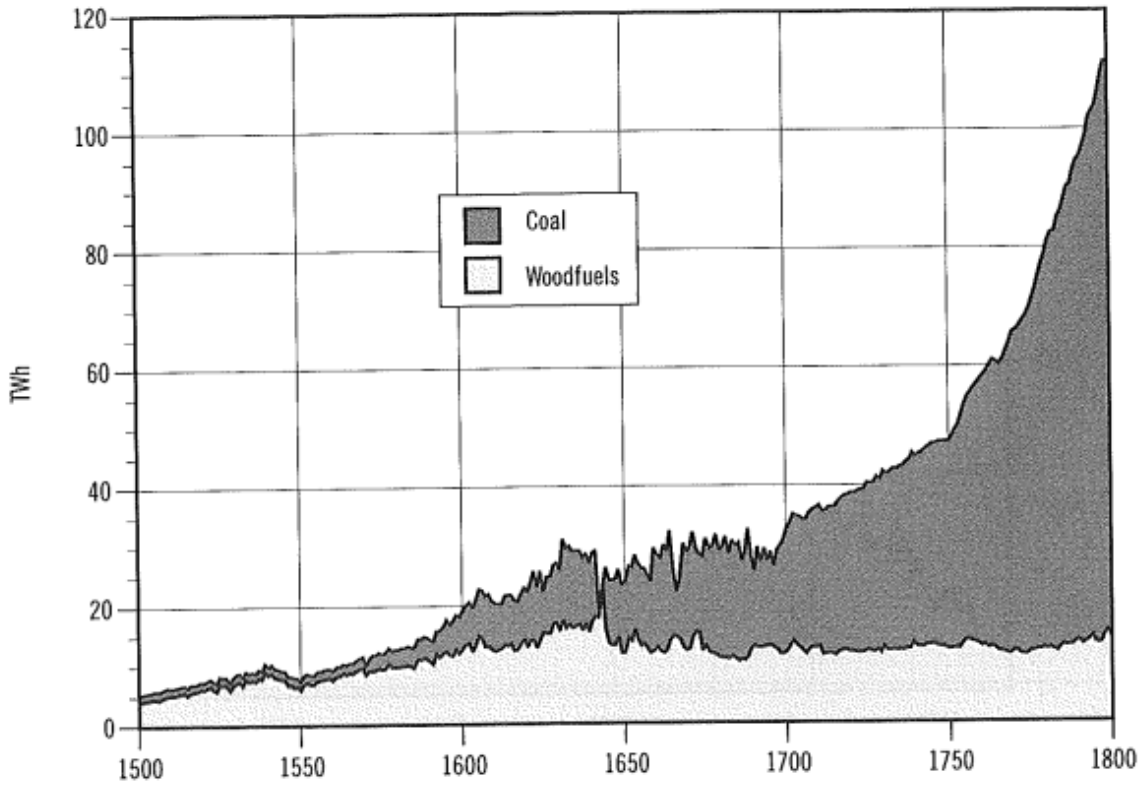




Coal and wood energy sources

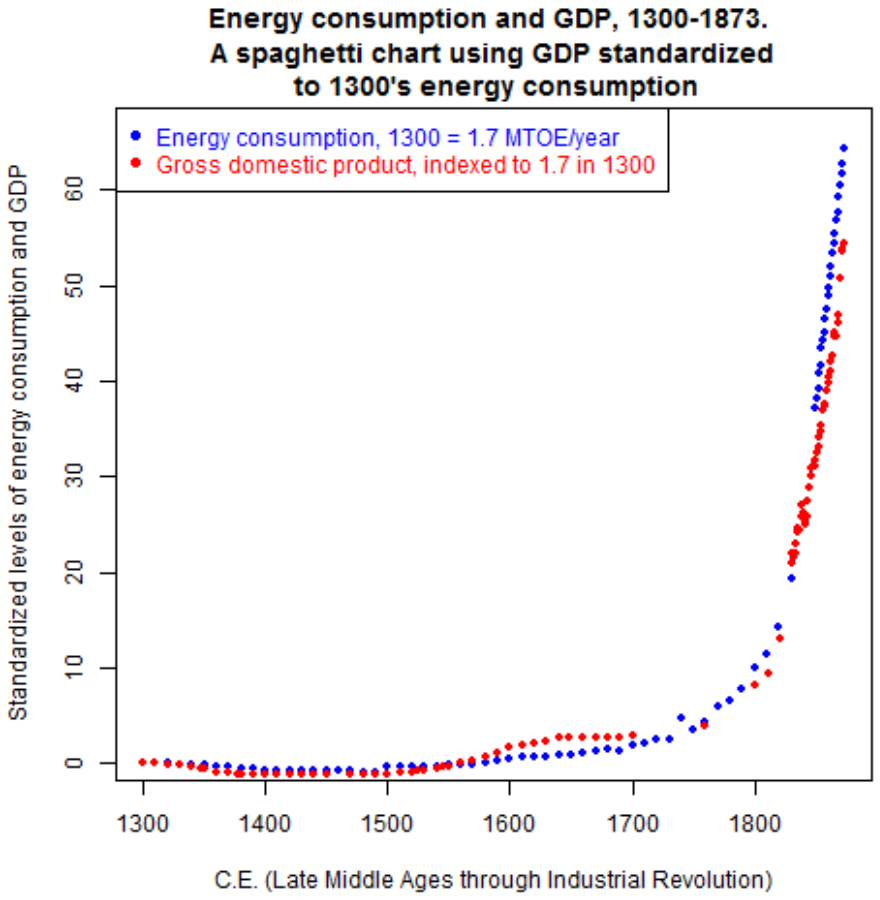
Source: Pearson & Fouquet

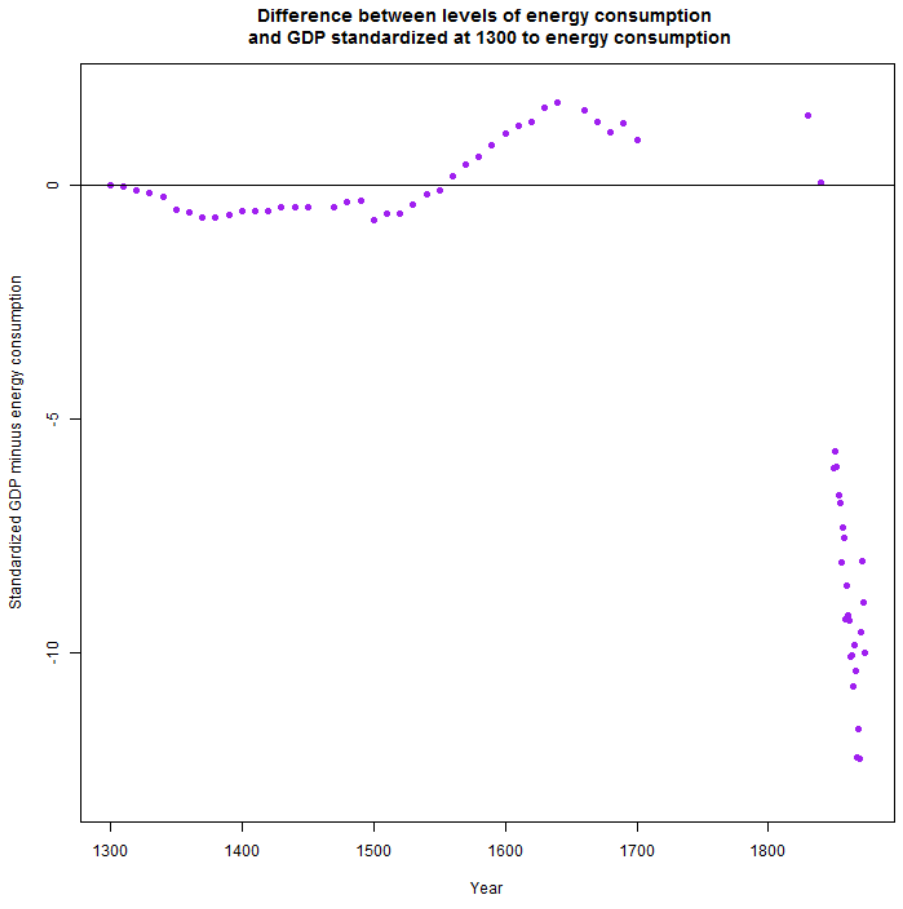
Figure 4: Energy consumption by final users (terawatt hours (TWh)), 1500–1800



