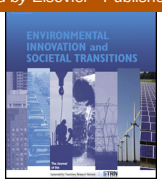
Contents lists available at ScienceDirect

Environmental Innovation and Societal Transitions

journal homepage: www.elsevier.com/locate/eist



Creating protective space for innovation in electricity distribution networks in Great Britain: The politics of institutional change

Matthew Lockwood *

Energy Policy Group, University of Exeter, United Kingdom

ARTICLE INFO

Article history:
Available online 6 June 2015

Keywords:
Institutions
Politics
Protective space
Regulation
Smart grid

ABSTRACT

Innovation in electricity distribution networks will be an important element in the transition to a sustainable low-carbon energy system. The nature of networks as regulated monopolies means that the locus of the evolution of protective space for innovation is regulatory institutions, and that the politics of creating protective space is the politics of institutional change. In this paper I examine the case of Britain, where protective space for research, development and demonstration projects was created over the course of the 2000s in the form of funding mechanisms within the regulatory regime. The case study is used to test structural and discursive theories of gradual institutional change. I conclude that these theoretical frameworks are consistent with the evidence, but that the characterisations of change actors and of dominant policy paradigms are insufficiently flexible. I also conclude that the framework for innovation in the British regulator remains incomplete.

1. Introduction

In the analysis of innovation processes for sustainability transitions, the multi-level perspective (MLP) on socio-technical transitions currently plays a dominant role (Smith et al., 2010). The MLP

* Correspondence to: Penryn Campus, Treliever Road, Penryn, Cornwall TR10 9FE, United Kingdom. Tel.: +44 01326 259237.
E-mail address: m.lockwood@exeter.ac.uk

http://dx.doi.org/10.1016/j.eist.2015.05.007

provides the concepts of niches, socio-technical regimes and the wider landscape, with technological transitions emerging from interactions between these (Kemp et al., 1998; Geels and Schot, 2007; Geels, 2002, 2010; Smith et al., 2005). Within this framework, the concept of 'protective space' in niches for emergent radical innovations plays a particularly important role (Smith and Raven, 2012). However, the MLP approach (and indeed the wider socio-technical transitions literature) has been widely criticised for a lack of analysis of politics (e.g. Meadowcroft, 2009; Scrase and Smith, 2009; Kern, 2011). This critique then raises the question of exactly *how* politics should be theorised and brought into the analysis of sustainability transitions. In this paper, I turn to the approach that has played a central role in political analysis – institutionalism – to analyse contested ideas and institutional change in the creation of protective space for innovation in electricity distribution networks in Great Britain.[1]

The background for such innovation is the anticipated transformation of electricity systems, with growth in small-scale renewable electricity generation technologies, at least partial electrification of heat and transport, and the possibility of greater demand side response. To fully realise the value of such 'distributed energy resources' (Agrell et al., 2013; Ruester et al., 2014), many governments now take the view that electricity distribution systems will have to be transformed in their ability to observe and control power flows and quality through the application of information technologies, i.e. the 'smart grid' agenda.

However, the context for innovation in electricity networks is very different from that in competitive markets, where most studies of innovation for sustainability are focused. Considered to be natural monopolies, networks are either state owned and operated or are heavily regulated. The balance of risk and reward for regulated companies is determined almost entirely by the nature of the regulatory regime, and those companies react to that regime rather than to market opportunities. In Britain, electricity distribution network companies have historically been seen as risk averse and lacking the skills, capacity and incentives for innovation (e.g. Smith, 2010).

The history of the smart grid policy agenda and the evolution of regulation for network innovation in GB have been widely discussed. As Bolton and Foxon (2011) note, innovation was 'off the agenda' until the early 2000s. The focus of the GB regulator, Ofgem,[2] was on incentivising cost reduction, largely achieved by network companies by squeezing operational expenditure. However, in 2005 Ofgem introduced two mechanisms to support R&D by electricity distribution network companies, an approach which was subsequently expanded from 2010. The focus of this paper is on examining the politics of this pivotal episode of institutional change.

