

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

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Abstract

Several studies have emphasised the path dependent, locked-in states of incumbent high carbon technologies and industries ('carbon lock-in'), and their potential capacity to delay the development and penetration of low carbon technologies and practices (LCTs). Even if LCTs have similar attributes to existing technologies, apart from low carbon, if the existing technologies are already under pressure to improve, then LCTs may face a moving target. However, other analyses point towards the possibilities of path creation and creative accumulation by incumbents. This paper examines these issues, explains why history and incumbents matter in the low carbon energy transition and investigates the roles that might be played by incumbents both in delaying and – sometimes - in actively advancing the transition.

Studies of large technological systems in energy, show the positive and negative aspects of path dependency. Arapostathis et al. (2014), for example, shows both the advantages – how the development of the UK's natural gas system benefited from the earlier construction of a 'backbone' distribution pipeline system for LNG - and the disadvantages - how previous history constrained the development of the system before WWII to the point of 'incoherence' and how this was changed by nationalisation in 1948. The 'sailing ship' effect (SSE) or the 'last gasp effect of obsolescent technologies' (LGE) – occurs where competition from new technologies stimulates improvements in incumbent technologies/firms. Recent analyses of energy-related industries threatened by technological discontinuities offer insights into: why incumbent technologies might show a sudden performance leap; how current analyses may overestimate new entrants' ability to disrupt incumbent firms; and underestimate incumbents' capacities to see the potential of new technologies and to integrate them with existing capabilities (e.g. Bergek et al. 2013)

The paper argues that while incumbent technologies and firms can exert constraining influences on the success of low carbon technologies and policies, there may also be positive opportunities for system actors and policies to overcome lock in, accumulate new competences and help create new low carbon paths. It is argued that the urgency of a low carbon transition, the short time scales and the existing infrastructures mean that it is essential that incumbents, as well as new firms, engage rapidly with LCTs.

Introduction: incumbents and the low carbon transition

There has been much recent emphasis on encouraging the development and penetration of new low carbon technologies and related innovations. International experience has shown that incumbent high carbon technologies and firms can be important influences, negative or positive, on the success of low carbon technologies and policies. Analyses have emphasised the *path dependent, locked in* states of incumbent high carbon technologies and/or industries and their capacity to delay a low carbon transition (e.g. Unruh, 2000; Unruh and Carillo-Hermosilla, 2006). The challenges for new entrants and fledgling technologies also include the potential for high carbon incumbent firms and technologies to improve or otherwise protect their competitiveness or dominance, creating a moving target. Nevertheless, there can also be positive opportunities for system actors (and the policies that influence them) to overcome lock in, accumulate new competences and help create new low carbon paths and technologies. For example, other analyses in the innovation literature, have pointed towards possibilities of *path creation* and *creative accumulation* by incumbent firms (e.g. Garud and Karnoe, 2001; Pavitt, 1986; Bergek et al. 2013). This paper discusses these issues and explores the roles – both negative and positive - that incumbents might play in the innovation processes of a low carbon transition.

Path dependence and lock-in

We begin by outlining path dependence and lock-in and the factors that influence them (Foxon, 2006). Long-term technological systems change can be path dependent, in that a system's present and future evolution depends on the past sequence of events that led to its current state (David, 2001). So a system state may be locked in because of particular historical experiences, creating barriers to moving to an alternative state, although the conditions leading to that lock-in no longer obtain or are no longer relevant. Arthur (1994) showed that four types of *increasing returns* can lead to technological 'lock-in' - *scale, learning, adaptation and network effects*. These effects then yield cumulative socio-technical advantages for the incumbent technology, impeding adoption of a potentially superior alternative (Arthur, 1989). North (1990) argued that analogous factors leading to increasing returns can also apply to institutions (i.e. social rule systems), creating conditions favourable to lock-in. And Pierson (2000) suggested that increasing returns may be prevalent in some political institutions, such as market or regulatory frameworks, making them path dependent and hard to change; in some circumstances this may allow incumbents to exert undue influence to protect their interests.