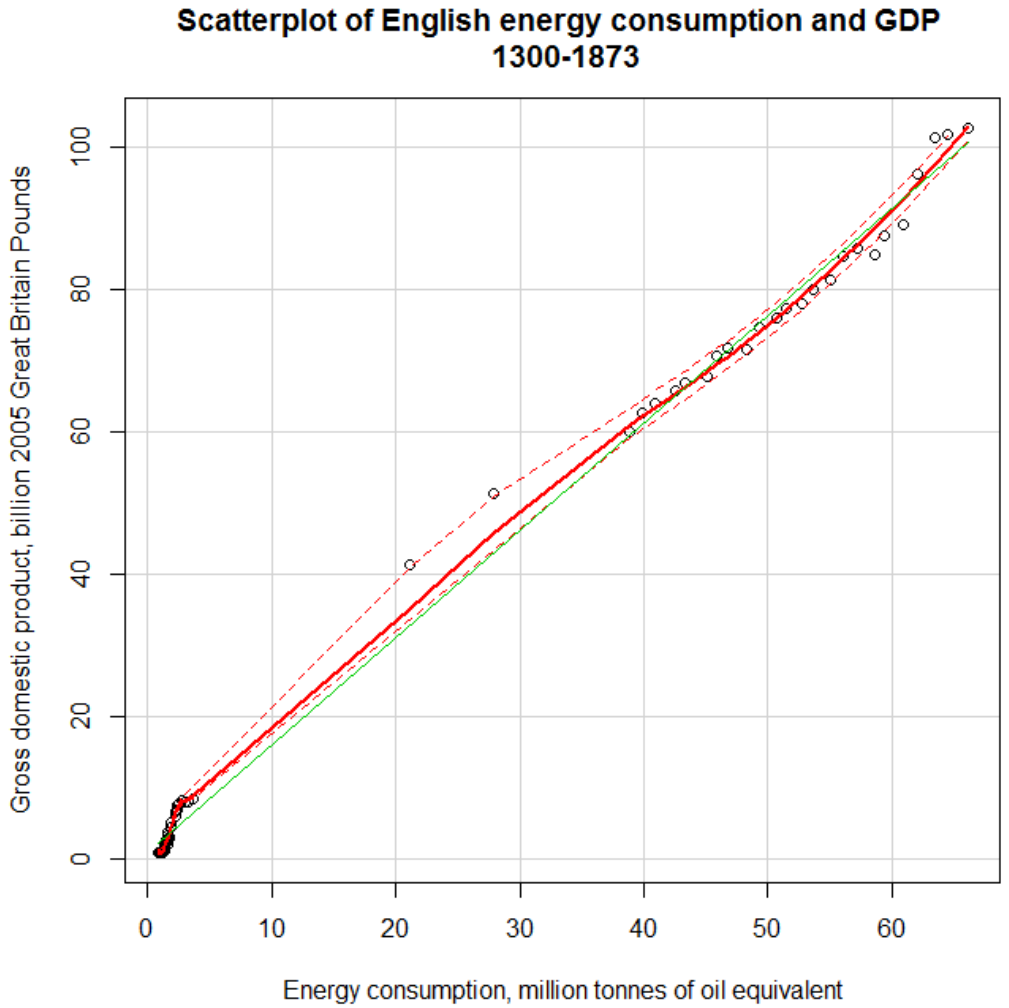
Note: The consumption of candles is not visible in this graph: even by 1800, it was only equivalent to 0.5TWh, while in 1500 it was only 0.1TWh. As a percentage share, it is just visible between 1500 and 1700, with its maximum value being around 4% of energy used (see Figure 10).

