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Path dependence & path creation: roles for incumbents in the low carbon transition?

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REALISING TRANSITION PATHWAYS

Outline: Path dependence & creation: roles for incumbents

Proposition: incumbents can play both negative & positive roles in the transition to low carbon technologies (LCTs)

- **Negative**: studies emphasise the *path dependent, locked-in* states of incumbent high carbon technologies & firms
  - Even if LCTs have attributes like those of existing technologies, apart from low carbon,
  - If incumbents respond to competitive pressures, LCTs & policy-makers face moving targets & delayed transitions.
- **Positive**: but other studies point to possibilities for incumbents to overcome lock-in & engage in *path creation & creative accumulation.*
- So policies should be tuned to ensure that incumbents, as well as new entrants, engage rapidly with LCTs.

Path dependence & lock-in

- Long-term technological systems change can be *path dependent*, in that:
  - A system's present & future evolution depends on the past sequence of events that led to its current state (David).
- So a system state may be *locked in* because of particular historical experiences
  - Creating barriers to moving to an alternative state,
  - Even though the conditions that led to that *lock-in* are not still relevant or no longer persist (QWERTY keyboard, etc.)
- Path dependence & lock-in are specially relevant for large technological energy systems (Hughes),

Increasing returns to technologies & institutions

- Arthur: 4 types of *increasing returns* that can lead to technological 'lock-in':
  - Scale, learning, adaptation & network effects
  - Which then yield cumulative socio-technical advantages for the incumbent technology
  - Impeding adoption of a potentially superior alternative
- North: increasing returns also apply to adoption of *institutions* (i.e. social rule systems).
- Pierson: increasing returns prevalent in *political institutions*, e.g. market or regulatory frameworks
  - Legally binding rule-systems become hard to change
  - & can allow incumbents to protect their interests
- Sydow *et al*: showed how *organisations* can become path dependent

Carbon lock-in & virtuous cycles

- Foxon: these insights suggest that analysing the co-evolution of technologies & institutions can inform how techno-institutional systems form & may get locked-in
- Unruh: co-evolutionary processes & mutually reinforcing positive feedbacks led to the lock-in of current high carbon energy systems: *carbon lock-in*
- But while co-evolutionary thinking highlights the difficulty in leaving a pathway supported by powerful actors.
- If increasing returns to adopting alternatives can be set off, this may lead to *virtuous cycles* of rapid change
- So lock-in can be overcome but this usually requires strategic action by market actors &/or governments.

Path creation & avoidance of lock-in

- Garud & Karnoe: argued for *path-creation*: entrepreneurs may choose to depart from structures they jointly create.
- Historical studies suggest lock-in can be avoided
  - Through forming diverse technological options: Arapostathis et al: UK transition to natural gas after earlier experimentation
  - Ensuring promising options benefit from increasing returns & learning, to challenge dominant technologies.
- Need investment & other forms of support for risky R&D, demonstration & early stage commercialisation of LCTs
  - To enable them to travel along learning/experience curves, cut costs and create conditions for success.
- And policies to *destabilise* incumbents (Turnheim & Geels) & stimulate their innovative activities.

Path Dependence and Incumbents

- Studies of large technological systems in energy (Hughes,1983, etc.), have shown positive & negative aspects of path dependency:
- Arapostathis et al. (2014), 'UK natural gas system integration in the making, 1960–2010'
  - It shows advantages – how the natural gas system benefited from the earlier construction of a 'backbone' distribution pipeline system for LNG.
  - And how previous history constrained the development of the system before WWII to the point of 'incoherence'
  - And was changed after nationalisation in 1948.

Sailing Ship Effect (SSE) / Last Gasp Effect (LGE)

- The ‘Sailing Ship Effect’ or ‘Last Gasp Effect of obsolescent technologies’ – occurs where competition from potentially superior new technologies stimulates improvements in incumbent technologies & firms
- Recent analyses of industries threatened by such ‘technological discontinuities’ offer insights into
  - Why incumbent technologies might show a sudden performance leap, deferring the transition.
  - How current analyses may overestimate new entrants’ ability to disrupt incumbent firms; and
  - Underestimate incumbents’ capacities to see the potential of new technologies & to integrate them with existing capabilities.

SSE and LGE

- As well as responding with performance enhancements, high carbon actors also lobby to resist institutional & policy changes favouring LCTs
  - Example: efforts of large German utilities in the 1990s to lobby for repeal of renewable energy FiTs (Kungl)
- So sailing ship & last gasp effects can act to delay or weaken transitions to LCTs.
- *Note:* the threat is partly from LCTs promoted by government rather than by market actors, incentives & pressures;
  - As yet not all such technologies have attributes that are superior &/or cost-competitive with incumbents,
  - Placing high carbon incumbents in a strong position to respond.

