Insights from Historical Analyses: A Low-Carbon Industrial Revolution?

Peter Pearson, Cardiff University

Tim Foxon, Leeds University

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A Low Carbon Industrial Revolution?

- Policy-makers & academics have argued that a UK low carbon transition could/should amount to a ‘low carbon industrial revolution’.
- Two propositions underlie this suggestion.
  - The productivity gains & economic benefits from a low carbon transition would resemble those of past revolutions, making such a transition economically & environmentally desirable (Huehne 2011, Rifkin 2011).
  - The scale of changes in technologies, institutions & practices needed to reduce GHG emissions is comparable with those of past industrial revolutions or ‘waves’ of technological transformation (Stern 2011a, 2011b).

The Attraction of a New Industrial Revolution

- Especially in today's context, isn't hard to understand:
  - Draws on recognition that earlier revolutions saw new technologies supplement & displace incumbent, less efficient fuels & technologies
  - And led to a growing & sustained stream of productivity improvements, other innovations & economic gains
- This suggests the value of :
  - Examining the factors that stimulated these past advances & sustained the improvements they spawned.
  - Exploring the properties of these innovations, to understand what low carbon technologies might emulate.
  - Considering relationships between new & incumbent technologies, since they must displace fossil fuelled technologies & the institutions & routines that sustain them.

Sources

- We draw on analyses which have examined
  - The 1st industrial revolution in the 18th & 19th Centuries (Allen 2009; Wrigley 2009; Crafts 2010)
  - The relations between long-term technological, institutional & economic changes (Freeman & Perez 1988; Freeman & Louca, 2001; Mokyr 2009)
  - The role of 'general purpose technologies' in long-term growth (Helpman 1998; Lipsey et al. 1998, 2005).
- Our thinking also been informed by the literature on socio-technical transitions (Geels, 2002, 2005; Grin et al., 2010), though it doesn't concentrate on the economic aspects that are the main focus here.

Two key features of the low carbon transition

1. The market prospects/incentives for low carbon technologies differ from those of the industrial revolution
   - GHG emissions are 'externalities' not fully traded/ priced in markets: reduction GHGs lacks durable/credible market value.
   - So climate change a societal issue unachievable solely through private markets.
   - Implies a bigger role for public policy in 'managing' this transition.
   - Raises key questions about the roles & influence of government, market & civil society actors.
2. Low carbon policies strongly influenced by interplay between climate, energy security & affordability.

- These features influence whether/how a low carbon transition might/might not resemble an industrial revolution.

Britain's 1st Industrial Revolution

- This long socio-economic transformation is regarded as the 1st instance of modern economic growth
- We focus on major interpretations by Robert Allen (2009) & Joel Mokyr (2009). Crafts argues that they offer analyses that are complementary & significant:
  - "Allen stresses that the new technologies were invented in Britain because they were profitable there but not elsewhere, while Mokyr sees the Enlightenment as highly significant & underestimated by previous scholars" (Crafts 2010).
- Allen (2009): "The success of the British economy was … due to long-haired sheep, cheap coal & the imperial foreign policy that secured a rising volume of trade."

The Industrial Revolution: C16th-C19th Energy Transition

- **From** a traditional agricultural 'organic' economy, with limited
  - Productivity of land & current technologies
  - To supply food, clothing, housing & energy
- **To** a new regime: growth/ welfare transformed by exploiting
  - A fossil **stock** (coal) for larger energy **flows** (Wrigley)
- With innovations including
  - » The steam engine
  - » Cotton mills & new spinning & weaving technologies
  - » Substitution of coal/coke for wood/charcoal in metal manufacture
  - » & other major social, cultural, political & institutional changes
- That helped drive the 1st 'Industrial Revolution'

TRANSITION PATHWAYS

Why was the Industrial Revolution British? Allen (2009):

- Late C16-C18 British trade success (wool textiles) =>
  - rural industrialisation & urban growth
- E.g. London's growth (1500-1800: 15,000 - 1 million people) =>
  - woodfuel shortage eased by exploiting relatively cheaper coal (coal & ports gave Britain cheap energy)
- Responsive agriculture raised food supply & labour productivity to feed the towns =>
  - freeing labour for manufacturing
- City & manufacturing growth =>
  - higher wages & living standards (inc. diet: beef, beer & bread)
- Trade success also created UK's high wage economy
- High wages & cheap energy (coal) =>
  - demand for technology to substitute capital & energy for labour

Allen (2009), cont.