Energy consumption vs. standarized GDP





Scatterplot of energy consumption vs. GDP



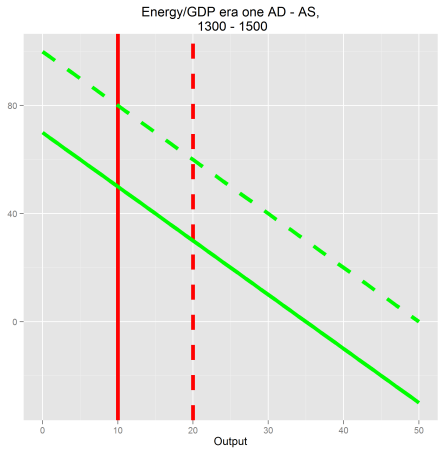
No “Solow” residual

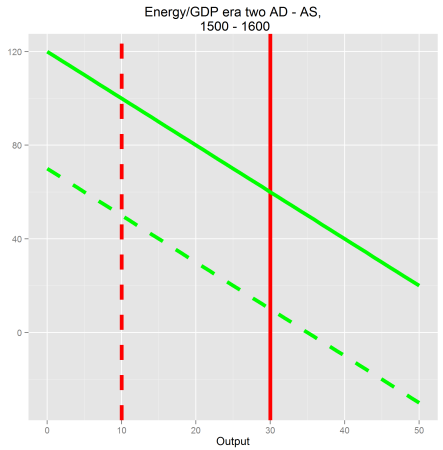
Granger tests of energy/GDP dynamics

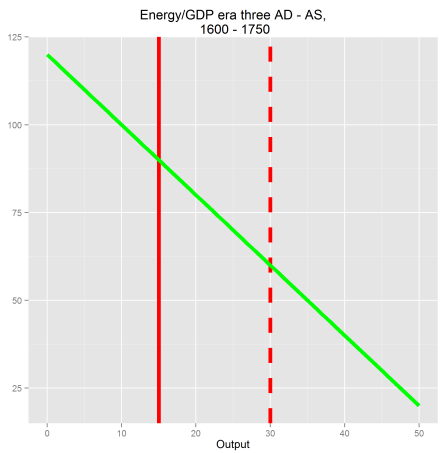
Era	Energy ~ GDP Pr(>F)	GDP ~ Energy Pr(>F)	AS/AD regime
1300 – 1500	0.0106	0.0003	EMP [1], Black Death: increasing wages, family income
1500 – 1600	0.1939	0.6126	Positive demand shock
1600 – 1750	0.3529	0.5185	Energy supply constraint
1750 – 1873	0.0024	0.1100	Positive supply shock: “virtuous” macro feedback cycle
1300 – 1873	0.0002	0.0361	Total study period

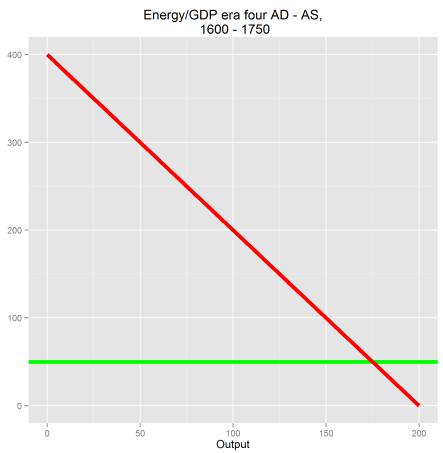
[1] European marriage pattern (Hajnal)

