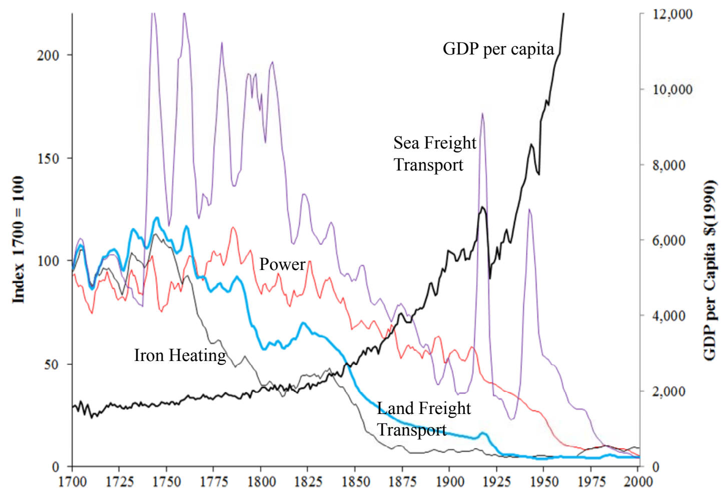
The Role of Energy Technologies in Long Run Economic Growth

By Roger Fouquet*

What will be the implications of a transformation of the global energy system for economic growth? A first step towards answering this question is to understand the powerful effects previous periods of energy system transformation have had on economic growth and development. Afterall, the transition out of coal and towards oil, and the associated low oil prices between 1945 and 1973 and again from 1986 to 2005, were undoubtedly critical to the booms after the Second World War and in the 1990s and early 2000s (Hamilton 2013)[1].

Similarly, cheap coal has been seen as pivotal to the Industrial Revolution in Britain (Allen 2009). Along with cheap energy sources, these periods experienced dramatic technological development. Together, the cost of energy services (Nordhaus 1996) – that is, of heating, power and transportation - fell dramatically over the last two hundred years (see Figure 1). However, a lack of data has previously hampered attempts to assess the influence of energy and related technologies on long run economic growth.



Source: Fouquet (2011), Broadberry et al (2011)

Figure 1. Price of Energy Services (and GDP per capita) in the United Kingdom, 1700-2010

Purpose and Methods

By combining two new data sets on GDP per capita (Broadberry et al 2011) and the price of energy services (Fouquet 2011), this study offers preliminary evidence on the impact of the changing effect of energy service prices on the First (1760-1830) and Second (1870-1913) Industrial Revolutions. Following the similar approach as Fouquet and Pearson (2012) and Fouquet (2014), a vector error correcting model was used to provide an econometric analysis of the data and the trends, and (where non-stationary was present) estimate the cointegrated relationship between GDP per capita and energy service prices.

By looking at energy services, this study effectively combines the physical capital and energy as complements into a single variable. While it is accepted that many other variables are relevant for determining past economic growth (and there is a risk of omitted variables), this study focusses on the three key energy services for productive and distributive activities, heating, power and transport.

Results

The preliminary econometric estimates indicate that the British economy benefitted from a series of declines in energy service prices. However, their influence on growth varied considerably over time and at different levels of economic development. To identify the pivotal declines in energy service prices, it is important to compare the econometric results in Figure 2 (showing when changes in energy services price had a greater impact on per capita GDP) with the data in Figure 1 (showing when enery service prices actually fell).

Based on this evidence, the First Industrial Revolution (1760-1830) may have been kick-started, from the late 1750s, by the decline in the costs of industrial heating for iron production (or smelting, to be more precise). Charcoal had traditionally been used for smelting iron. While Abraham Darby had introduced a new method for smelting iron by using coke in 1709, it only became cheaper to use from the 1740s (Fouquet 2008). Also, these new coking furnaces were relatively large and capital-intensive, requiring significant and initially risky investments. In addition, they needed major and reliable supplies of coal. As their efficiency improved (the fuel requirements fell from ten to four tonnes of coke per tonne of pig iron produced (Smil 1999 p.167)) and freight transport improved, the price of iron smelting fell. Pig iron production rose from 28,000 tonnes in 1750 to 285,000 tonnes by 1800 - accounting for more than 10 percent of total British coal use (equivalent to one million tons of oil). Coke iron