The context for innovation has implications for the way in which the creation of niches and changes to socio-technical regimes are conceptualised. At least initially, technological niches for networks have to be created in the most immediate sense by state or regulatory institutions rather than firms. As a consequence, the politics of protective space pivots around the *politics of change in those institutions*. This fact then drives the selection of a theoretical framework for analysing these politics. In this paper I draw on two institutional frameworks. One is Mahoney and Thelen's (2010) theory relating types of institutional change to political context, institutional characteristics and types of institutional entrepreneurs. The second is John Campbell's framework for understanding the conditions under which ideas are likely to change institutions. In a study of the introduction of support for R&D in networks to develop a smarter grid through a change in the British regulatory regime, the explanatory power of these two frameworks is assessed against evidence obtained from official documentation and interviews with participants in that change (Annex 1).

I find broad support for these two approaches. However, the case study also suggests that the characterisations of change agents and of policy paradigms in these theoretical frameworks need to be made more flexible. I also conclude that while the understanding within Ofgem of R&D and demonstration processes changed significantly over the last decade, it is not clear that other aspects of the innovation process, and in particular the risks associated with moving to business-as-usual investment, have yet been engaged with.

[1] Electricity networks in Northern Ireland are regulated separately from those in the rest of the United Kingdom. This paper focuses solely on networks in GB (i.e. England, Wales and Scotland).

[2] The full name is the Office of Gas and Electricity Markets.

The paper is organised as follows. In the next section, I clarify the nature of the protective space problem for smart grids in GB, and justify the focus on institutional change within Ofgem. Section 3 introduces the theoretical framework and presents the hypotheses to be explored. In Section 4 I give an account of the pivotal episode based on interviews with actors playing major roles in the changes, Ofgem documentation and other sources. Section 5 discusses how far the empirical material can be explained by the theoretical frameworks and reflects back critically on those frameworks. The conclusion addresses both the nature of the evolution of smart grid policy, and on the analytical project of introducing political analysis into the study of sustainability transitions.

2. Network innovation and the locus of protective space in Britain

Technological change has been a feature of electricity networks since the original development of the electricity supply industry from the 1880s onwards (Hughes, 1983). Innovation continued through the scaling up of generation and the building of high-voltage transmission networks in the period 1930–1950, and into the years of state ownership. In Britain, the Central Electricity Generating Board supported innovation in networks throughout the 1960s and 1970s, with overall energy R&D rising from 0.2% of turnover in 1958 to 2.2% in 1989 (Lehtonen and Nye, 2009). However, with privatisation this picture rapidly changed (Jamasb and Pollitt, 2008), and by the early 2000s spending by UK network companies on RD&D had declined to less than 0.1% of revenue (Pollitt and Bialek, 2008). Distribution companies in particular were focused on increasing efficiency not through technological change but rather through short-term cost cutting (Bolton and Foxon, 2011: 14).

The collapse in innovation would have slowed long-term efficiency gains in networks even if the electricity system had remained the same. However, by the early 2000s, signs were emerging that electricity systems were likely to change fundamentally over the coming decades. New renewable technologies, especially wind, produced generation that varied over time, implying much lower network utilisation rates unless new approaches to planning and operation were adopted. A significant proportion of wind capacity was starting to connect directly to distribution networks,[3] followed by a rapid take-off of distribution-connected solar PV in the late 2000s. However, distribution networks were not designed to accommodate generation, especially on low voltage parts of the network, and there were potential challenges of increased fault levels and voltage control (Baker and Chaudry, 2010: 8–9).