Aggregate Supply - Aggregate Demand
Four energy/GDP regimes









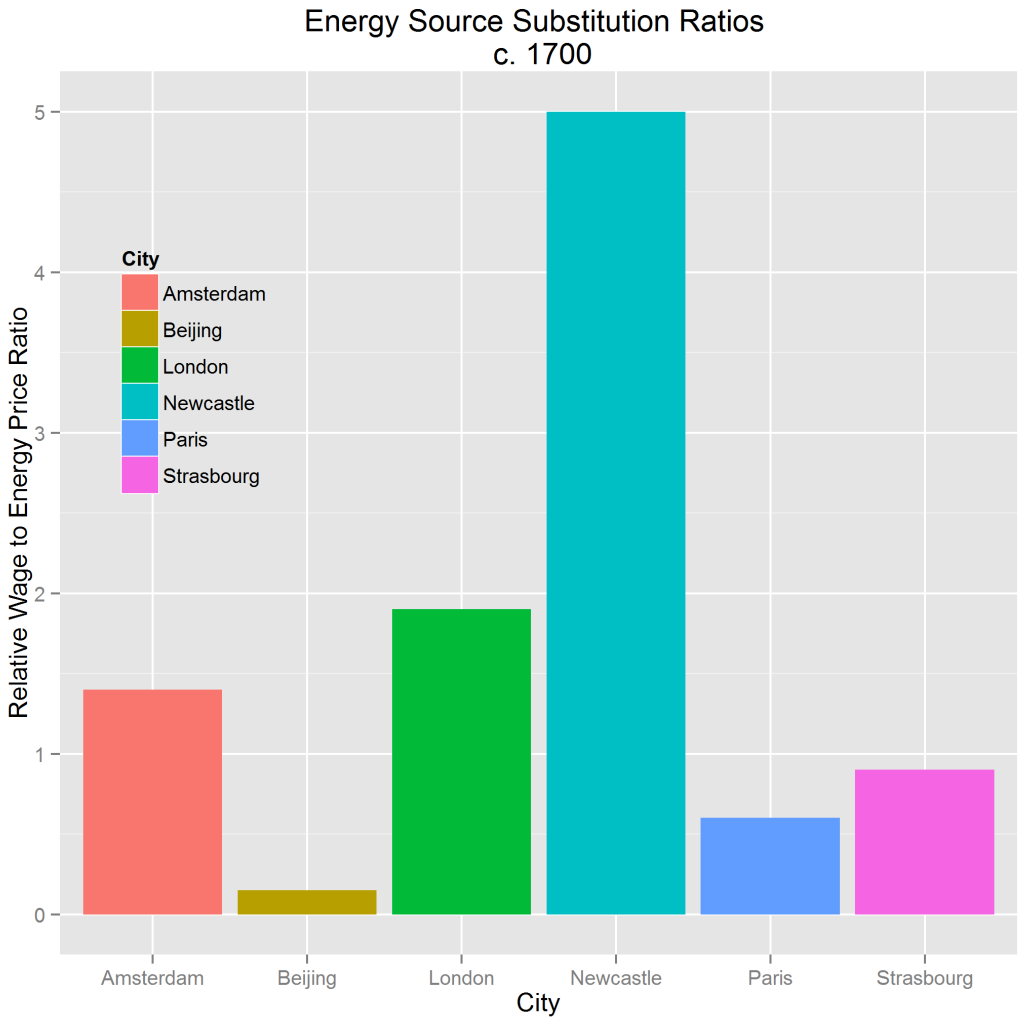
Desagulier manuscript

rection P *p*, and a Quantity of Water properly [illegible] be lifted up, and run out at P. This may be done 15 or 16 times in a Minute, becauſe each Man would pull down but 30 Pounds at a time, after the manner that People ring Bells. But as no Time is to be loſt, leſt the Mine be overflow'd by the Springs below, there muſt be 100 more Men to relieve theſe when they are weary. Now as it muſt be a rich Mine indeed whoſe Profit can afford to keep 200 Men at this Work; that

Lect. XII. Place 36.

that Thought muſt be laid aſide. We'll conſider therefore what can be done by Horſes. As an Horſe is equal to five Men, we muſt work 20 Horſes at a time to raiſe the Water requir'd; and as Horſes muſt be reliev'd even more than Men, about 50 Horſes muſt be kept to carry on this Work conſtantly, and bring down the End of the Beam *b*, 16 times in a Minute, and make the number of Strokes requir'd in the Pump, the Weight of whoſe Rod after every Stroke will bring down the End *b* 2, by drawing along the Tangent *i* H. It is plain to any body, that tho' the Horſes may be had cheaper than Men, yet that will be a very expenſive way. For the next Contrivance, we'll ſuppoſe a Philoſopher to come, and find a means to bring down the End of the Beam, without Men or Horſes, in this manner. To the Chain H L he fixes a

Real wage to energy ratios
Source: Robert Allen (2009)



Microeconomic theory

$$\frac{\text{Marginal Revenue Product}_{\text{organic energy joule}}}{\text{Price}_{\text{organic energy joule}}} = \frac{\text{Marginal Revenue Product}_{\text{fossil energy joule}}}{\text{Price}_{\text{fossil energy joule}}} \tag{1}$$

English Industrial Revolution, 1590 - 1876

- Modern economic growth
- Unconstrained quantity of fossil carbon energy – an *energy* revolution led by a demand revolution
- Little statistical space for institutional or cultural events – except to explain structural breaks
- Macro and micro explain a great deal
- Framework applicable across time series, space, and time