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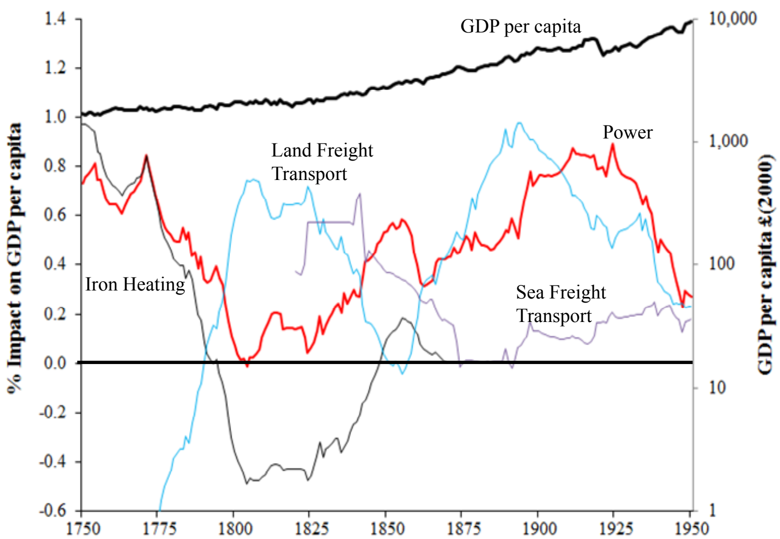

Source: see Appendix

Figure 2. Impact of % Decline in Energy Service Prices on % Increase in GDP per capita, 1750-1950

was particularly valuable for cast iron products, such as stoves, firebacks, and steam engines.

The econometric evidence also indicates that, during the First Industrial Revolution, cheaper power, from the 1780s, boosted economic growth, until about 1800. Prior to the Industrial Revolution, animals, particularly horses, provided around 70% of all the power needs in Britain (Fouquet 2008). So, the supply of energy (i.e., fodder or provender) for most power depended on agricultural production. While water and wind mills provided around one-tenth of the power during the eighteenth century, the major decline in the price of power occurred as steam engines were gradually adopted - first, from the early 1700s, to extract coal, then, from the 1750s, to bellow coke iron smelting, and, from the late 1780s, for cotton spinning (Nuvolari et al 2011).

Finally, in the 1780s and 1790s, the economy appears to have also been stimulated by declines in the prices of land freight transport. These declines were prinicipally associated with improvements in transport management, including better road maintenance, road surfaces and horses. As mentioned, these were critical for driving down the costs of fuel inputs for iron production, as well as most other industrial activities, and delivering products. Thus, the evidence from the data and econometric results indicate that energy transitions and energy efficiency improvements, combined with better transport services, were pivotal to the First Industrial Revolution.

A 'Second' Industrial Revolution appears to have been kick-started, in the 1830s and 1840s, by cheaper land and sea freight transport. The expanding railway network provided cheap and rapid distribution of goods around the country. From the 1830s, the improvements in sailing ships and then their eventual replacement by steam ships enabled Britain to export its low-cost products around the World.

Despite the apparent role of steam power in the First Industrial Revolution, its widespread use only occurred during the second half of the nineteenth century, as the efficiency of steam engines tripled between 1850 and 1900 – leading to fourfold decline in the price of steam power and a halving of the average price of power (Figure 1). While transport's role started to ebb from 1890s, the influence of industrial power on economic growth continued to increase until the 1920s, peaking with the advent of electricity. In addition to the declining prices for power, the shift from steam engines to electricity enabled a much more flexible and decentralised production process (Devine 1983).

Conclusions

Despite the prelimary nature of the results and the limitations of transferring lessons from the past (especially distant past), this analysis provides a number of insights for the potential implications of future energy system transformations. First, cheaper energy and particularly major improvements in energy efficiency appear to have had (and are likely to have) major influences on economic growth and development (including possibly changing the nature of production and consumption processes). Second, the energy services that will kick-start and drive major periods of economic growth and development change – and these will be particularly hard to anticipate. For instance, despite major innovations that reduced the cost of iron production greatly in the mid-nineteenth century (including the use of hot blasts and waste gases), these only had a modest impact on increases in GDP per capita. Thus, it is worth considering which energy services have the potential to kick-start and to push forwards a New Industrial Revolution, and what transformations in the global economy they are likely to stimulate.

Footnote

[1] See Ayres and Warr (2009), Stern and Kander (2012) and Ayres and Voudouris (2014) for other studies of the impact of energy on economic growth.

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