- Led to supply of technologies that substituted capital & energy for labour, raising output per worker =>
  - Newcomen steam engines used more capital & coal to do this
  - Cotton mills used machines to do it
  - New iron-making technologies substituted cheap coal for expensive charcoal; & mechanisation raised output/ worker
- Growth of R & D, an important C18 business practice, supported by venture capital & use of patents to recoup development costs
- Engineering challenges of these (inefficient) 'macro-inventions' required 'micro-inventions'
- The high wage economy =>
  - Led to rising demand for literacy & numeracy skills & gave parents income to purchase them
  - Supplied Britain with skills for the 'high-tech' revolution
- The innovations tailored to British conditions: for years were not profitable in countries with lower wages & costlier energy

Mokyr's Interpretation

- He sees the IR as the set of events that made technology 'the main engine of economic change'
  - Britain led the IR because it was uniquely able to exploit its "endowment of human & physical resources thanks to the great synergy of the Enlightenment: the combination of the Baconian program in useful knowledge & the recognition that better institutions created better incentives" (Mokyr 2009).
  - What was needed to generate an industrial revolution was the right combination of useful knowledge generated by scientists, engineers & inventors to be exploited by a supply of skilled craftsmen in an institutional environment that produced the correct incentives for entrepreneurs.
- The ideology of the Enlightenment improved both technological capabilities & institutional quality – a supply-side argument.

A Combined Hypothesis?

- Allen & Mokyr's ideas not mutually exclusive?
  - A combination of both claims "might produce the hypothesis that this resulted from the responsiveness of agents, which was augmented by the Enlightenment, to the wage & price configuration that underpinned the profitability of innovative effort in the eighteenth century" (Crafts 2010).
- These analyses, *& others*, show that a complex blend of economic, cultural, institutional & technological factors preceded, catalysed & sustained the1st IR.
- Though not a 'managed' transition in the modern sense, & about much more than energy, it was also shaped by the choices & agency of a range of actors & institutions

Long-term technological change & economic growth

- A parallel literature also argues that technological innovations that stimulate wider opportunities, like those of the IR, have been a key source of economic growth:
  - One strand argues that radical technological change has led to 'long waves' of economic development
  - while the second strand focuses on the economic consequences of 'general purpose technologies'.
- *General purpose technologies* (GPTs) have been defined as "a single generic technology […] that initially has much scope for improvement & eventually comes to be widely used, to have many uses, & to have many spillover effects" (Lipsey et al. 2005)

General purpose technologies: 3 Properties

- Three core properties:
  - *Technological Dynamism:* capacity for continued innovation, so costs fall & quality rises.
  - *Pervasiveness: a* wide range of general applications.
  - *Innovational Complementarities:* GPT users improve their own technologies & find new uses for the GPT.
- Steam engines, electrification, ICE & ICT cited as examples from earleir industrial revolutions.
- Widespread diffusion of the GPT & linked technologies enables further innovative activities leading to mutually reinforcing productivity gains over long time periods.
- The idea of a GPT helps explain why the technological progress of the 1st IR continued rather than petering out, as previously (Broadberry 2007).

General purpose technologies & time

- GPT & time lags
  - GPTs have raised productivity growth - but took decades
  - Since a GPT's penetration involves a long 'acclimatisation'
  - While other technologies, forms of organisation, institutions & consumption patterns adapt to & gain from the GPT
  - E.g. steam: hard to find productivity fx. until after 1850 (Crafts, 2004)
- As noted by evolutionary economists: Freeman & Perez (1988) - widespread deployment of radical new technologies leads to structural crises of adjustment.
- Identified 5 'long waves', where growth driven by development & application of new technologies/ processes but full economic benefits only realised after wider institutions & practices had time to adapt.