Foxon (2006) argues that these insights suggest that analysing processes of co-evolution of technologies and institutions can inform how techno-institutional systems form and may get locked-in. Thus for example, Unruh (2000, 2002) (also Unruh and Carillo-Hermosilla, 2006) shows how co-evolutionary processes and mutually reinforcing positive feedbacks led to the lock-in of current high carbon energy systems, described as carbon lock-in. Thus high carbon energy technologies and supporting institutional rules have co-evolved, leading to systemic barriers to investment in low carbon technology systems. As well as responding with performance enhancements, high carbon actors also lobby to resist institutional and policy changes that favour low carbon technologies, evidenced, for example, by efforts of large German energy utilities in the 1990s to lobby for the repeal of renewable energy feed-in tariffs. A further aspect of lock-in may be the unwillingness or inability of some large incumbent firms and their industries (for reasons of structure, technological capabilities, culture, etc.) to develop or embrace potentially disruptive innovations, a phenomenon sometimes known as the *incumbent's curse*.

Nevertheless, although co-evolutionary thinking highlights the difficulty in leaving a pathway widely supported by powerful actors, if increasing returns to the adoption of alternatives can be set off, this may lead to virtuous cycles of rapid change. For example, Garud and Karnoe (2001) argued for *path-creation*, whereby entrepreneurs may choose to depart from structures and technologies they jointly create. Historical studies have also suggested that lock-in can be avoided through forming diverse alternative technological options (Arapostathis et al., 2014) and ensuring promising options benefit from increasing returns and learning, to challenge dominant technologies. Moreover, notwithstanding the potential of the incumbent's curse, recent analyses have drawn attention to the potential in some circumstance for creative accumulation by incumbents (e.g. Bergek et al., 2013; see also Pavitt, 1986) and to the ability of some to respond to the stimulus of radical technical innovations and new market challenges (e.g. Chandy and Tellis, 2000; Hill and Rothaermel, 2003; and Hockerts and Wüstenhagen, 2010).

Sailing ship and last gasp effects (SSE/LGE)

The 'sailing ship' effect (SSE) or the 'last gasp effect of obsolescent technologies' (LGE) – occurs where competition from new technologies stimulates innovation and improvements in incumbent firms and their associated technologies. Recent analyses of industries threatened by technological discontinuities offer insights into: (i) why incumbent technologies might show a sudden performance leap (Furr and Snow 2013); why such behaviour may be economically rational (Sick et al. 2016); and (ii) how current analyses may overestimate new entrants' ability to disrupt incumbent firms and underestimate incumbents' capacities to see the potential of new technologies and to integrate them with existing capabilities (Bergek et al. 2013).

There is now a substantial but diverse literature on the SSE/LGE. Thus research on competition between sailing and steamships by Gilfillan (1935), Graham (1956) Harley (1971) and Geels (2002) led to the suggestion of the SSE, also discussed by Rosenberg (1972a, 1972b, 1976). Rothwell and Zegfeld (1985) claimed the existence of the SSE in the C19 alkali industry. Utterback (1996) cited two C19 US cases: gas vs. electric lighting (“The gas companies came back against the Edison lamp ... with the Welsbach mantle”) and mechanical versus harvested ice. Cooper and Schendel (1976) studied 22 firms in 7 industries: ‘[i]n every industry studied, the old technology continued to be improved and reached its highest stage of technical development after the new technology was introduced;’ Tripsas (2001) identified the effect as the ‘last gasp’ of a technology. There has been some debate about whether all instances of the SSE bear closer scrutiny (Howells, 2002; but see Arapostathis et al. 2013), including that of the sailing ship itself (Mendonca, 2013). Overall, however, recent evidence suggest that the proposition that some firms respond when the ascendancy of their technologies is threatened by competition from new technologies carries weight and merits further conceptual and empirical investigation (Dijk et al, 2016; Sick et al. 2016).

The responses of incumbents in the face of radical technological innovation

Growing management and innovation literatures have investigated the performance and responses of incumbents in the face of radical technological innovation. We consider several recent studies, including those of Arapostathis et al. (2013); Furr and Snow (2013); Dijk et al. (2016), Sick et al. (2016) and Bergek et al. (2013).