At the same time, debates about the role of electrification in the decarbonisation of transport and heat were emerging. How far this process will go in the UK is disputed. Initial expectations in government about the potential of heat pumps have moderated, and the current heat strategy involves a mix of electrification and other low carbon pathways (DECC, 2013). Nevertheless, even partial electrification implies a substantial increase in electricity demand. Wilson et al. (2013) estimate that shifting even 30% of heat demand to electricity would mean daily electricity demand doubling if resistive heating is used, and increasing by 25% if heat pumps are used. Peak demand increases would be larger. The move to electric vehicles and consequent demand for charging will add to this challenge (Pieltain et al., 2011). Overall, Pudjianto et al. (2013: 77) estimate that the electrification of heat and transport could increase daily electricity use by 50%, while doubling peak demand.

Accommodating these changes using conventional approaches to network design and operation would require very large investments, especially at low voltage levels. The alternative 'smart grid'[4] approach is to use information and communication technologies (ICT) to actively manage demand and distributed generation so as to reduce peak power flows, and extend the life and increase the utilisation of wires, transformers and other equipment by remote monitoring and fault correction (e.g. McDonald, 2008; Strbac et al., 2010; Pudjianto et al., 2013: 77; ECC SC, 2013: 13–14), all of which should reduce costs by deferring or avoiding the need for network reinforcement or replacement. The smart grid agenda implies a very different role for distribution network operators. Rather than designing and

[3] Defined as 132 kV and below in England and Wales, but now 33 kV and below in Scotland – see below.

[4] The smart grid literature is very large. For a recent review of developments in the UK see Xenias et al. (2014). For definitions of smart grids see http://www.smartgrids.eu/ETPSmartGrids and DECC (2009).

building passive networks with large amounts of headroom,[5] they would become system operators, monitoring power flows, anticipating faults and managing demand peaks by communicating with distributed generators, storage devices, heat pumps, electric vehicles and appliances through smart meters, sending appropriate price signals or allowing automated control.

The smart grid agenda implies not only major technological innovation but also organisational change (Shaw et al., 2010; Cary, 2010; Agrell et al., 2013; Ruester et al., 2014). It involves a huge increase in the number of active participants in the electricity system, and in its complexity (IET, 2013: 7). By contrast, since privatisation distribution network operators (DNOs) have been largely uninnovative and risk averse (Ofgem, 2009a: 21; Sansom, 2010; Shaw et al., 2010: 5928). As late as 2010, a senior Ofgem figure stated that "it would be crude but not an unrealistic simplification to say that the way energy networks are designed, built and operated has not changed significantly since they were built in the post war period" (Smith, 2010: 9).

The ultimate causes of this problem, however, lay not with the network companies themselves but with the regulatory regime. Known as RPI-X, post-privatisation network regulation was designed to provide an incentive to bear down on costs within each 5 year price control period, through capping the revenue that DNOs could collect but allowing them to keep a portion of any cost savings that could be made. There are a number of reasons that this regime did not incentivise longer-term technological and organisational innovation.[6] There was no driver for companies to develop new technologies as long as the costs of existing technologies were funded within the regulatory framework, and as regulated monopolies they did not face competition. Many of the potential benefits of innovation on networks would accrue to consumers, suppliers, and owners of distributed generation, yet it was network companies who would have to invest to realise those benefits. Moreover, any expected benefits of innovation may not accrue for some time. Not only may such benefits be heavily discounted, but if they occurred mainly in future price control periods, companies faced the risk that their investments in innovation would not be judged to be efficient and so would be disallowed from inclusion in approved expenditure.

The fact that DNOs have been essentially reactive in their strategies and that incentives for innovation are so bound up with the regulatory regime makes the *regulatory institution the primary focus for understanding the politics of niche creation* (Bolton and Foxon, 2011). While contestations over niches in competitive contexts are typically networks of actors supporting different technologies and vying with each other for the benefits of protective space (Smith and Raven, 2012), in the case of network innovation the struggle has been not so much about which technology gets protection as whether there is any protective space at all.

