

# What *really* happened in the English Industrial Revolution?

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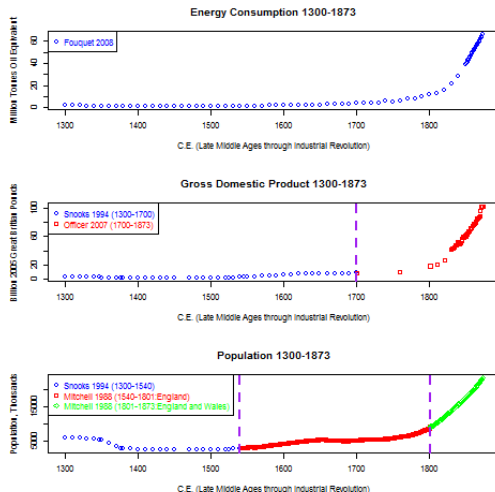
# English Industrial Revolution, 1590 - 1876

- 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

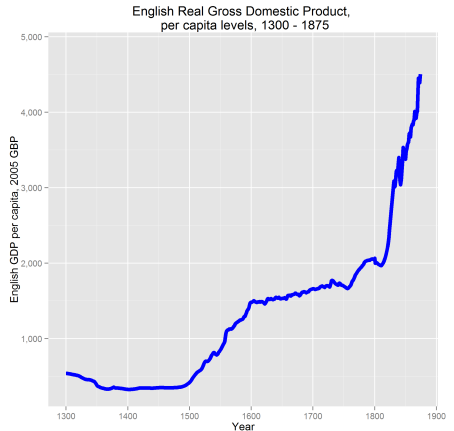
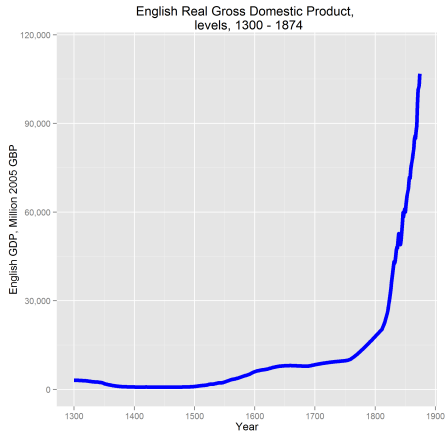
# Taxonomy of EIR explanations

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)

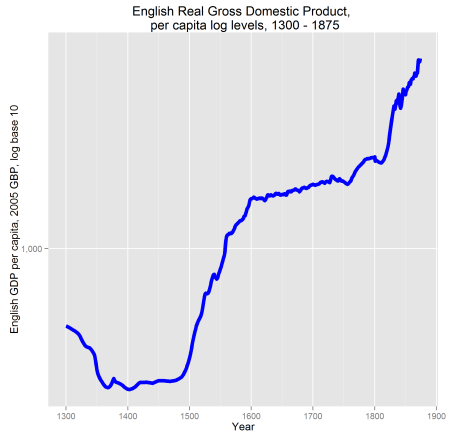
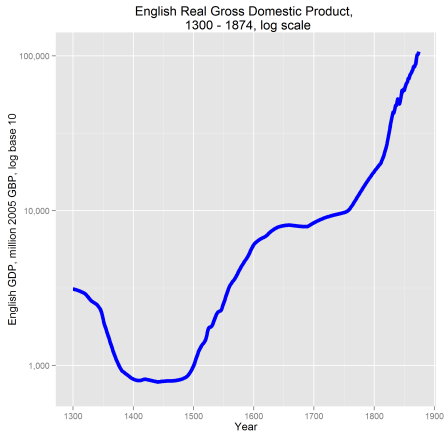
# Author/time-span series of energy consumption, GDP, and population



# English real gross domestic product, levels and per-capita

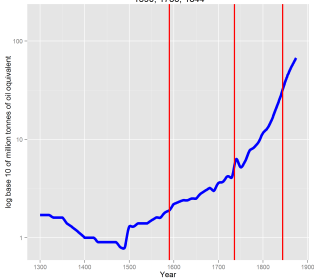


# English real gross domestic product, log levels and log per-capita

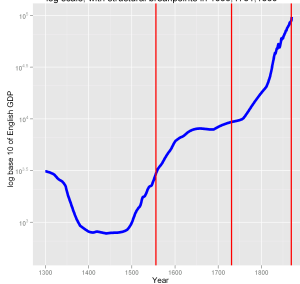


# Structural break comparison

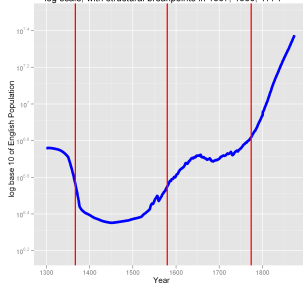
Annual English energy consumption,  
log scale, with structural breakpoints at  
1590, 1736, 1844