Thank you

English wood enegy supply constraint

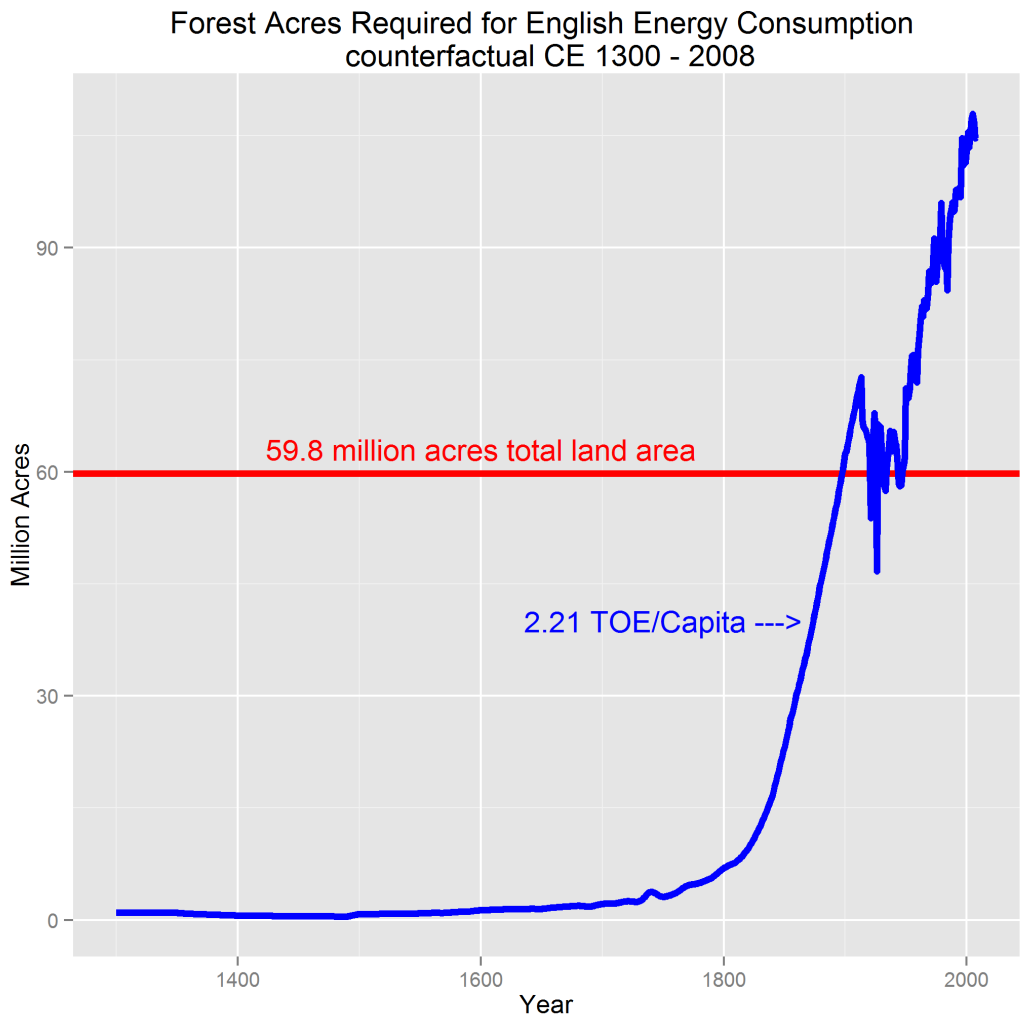