Low carbon technologies as GPTs? (i)

- Implications for the idea of a fourth & *low carbon* industrial revolution or sixth 'long wave' of low carbon growth
  - For a low carbon transition to become a successful industrial revolution, key technologies should be able to stimulate & sustain long-term delivery of big, wider productivity gains & other benefits.
  - Means more than just substituting a few low carbon technologies into existing uses & institutional structures.
  - For wider economic benefits. low carbon technologies would need to be more like GPTs, i.e. with the capacity to be widely diffused & used; for continuous innovation & cost reduction; & to stimulate innovation in a wide range of complementary technologies.
- It is not clear that the set of available low carbon technologies yet possess these properties.

Low carbon technologies as GPTs? (ii)

- The 5th ‘long wave’ is based around ICTs. Significant productivity improvements have been made in ICT production & use, as firms reorganised production & supply systems to take advantages of their potential.
- Suggests ta major opportunity for realising economic benefits from low carbon technologies may lie in the integration of these technologies with ICTs in so-called ‘smart’ systems & controls (Pudjianto et al. 2012).
- We suggest, however, that if they are to develop the properties of GPTs, then truly ‘smart’ developments in low carbon energy & ICT will need to go well beyond clever management of current assets, technologies & practices.

New low carbon technologies & practices?

- Lesson from previous GPTs is not to be too narrowly focused on *existing* energy & energy-related services when envisaging future low carbon technologies.
- New low carbon 'technologies' could look very different from those we know - & might be developed/ provided by entities different from today's big incumbents.
- Will incumbents have the flexibility to move into these markets or be locked into established technical foundations, habits & institutions?
- Will established regulatory systems & standards constrain or stimulate such progress?

Displacing Incumbents

- Low carbon technologies must compete with & displace incumbent fossil fuels , technologies & institutions.
- People & markets demand valued 'bundles' of socio-technical 'characteristics' (Lancaster, 1966).
- Low carbon technologies have the *socially* desirable but not fully priced characteristic of low emissions,
- But as yet, except in niches, tend to lack bundles with superior *private* market value to entrenched fossil fuels
- Challenge
  - Can they, with appropriate support, offer a superior combination of characteristics with market value?
  - & show capacity to kick-off growing stream of innovations/gains?

Incumbents' Responses: the Sailing Ship Effect

- Where existing technologies are mature & under pressure, low carbon technologies fight moving targets.
- E.g., recent developments in performances of petrol & diesel engines, make it harder for electric, H2 & fuel cell powered vehicles to penetrate.
- Tendency for improvements in incumbents to be stimulated by new competition, known as 'sailing ship effect ' (Geels 2002)/ 'last gasp effect' of obsolescent technologies
- Also suggests incumbents have incentives to frustrate institutional changes.
- E.g. German utilities lobbied for repeal of renewables FiT

Discussion (i)

- The industrial revolution & long wave literatures show how new technologies with GPT characteristics yielded enduring productivity gains & wider economic benefits.
- For the low carbon transition to resemble an industrial revolution & its long-run gains, its technologies would need ultimately to have properties like these.
- Some low carbon technologies may have the potential for these properties to emerge & hence to give rise to a new wave of dynamic, innovative & creative activity, as Stern (2011b) suggests.
- But as yet, unlike many previous GPTs, they tend not to offer significant private benefits to technology developers or users, beyond the social benefit of lower carbon.

Discussion (ii): more analysis needed!

- More sophisticated analysis needed to better understand the implications of a distinctively low carbon transition.
- It ‘s not enough just to invoke vague comparisons with past industrial revolutions.
- After all, the first & second revolutions were *high carbon* revolutions.
- Their success was built on the exploitation, largely un-constrained by environmental concerns, of fossil fuel stocks, freeing the economy from constraints it faced.
- Suggests there is value in developing a richer understanding of how a low carbon transition in today’s world presents different challenges & opportunities from those involved in previous high carbon revolutions.

Finally

- The paper informs the challenges of promoting a low carbon transition aimed at delivering economic & wider benefits like those of previous industrial revolutions.
- But the larger benefits of previous IRs took decades, while climate science posits the urgency of large-scale, rapid GHG mitigation.
- Literature on IRs & long waves shows they involved profound, long drawn-out, interacting changes, not just in technology but also in markets, institutions, culture & society, much of whose complexity we've barely touched on.
- For the low carbon transition to really 'work', it may prove necessary to transform our energy & related systems in more profound - & revolutionary - ways than we have yet realised & acknowledged.

Thank You!