English Gross Domestic Product, 1300 - 1874  
log scale, with structural breakpoints in 1556, 1731, 1869



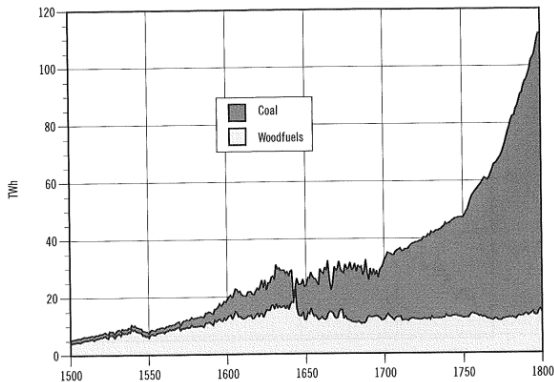
English Population, 1300 - 1874  
log scale, with structural breakpoints in 1367, 1580, 1774



# Coal and wood energy sources

Source: Pearson & Fouquet

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

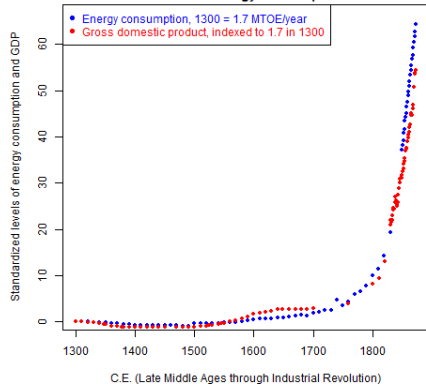


*Note:* The consumption of candles is not visible in this graph; even by 1800, it was only equivalent to 0.5TWh, while in 1500 it was only 0.1TWh. As a percentage share, it is just visible between 1500 and 1700, with its maximum value being around 4% of energy used (see Figure 10).

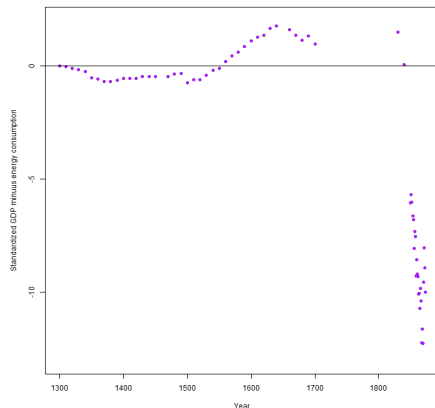


# Energy consumption vs. standardized GDP

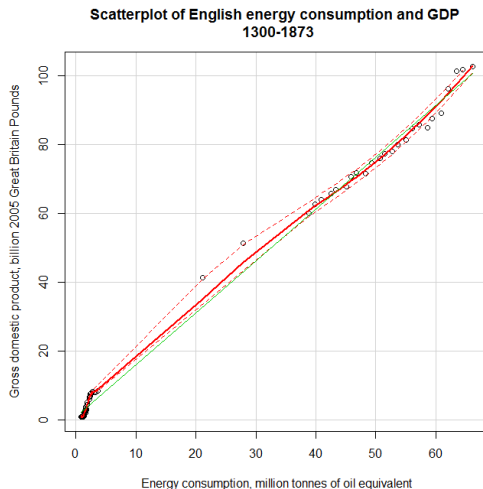
Energy consumption and GDP, 1300-1873.  
A spaghetti chart using GDP standardized  
to 1300's energy consumption



Difference between levels of energy consumption  
and GDP standardized at 1300 to energy consumption



# Scatterplot of energy consumption vs. GDP



No “Solow” residual

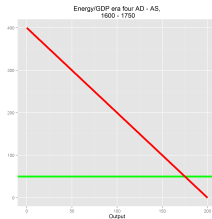
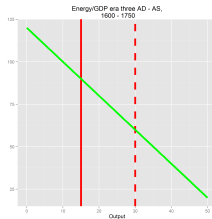
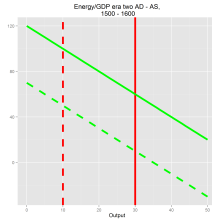
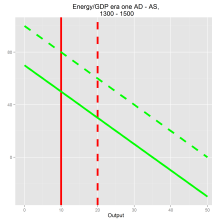
# Granger tests of energy/GDP dynamics

Era	Energy ~ GDP $\Pr(>F)$	GDP ~ Energy $\Pr(>F)$	AS/AD regime
1300 – 1500	0.0106	0.0003	EMP <sup>1</sup> , 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

<sup>1</sup>European marriage pattern (Hajnal)