In some other European countries, debates on smart grids have been institutionally more dispersed, with concepts such as local semi-autonomous micro-grids beginning to play an important role (see e.g. Blanchet, 2015 for the case of Berlin). However, this has not been so evident in Britain. Micro-grids made up one element in Ofgem's 2008 Long-term Electricity Network Scenarios (LENS) study and in some technical studies carried out in the mid-2000s (Abu-Sharkh et al., 2006), but these have not been followed up in any major way. The micro-grid concept is mentioned only in passing even by civil society enthusiasts for a decentralised, smarter network (Greenpeace, 2005; Willis, 2006). While this may change in future, the main focus of debate on network innovation in Britain has remained firmly on the role of regulation and the relationships between regulator and DNOs.

This contrast with other countries may be related to differences in the size and ownership of networks. In GB, there are 14 large distribution network operators owned by 6 parent companies, with an additional 5 tiny independents, mainly representing private wire networks in new developments. There is only a handful of micro-grids, including those on Scottish islands (Eigg, Shetlands) – see Ward and Phillips (2014). By contrast, some other European countries have a large number of relatively small electricity distribution operators. Germany stands out, with 869 distribution operators in 2012,

[5] Sometimes characterised as a 'fit-and forget' approach (e.g. Shaw et al., 2010: 5930).

[6] By the late 2000s, these issues were widely recognised in the academic and industry literature (e.g. ENA, 2009a; IET, 2009; Bolton and Foxon, 2011; Smart Grid GB, 2012; Sansom, 2010; Ruester et al., 2014: 3) and also by Ofgem (2009b). However, this was not the case in the early 2000s.

of which 794 had fewer than 100,000 customers (Pérez-Arriaga et al., 2013). But Spain, the Czech Republic, Sweden, Italy, France, Poland and Austria each have over 100 distribution network operators, and Finland and Denmark are not far behind. Some of these networks are owned by municipalities or even cooperatives of consumers. This scale of ownership fits the concept of micro-grids more naturally.

3. Theorising the politics of institutional change

The analysis of innovation for sustainability transitions is currently dominated by the literature on socio-technical transitions (STT), and especially the multi-level perspective (MLP) on such transitions (Smith et al., 2010). This literature, emerging from the sociology of technology and innovation studies, is useful in its emphasis on the ways in which technological systems are embedded in wider social institutions and practices, and in its distinction between incumbent socio-technical 'regimes', 'niches' in which innovation is nurtured and wider 'landscape' factors. However, it has also been widely criticised for a lack of analysis of politics (Meadowcroft, 2009, 2011; Smith et al., 2005; Shove and Walker, 2007; Fouquet, 2010; Kern, 2011). This critique then raises the question of exactly how politics should be theorised and brought into the analysis of sustainability transitions.

A range of different attempts to do this have been put forward within the socio-technical transition literature. Meadowcroft (2009, 2011) – who mainly focuses on the absence of politics in STT rather than providing an alternative framework – has a short discussion of the importance of democratic political processes as a way of building legitimacy for sustainability transitions, while Ulmanen et al. (2009) use Sabatier's advocacy coalition framework, Kern adopts a discursive-institutionalist framework, Smith and Raven (2012) also draw heavily on the concept of discourse but as developed in organisational studies and Geels (2014) prefers a neo-Gramscian approach to political economy.

This has produced an interesting variety of approaches to political analysis, although it is not always clear why exactly the chosen framework and not another is being adopted in any particular case.

To an extent this heterogeneity reflects the range of potential political, sociological and organisational theories available, but it may also reflect the fact that different authors are focusing on different parts of the socio-technical transitions model. Thus some are trying to account for the politics of regime transformation as a whole (Meadowcroft, Smith et al., Geels), while others, more relevantly for this study, are focusing on the creation and development of 'niches' for new technologies and practices. These different scales or levels of analysis matter; while niche creation and development form part of regime transformation, the level and type of politics involved at this scale differs from that involved 'at the point of committing large scale public resources to particular technologies or tilting policy to favour particular approaches' (Meadowcroft, 2009: 336).