An early SSE: the Incandescent Gas Mantle (Arapostathis et al. 2013): gas light consumption in the UK grew steadily in the latter half of the nineteenth century (gas from coal). Gas lighting had developed through incremental innovations such as changes to the shape of the burner. But in 1892, the chemist Carl Auer (later von Welsbach) patented a key innovation, the incandescent mantle: mantle lighting was brighter, cleaner and cheaper, requiring “about a quarter of the gas consumption for a given degree of illumination”. But early mantles were fragile and expensive (monopoly) and some gas engineers feared increased efficiency would lead to lower gas consumption. By the early 1900s the situation had changed: the cost of incandescent electric light (Edison/Swan) had decreased, increasing competition with gas. In 1901 the industry got together to mount a successful legal fight against the holder of the British Welsbach mantle patent. Incandescent gas mantles were then widely adopted, strengthening the competitive position of gas light, enabling it to stay in the lighting market. Electric light only became competitive with gas light by around 1920 (Fouquet and Pearson 2006). So, in our view, this was an early SSE.

The case of the carburettor: Furr and Snow (2012): they examined carburettor manufacturers’ behaviour, when threatened by electronic fuel injection (EFI) from 1980 on, using data on the performance and attributes of 700 car models per year for the period 1978-1992. Rather than assuming that the LGE comes from incumbents simply ‘trying harder’, they found that some incumbents explored hybrid technologies that contributed to the LGE and helped them cross to EFI.

The paper offers some empirical verification of the LGE. It explores 4 hypotheses: when threatened by a new technology generation -

1. The technology trajectory of an existing technology may exhibit a last gasp (a sudden increase in product performance in excess of existing technology trajectory).

And incumbents may innovate, reconfigure or recombine, via:

2. *Efforts to extract greater performance* from existing technology;
3. *Reconfiguring* to market segments where they have comparative advantage relative to the threatening technology;
4. *Recombining* components from the threatening technology with extant technology.

Furr and Snow’s findings offer initial empirical verification of the LGE in the carburettor industry, when threatened by a potential technical discontinuity - the emergence of EFI. It suggests two other potential sources of the LGE —reconfiguration and recombination—as well as the common ‘trying

harder' explanation in the literature. All three sources contribute to a LGE, but in some unexpected ways: some incumbents retreat and reconfigure, creating an apparent LGE: the performance 'improvement' comes from the product retreating from less to more efficient applications and market segments. Also recombination, or creation of hybrids between old and new technology generations, contributes significantly to the LGE. Once they accounted for incumbent technology choices, they found that incumbents focusing their efforts on the original carburettor contributed to a last gasp in standard carburettors, while those focusing on hybrid carburettors contributed to a last gasp in hybrid carburettors. The LGE deferred the technology discontinuity for a time: while no incumbents leapt immediately to EFI, only those incumbents first investing in hybrid carburettors survived the transition to EFI technology.

Other studies of the automotive industry: In a new study of the automotive industry, Sick et al. (2016) combine ideas about the SSE with the rationales of path dependence to show how such behaviour may be economically rational. They also suggest that their patent-based evidence shows that automotive original equipment manufacturers (OEMs) of propulsion technologies have been exhibiting a temporary SSE through their tendency to focus on incremental innovations in traditional technologies as they respond to low carbon emission regulations and a rising societal demand for sustainability. Similarly, Dijk et al. (2016) argue that vehicle manufactures have tended to avoid costly and risky radical technical innovation and regime disruption, instead showing 'an inclination to regime reproduction, or reorganization, partly by incorporating elements of disruptive niches into the regime.' This they describe as an SSE.