# Aggregate Supply - Aggregate Demand

## Four energy/GDP regimes



## Desagulier manuscript

rection P  $\phi$ , and a Quantity of Water per Minute  
 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

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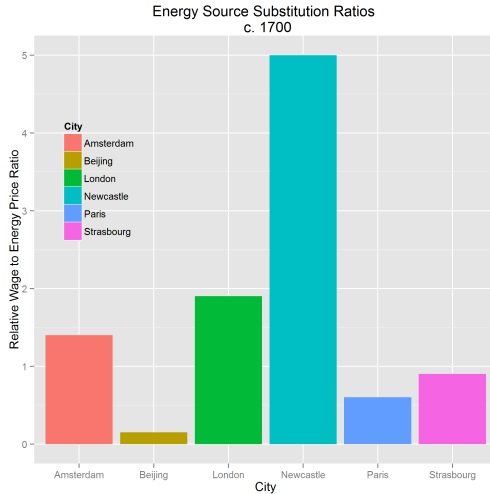
## FIRE-ENGINE.

Left. XII. 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 re-  
 liev'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, with-  
 out Men or Horses, in this manner. To the Chain H L he fixes a

Place 36.

# Real wage to energy ratios

Source: Robert Allen (2009)



# Microeconomic theory

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

## 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 energy supply constraint

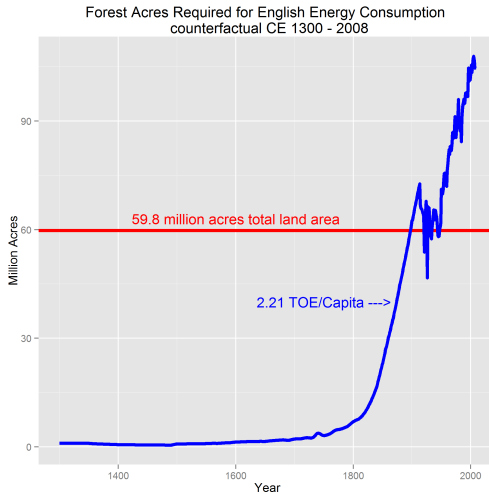


Figure: Standardized English energy intensity of GDP

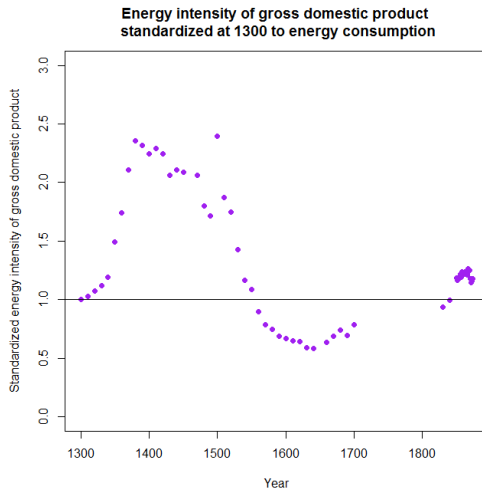


Figure: Log of GDP, with structural breaks

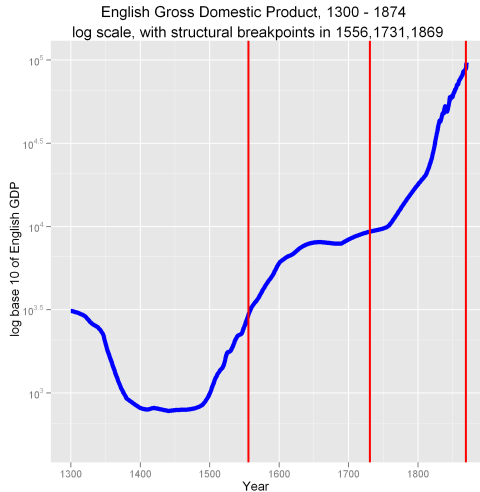
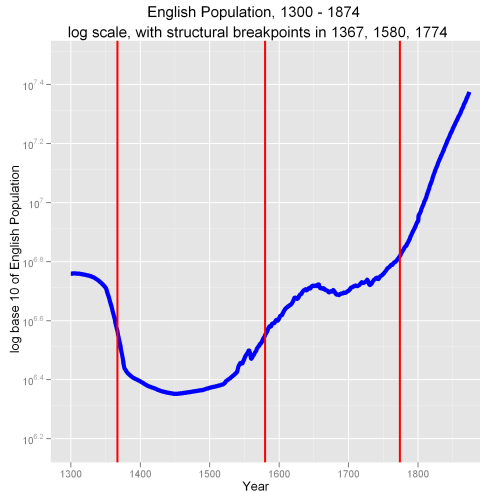


Figure: Log of population, with structural breaks



## 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