Figure: Standardized English energy intensity of GDP

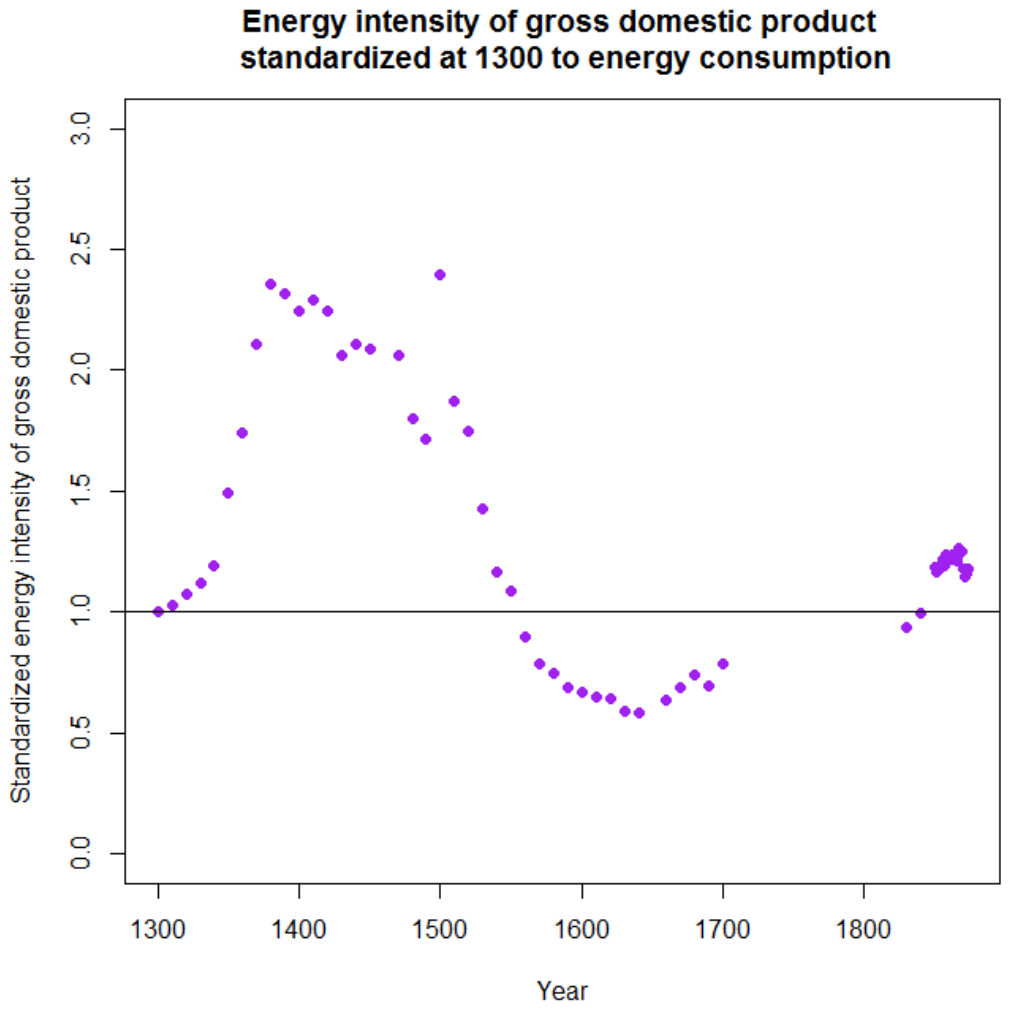


Figure: Log of GDP, with