Potential Significance of SSE/LGE for Low Carbon Transitions

- Where incumbents significantly increase their competitiveness/ protect their markets in response to new LCTs, this can:
- Slow LCT uptake & penetration
  - Delaying travel down LCT experience curves
  - As LCTs chase incumbents' shifting experience curves &costs
- Raising policy costs via higher subsidies needed for competitive penetration
  - While forecasts that don't allow for SSEs/LGEs could overestimate penetration
- Requires proper attention to dynamic interactions between new & incumbent technologies, firms & the regime
- Policies that address *both* new technologies & incumbents.

Background & Literature on SSE & LGE

- Research on competition between sailing & steamships by Gilfillan (1935), Graham (1956) Harley (1971) & Geels (2002) gave rise to the idea of the SSE
  - Rothwell & Zegfeld (1985) claimed the presence of the SSE in the C19 alkali industry
  - Utterback (1996): two C19 US cases: gas v. electric lighting ('The gas companies came back against the Edison lamp … with the Welsbach mantle') & mechanical v. harvested ice
  - Cooper & Schendel (1976): 22 firms in 7 industries: '[i]n every industry studied, the old technology continued to be improved & reached its highest stage of technical development after the new technology was introduced.'
- Tripsas (2001) identified the effect as the 'Last Gasp' of an obsolescent technology

Incumbents and SSE/LGE

- Although some debate about whether *all* SSE/LGE instances stand up to scrutiny (Howells, 2002 – but see Arapostathis et al., 2013; Mendonca, 2013)
  - There is evidence that some firms try harder when new competition threatens their technological ascendancy.
- Growing management & innovation literatures have investigated performance & responses of incumbents facing radical technological innovation
  - Including recent studies by:
    - Arapostathis et al. (2013, 2014) - gas;
    - Furr & Snow (2013) – carburettors & fuel injection;
    - Dijk et al. (2016) & Sick et al. (2016) – automotive
    - Bergek et al. – turbines and automotive (2013)

An early SSE: the Incandescent Gas Mantle*

- UK gaslight use grew rapidly in 2nd half of 19th century (gas from coal)
- Gas lighting had seen incremental innovations, e.g. burner shape changes, better technical efficiency.
- In 1892, chemist Carl Auer (later von Welsbach) patented the incandescent mantle - a key innovation.
  - Mantles brighter, cleaner & cheaper; needed 'a quarter of the gas consumption for a given degree of illumination';
  - But early mantles expensive (Welsbach Company monopoly) & fragile;
  - Some gas engineers feared higher efficiency meant lower gas consumption (a common fear).

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*** Source:** Arapostathis et al. (2013)

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An early SSE: the Incandescent Gas Mantle

- But by early 1900s, cost of incandescent electric light (Edison/Swan patents, 1880) had fallen: now more competitive with gas
- Gas industry got together in 1901 to win legal fight against the British Welsbach mantle patent holder.
  - Cheaper & now sturdier gas mantles then widely adopted
  - Strengthening gaslight's competitive position, enabling it to stay in the lighting market
  - Electric light not price competitive with gas light until 1920 (Fouquet & Pearson, 2006).
- So this was an early SSE.

Furr & Snow (2012), 'Last gasp or crossing the chasm? The case of the carburettor technological discontinuity'

- Insufficient empirical research into the (LGE), so
- Examined carburettor manufacturers' behaviour, when threatened by electronic fuel injection (EFI) from 1980 on,
  - Using data on performance & attributes of 700 car models per year for period 1978-1992.
- Four LGE hypotheses: when a new technology threatens
  1) An existing technology's trajectory may show an LGE (sudden rise in performance), in which incumbents may:
     2) Improve their existing technology ('try harder'); or
     3) Reconfigure & retreat to more efficient appl; or
     4) Recombine.
- A nuanced story: all of 2, 3 & 4 contributed to an LGE, but it came from more than just the standard 'trying harder'.