Amongst recent papers focusing on the politics of niche creation, Ulmanen et al. (2009) and Smith and Raven (2012), while differing in the language used, do share some common theoretical elements. Both studies contrast the technocratic nature of the STT-influenced strategic niche management approach with the fact that in practice 'ideas for how protective space *ought* to operate soon encounter confounding and conflicted realities' (Smith and Raven, 2012: 1031). Both studies emphasise the importance for niche creation of the efforts of groups of actors ('advocacy coalitions' in Ulmanen et al. and 'actor networks' in Smith and Raven). Finally, both also focus on the importance of the use of ideas in political strategies for achieving institutional reforms that create and empower niches ('discourse' in Ulmanen et al. and 'narratives' in Smith and Raven).

These frameworks are useful, but remain at quite a general level. Here I seek to adapt them to make them more specific to the institutional context. First, on the role of ideas in niche creation, few would disagree with Ulmanen et al.'s (2009) statements that "discourses are a resource for advocacy coalitions to articulate problems, put pressure on regimes, and promote solution" and "those who control the dominant discourse can control the direction of change" (p. 1407). However, to understand this process more fully we should be interested in the institutional conditions under which a particular attempt to do this sometimes fails and sometimes succeeds. Kern (2011), for example, develops such an approach in a comparative study of system innovations in the UK and the Netherlands. Here, as discussed below, I adopt an existing framework for analysing the role of ideas in institutional change from the neo-institutionalist literature.

A second issue concerns the characterisation of actors. The role of networks or coalitions of actors both inside and outside of governments is clearly important in niche creation in many cases. However, in the case of niche creation for electricity networks in Britain in the early 2000s, as discussed below in Section 4, change was largely due to a single actor within the regulatory institution, and even in the late 2000s networks advocating more support for R&D were small and relatively weak, with change again being driven from within the regulator. I would argue that this situation is primarily due to the regulated nature of electricity network companies, since they lack an incentive to form advocacy coalitions for niche creation. While others, especially ICT firms in the supply chain and environmental NGOs, did advocate for R&D support, especially by the second half of the 2000s, this coalition was relatively weak and poorly organised, mainly because the attention of its members was mainly elsewhere (NGOs on coal-fired power generation and the ICT industry on smart metres).[7] Moreover, the coalition was in a structurally weak position for institutional reasons, since it is harder for external groups (other than the regulated industry itself) to lobby an independent regulator than a government. The overall point here is the need to allow for a greater range of types of potential actors in the analysis of niche creation.

This review of the uses of political theory in the STT literature points to the desirability of justifying theory selection by its relevance to the problem being studied and by its explanatory power. My starting point for theory selection is to note, as discussed above, that the creation of protective space for network innovation in Britain is essentially a problem of *institutional change* in the regulatory regime. This suggests looking to the body of *institutionalist theory* that plays a central role in modern political analysis (Peters, 2012), and in particular how such theory has sought to explain change.

A second point is to characterise the institutional change in Ofgem over the 2000s that led to the creation of a new space for R&D in electricity networks as essentially incremental. As discussed in more detail below, in creating a technological niche for network innovation, actors in Ofgem did not sweep away the core of the previous regulatory regime but rather added new elements to it. To some extent, this will always be true of niche creation, precisely because this process is only a potential precursor to regime change. Early institutionalist theorising saw institutions as heavily path dependent and fundamentally stable, an idea that is familiar in the case of sustainable energy in the form of 'carbon lock-in' (Unruh, 2000). In such approaches change can occur only as the result of exogenous shocks or crises (Kingston and Caballero, 2009; Peters, 2012: 62–63), which again is a familiar theme from the STT and MLP literature. However, it has been increasingly recognised that much important institutional change happens incrementally (e.g. Streeck and Thelen, 2005) and that much of this more gradual institutional change is endogenous in nature, with internal institutional actors playing central roles (Battilana et al., 2009). The form of change observed in the regulatory regime for electricity networks takes a form that has been characterised as 'layering', i.e. the addition of new rules on top of or alongside existing ones, rather than other kinds of change that involve displacement or neglect of rules (Streeck and Thelen, 2005; Beland, 2007).