structural breaks

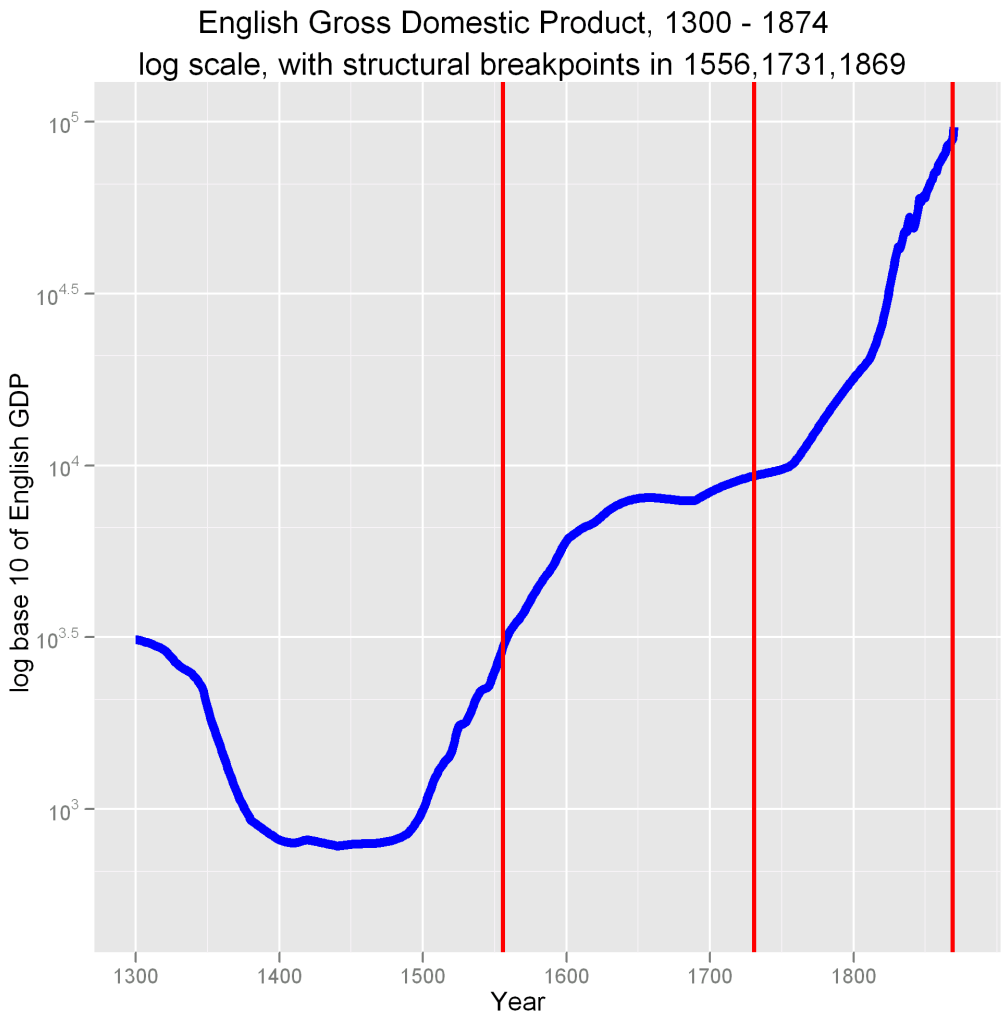
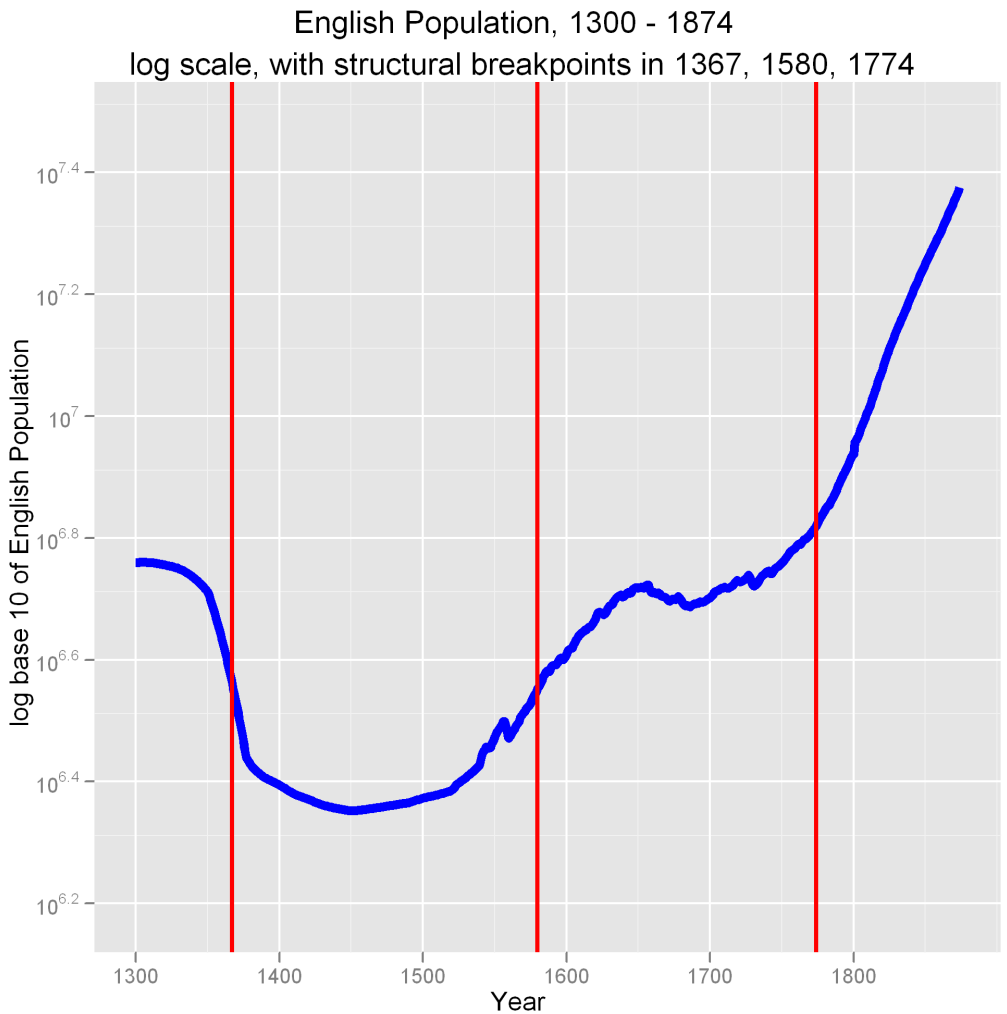