Furr & Snow: Findings (i)

- While there were some improvements in standard carburettors,
- Two other unexpected responses contributed to an LGE
  - Some incumbents retreated & *reconfigured*, creating an 'apparent LGE': the performance 'improvement' came from the product retreating from less to more efficient applications in particular market segments
  - While others *recombined* - creation of hybrids between carburettors and EFI, contributed significantly to the LGE.
- While none leapt at once to EFI, only those that first invested in hybrids survived the transition to EFI.
- The LGE deferred the technology discontinuity for a time

Other automotive studies of the SSE/ LGE

- Sick et al. (2016) combine ideas of the SSE & of path dependence to show how such behaviour may be economically rational; & their patent-based evidence
  - Suggests that automotive OEMs of propulsion technologies have exhibited a temporary SSE
  - Via their focus on incremental innovations in traditional technologies as they respond to low carbon emission regulations & growing pressures for sustainability.
- Dijk et al. (2016): vehicle manufactures have tended to avoid costly/ risky radical technical innovation & regime disruption
  - Showing 'an inclination to regime reproduction, or reorganization, partly by incorporating elements of disruptive niches into the regime.' (including hybrids)
  - This they describe as an SSE.

Bergek et al. (2013). 'Technological discontinuities & the challenge for incumbent firms'

- Contest two explanations of the 'creative destruction' of incumbents from discontinuous technological change.
  - These *competence-based* (Tushman & Anderson 1986) & *market-based* (Christensen 1997/2003) explanations,
  - Suggest incumbents challenged *only* by 'competence-destroying' or 'disruptive' innovations (that disrupt their performance trajectory & value network as new attributes dominate competition)
  - Making the firms' knowledge bases or business models obsolete, leaving them vulnerable to attack.
- Both explanations assume incumbents burdened with 'core rigidities' & 'legacy of old technology', thus
  - Predicting that technological discontinuities open up possibilities for innovative 'Attackers' to grab market share.

Bergek et al: Empirical Analyses of 2 Industry Cases

- Bergek et al. studied 2 competence destroying & potentially disruptive innovations (microturbines & electric vehicles)
- 1 sustaining innovation (CCGTs) & 1 competence-enhancing innovation (hybrid-electric vehicles).
- In gas turbines, incumbents predicted to be challenged by new entrants developing microturbines.
- In automobiles, Christensen said ‘electric vehicles have the smell of a disruptive technology’
- But Bergek et al. found that these approaches tended to
  - Overestimate new entrants’ ability to disrupt incumbents.
  - Underestimate incumbents’ capacities to appreciate new technologies & integrate them with existing capabilities.

Bergek et al: Findings (i)

- The attackers & their potentially disruptive innovations failed in both industries because:
  - They didn't meet performance demands in main markets
  - Lack of 'overshooting' in main markets
  - Industries' embeddedness in hard to change large socio-technical systems (path dependence)
- Predictions that incumbents only challenged by 'competence -destroying' or 'disruptive' innovations not born out. Firms' abilities to compete depended on ability to managing the challenges of 'creative accumulation' (Pavitt1986);
  - Such firms rapidly fine-tune & evolve existing technologies;
  - Acquire & develop new technologies & resources; &
  - Integrate novel & existing knowledge into superior products & solutions.

Incumbents and innovation

- Bergek et al.'s study helps explain why some new energy technologies may find it harder to penetrate than anticipated.
- But also suggests that some incumbents are/ may become able to embrace new technologies, including via hybridisation.
- The common management & innovation literature assumption that incumbents can't/won't respond to technological discontinuities is increasingly contested.
  - Other studies suggest *some* incumbents have/ might develop innovation & creative accumulation capacities (Chandy & Tellis, 2000; Hill & Rothaermel, 2003; Hockerts & Wüstenhagen, 2010)
- And relying only on new entrants could take too long
  - History shows that energy transitions usually take multiple decades (Bento & Wilson, 2016; Fouquet, 2008, 2010; Hanna et al., 2015; Kander et al. 2013; Pearson, 2016; Sovacool, 2016) but may be quicker if the incumbent engages (Arapostathis et al., 2015).

Conclusion (i)

- The *path dependent*, *locked-in* states of incumbent high carbon technologies & firms means they can delay LCTs & the low carbon transition;
- And SSE/LGE studies suggest that some incumbents can fight back, at least for a while.
- So policies should address this by *destabilising* incumbents:
  - *Weakening the cultural, political, economic & technological dimensions of fossil-fuel related industries is just as important as stimulating green options* (Turnheim & Geels, 2012; also 2013).
- And addressing perverse incentives, such as fossil fuel subsidies

Conclusion (ii)

- The paper argues that while incumbent technologies & firms can constrain & delay the success of low carbon technologies & policies
- There are also positive opportunities for system actors & policies to overcome lock in, accumulate new competences & help create new low carbon paths.
- The urgency of the climate change challenge and the need for a rapid low carbon transition mean it is essential that incumbents, as well as new firms, engage rapidly with low carbon technologies & practices.
- Policies should be tuned to ensure this.

Acknowledgement & Sources

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