The development of hybrids occurs elsewhere in the literature, including in a study called *'Technological Discontinuities and the Challenge for Incumbent Firms'* by Bergek et al. (2013): they contest two explanations of the 'creative destruction' (Schumpeter) of existing industries from discontinuous technological change. These *competence-based* (Tushman and Anderson 1986) and *market-based* (Christensen 1997/2003) explanations suggest that incumbent firms are challenged only by 'competence-destroying' or 'disruptive' innovations, which make the firms' knowledge base or business models obsolete, leaving them vulnerable to attacks from new entrants. From different standpoints, both assume incumbents are burdened with 'core rigidities' and the legacy of old technology. Hence these approaches suggest that technological discontinuities open up possibilities for new entrants. Both approaches explain the 'attacker's advantage' thus: incumbents are unable or unwilling to respond due to organizational, technological and strategic inertia, so allocate insufficient resources to respond to the threat and lose position because old competences are destroyed; or their performance trajectory and value network are disrupted as new performance attributes replace existing ones as the main basis for competition. The general prediction is that, while sustaining and competence-enhancing discontinuities reinforce the competitive positions of incumbents, incumbents will be threatened by disruptive or competence-destroying technological discontinuities. Hence innovations will be pioneered by new entrants, who take market shares from incumbents.

The cases analysed by Bergek et al. in the automotive and gas turbine industries suggest these approaches tend to: overestimate new entrants' ability to disrupt established firms; and underestimate incumbents' capacities to see the potential of new technologies and integrate them with existing capabilities via processes of 'creative accumulation'. *Creative accumulation* (Pavitt 1986) requires firms to: rapidly fine-tune and evolve existing technologies; acquire and develop new technologies and resources; and integrate novel and existing knowledge into superior products and solutions.

Bergek et al. studied two competence destroying and potentially disruptive innovations (microturbines and electric vehicles (EVs), and one sustaining and one competence-enhancing innovation (combined-cycle gas turbines (CCGT) and hybrid-electric vehicles respectively). In the gas turbine industry, incumbents were predicted to be challenged by new entrants developing microturbines. In automobiles, Christensen argued that 'electric vehicles have the smell of a disruptive technology'. In the case of the former, they found that: these are industries where

predictions of existing frameworks on competence destroying and disruptive innovation haven't materialized, while actual innovation processes have been harder for incumbents than existing theories assume. For microturbines, this was: 'a distributed technology that failed to disrupt'; it is 'unlikely that microturbine technology ever will become "good enough" in a comparison with large CCGTs'. But competition in large gas turbines was 'a life and death race', where 2 incumbents (Westinghouse and ABB) were forced to quit the market after failing to innovate on the basis of established technologies. In the case of battery electric vehicles and hybrids, they found that as yet BEVs have failed to disrupt the car industry, despite major investments. The Toyota Prius 1 (1977) was a critical discontinuity; now all major manufacturers have hybrids. 'Hybrid-electric power-trains remain the dominant alternative power-train... in spite of the hype surrounding EVs', while 'pure electrics may require extensive policy support until the late 2020s' (see also Dijk et al. (2016), who find that 'the disruptive niche of full-electric mobility is currently insufficient to displace the I[n]ternal C[ombustion] Engine regime.'). Despite greater complexity, hybrids have been relatively successful because of key performance advantages. Bergek et al. argue in relation to hybrids, that Toyota's strategy shows that when the knowledge base changed, as well as technical R and D, they had to access knowledge on manufacturing and cost, by joint ventures or in-house component production.

Bergek et al. found that the attackers and their potentially disruptive innovations failed in both industries because of failure to meet performance demands in main markets, lack of "overshooting" in main markets, and industries' embeddedness in hard to change large socio-technical systems. The cases studied did not bear out the prediction of the competence based and market based approaches, that incumbents are challenged only by 'competence-destroying' or 'disruptive' innovations. The incumbent firms' abilities to compete in new technologies depended on their management of the challenges of 'creative accumulation'. The competence based and market based approaches, they argued, tend to overestimate new entrants' ability to disrupt established firms, and underestimate incumbents' capacities to see the potential of new technologies and integrate them with existing capabilities via processes of 'creative accumulation'. Their findings help explain why some new energy technologies may find it harder to penetrate than might be anticipated. But they also suggest that some incumbents have or may develop the ability to embrace new technologies, particularly when hybridisation makes it possible to extend the life of existing technologies.