Figure: Log of population, with structural breaks



Data Sources

Data series	Year range	Geography	Source
Energy consumption	1300 – 1873	England/Wales	Roger Fouquet (2008)
Gross domestic product	1300 – 1700	England	Graeme Snooks (1994)
	1741 – 1873	England/Wales	Lawrence Officer (2009)
Population	1300 – 1540	England	Graeme Snooks (1994)
	1541 – 1800	England	B. R. Mitchell (1988)
	1801 – 1873	England/Wales	B. R. Mitchell (1988)

Table: growth rates by century

Year	1300	1400	1500	1600	1700	1801	1873	Total
GDP Million 2005 GBP	3114.7541	815.1288	994.4571	6031.953	8361.5911	18110	102811	
Century-over-century rate of growth		-0.738	0.220	5.066	0.386	1.166	4.677	32.008
Compounded annual rate of growth		-0.013	0.002	0.018	0.003	0.008	0.024	0.006
Energy consumption	1.7	1	1.3	2.2	3.6	11.6	66.1	
Century-over-century rate of growth		-0.412	0.300	0.692	0.636	2.222	4.698	37.882
Compounded annual rate of growth		-0.005	0.0026	0.005	0.005	0.012	0.024	0.006
Per-capita GDP 2005 GBP	542	329	421	1,484	1,663	1,999	4,392	
Century-over-century rate of growth		-0.393	0.282	2.521	0.121	0.202	1.198	7.108
Compounded annual rate of growth		-0.005	0.002	0.013	0.001	0.002	0.011	0.004

Table: Energy and GDP fit tests

Test	Statistic	p-value
Pearson's correlation	0.998	
Paired t-test	5.592	4.991e-07
Chi-square	2864	0.0004998