Potential policy significance of incumbent behaviour and the SSE/LGE

In cases where incumbents significantly increase their competitiveness in response to new LCTs, this can slow LCT uptake and penetration, delaying cost-reducing travel along LCT experience curves, as LCTs chase incumbents' shifting experience curves, costs and prices. This elevates policy costs via higher subsidies needed for competitive penetration, while forecasts that don't allow for SSEs/LGEs could overestimate penetration (see also McVeigh et al., 2000). So, appreciating SSEs/LGEs matters for a low carbon transition and suggests giving proper attention to dynamic interactions between new and incumbent technologies and industries. And, as argued earlier, the proposition that some incumbents threatened by competition from new technologies tend to respond, carries weight. Recent analyses (including Sick et al. 2016; and Dijk et al., 2016) suggest that the SSE/LGE and related concepts merit deeper analysis and empirical study.

It is now increasingly recognised that policy strategies aimed at stimulating innovation in and the penetration of low carbon technologies may require not only investment support for risky R and D, demonstration and early stage commercialisation but also policies that address path dependence and lock-in and reflect the need in some circumstances to *destabilise* high carbon incumbent firms and technologies (Turnheim and Geels, 2012, 2013). Thus, for example, Turnheim and Geels (2012, 47, 49) argue that '...industries are committed to existing industry regimes, and are likely to resist major change in technical competencies, core beliefs and mission. [...] Weakening the cultural, political, economic and technological dimensions of fossil-fuel related industries is just as important as stimulating green options.' And, in an example cited earlier in this paper, Dijk et al. (2016, 86) found that in the case of the automotive industry that '...we are struck by the stability of the

established regime. Vehicle manufacturers have tried to avoid costly and risky radical technological innovation, which emerges at industry level as a tendency to avoid regime disruption, and an inclination to regime reproduction or reorganization, partly by incorporating elements of disruptive niches into the regime.'

Nevertheless, as the cited papers demonstrate, the destabilisation need not be aimed solely at weakening incumbent regimes and firms. I suggest that we should also recognise that some incumbents may have the potential capacity to recognise both longer run opportunities and the writing on the wall of changing government policies and public attitudes towards climate change, and to engage in processes of creative accumulation. There are at least two further reasons why it might be important also to stimulate incumbents' engagement with low carbon technologies. Firstly, researches into the time taken for innovations to develop and commercialise successfully and for energy transitions to happen, suggest that these are slow processes that generally have tended to takes decades or more (Bento and Wilson, 2016; Fouquet, 2008, 2010; Hanna et al., 2015; Kander et al. 2013; Pearson, 2016; Sovacool, 2016); this contrasts starkly with the urgency of addressing climate change through non-incremental developments. To rely solely on new entrants to low carbon supply and energy service industries would be not to take advantage of the opportunity to build on and modify incumbents accumulated' technical and managerial capacities, infrastructure and learning.

Secondly, although as noted there was a tendency in the innovation and management literature to assume that incumbents could not and/or would not respond to the threat of disruptive innovations or technological discontinuities, this assumption has been contested in ways that suggest that some incumbents may have or may develop the capacity to do so. Thus for example, Hockerts and Wüstenhagen (2010, 489) argue in relation to sustainability initiatives by small firms ('Emerging Davids) and large incumbent firms ('Greening Goliaths') that the success – and the competitive threat - of some of the emerging Davids has stimulated some of the Goliaths to embark on more sustainable entrepreneurship; consequently the transformation of industries 'is not going to be brought about by either Davids or Goliaths alone, but instead that their interaction is essential.' Similarly, Chandy and Tellis (2000, 14), have argued that 'Our research in the consumer durables and office product categories suggest that incumbents or large firms are not necessarily doomed to obsolescence by nimble outsiders. [...] Perhaps the incumbent's curse is not as inevitable as it seems.' And Hill and Rothaermel (2003, 271) while not denying that many incumbents '...fail to cross the abyss created by a technological discontinuity. ', also present useful theoretical analysis of why some incumbents continue to do well in the face of radical technical change.

Finally, we have seen that for some low carbon technologies and contexts, incumbents' responses could delay, while in others they might enhance, their successful penetration and development. Therefore, this paper has argued that policy-makers keen to promote low carbon transitions should be mindful not only of support for low carbon technologies but also of incumbents' strategies and behaviours, as they resist or in some cases embrace the prospects of these technologies: policies should be tuned accordingly.

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