The question then arises as to why institutional change took the form of layering in this case. Mahoney and Thelen (2010) offer a theory that addresses this question.[8] First, drawing on Tsebelis's (2002) notion of veto points, they argue that if incumbent actors in an institution have strong *veto possibilities*, they are more likely to be able to resist both external and internal pressures for change that completely displaces existing institutional goals and rules (Mahoney and Thelen, 2010: 18–19). It is precisely in such contexts that one would expect to see layering rather than displacement. Second, they argue that the nature of institutional change will also depend on the degree to which actors in an institution have *discretion in how they interpret and enforce institutional rules* (Mahoney and Thelen, 2010: 21–22). In situations where there is a lot of discretion, a gap can open up between formal rules and enforcement, leading to a mode of institutional change identified as 'drift'. However, layering involves the development of new rules rather than new interpretations of existing ones, so it will be

[7] This analysis is based on the author's experience of working in the Department of Energy and Climate Change in 2009–2010 and interacting with Ofgem, the ICT industry and NGOs.

[8] Kern and Howlett (2009) also offer a framework for explaining why particular forms of gradual institutional change occur, in terms of instruments and goals. Here I choose Mahoney and Thelen's framework as it is both more complete and includes consideration of the types of actor involved.

the likely form of change where the implementation of institutional rules is controlled more tightly. Finally, they consider how modes of institutional change may be associated with different types of change agent (Mahoney and Thelen, 2010: 22–27). They argue that layering will tend to be associated with actors who seek to change the institution in which they are located, but 'in pursuing this goal they do not themselves break the rules of an institution.' (Mahoney and Thelen, 2010: 25). Instead they tend to work by biding their time and encouraging the promotion of new rules on top of existing ones. Change agents of this type are labelled '*subversives*'. Mahoney and Thelen (2010: 29–31) go on to argue that such agents are likely to 'work on their own, behind the scenes or in the shadows', rather than forming coalitions for change with institutional challengers or indeed with institutional incumbents.

Mahoney and Thelen's framework offers not only specific testable explanations about the form of change, but also introduces an additional level of analysis of the role and agency of actors. However, it has one major lacuna, which relates to the role of *ideas* in institutional change. As noted above, there is a justified interest in the socio-technical transitions literature in how actors deploy 'discourse' or 'narratives' to try to create protective space, and any theory of institutional change should also address this issue. However, as discussed above such discursive concepts are very broad and their use in much of the theory deployed in the socio-technical transitions literature remains underdetermined. In this context, Campbell (1998, 2004: 90–123) offers a useful framework for distinguishing different *types* of ideas based on two conceptual distinctions: whether ideas are normative or cognitive, and whether ideas are used strategically in the foreground of decision making or are present in the background as assumptions. This approach produces a four-fold categorisation. First are cognitive ideas in the foreground of decision-making, which Campbell calls 'programs' and defines as 'concepts . . . that enable or facilitate decision-making . . . by specifying . . . how to solve specific problems' (Campbell, 2004: 98). Programs are typically the key dependent variable in institutional change because they determine most directly how institutions change. Second are normative ideas in the foreground of decision-making, which Campbell labels 'frames'. Frames are used by policy elites or by advocacy groups to legitimise programs and changes to their target constituents. What many socio-technical theorists call 'discourses' or 'narratives' would fall into this category. A third set of ideas are cognitive ideas that take the form of background assumptions constraining the range of programs that are acceptable or available, which Campbell, following Hall (1993), calls 'paradigms'. Finally, 'public sentiments' are background normative assumptions (what some might call 'ideologies') which determine the range of programs that decision makers are likely to perceive as acceptable to society.

Given that endogenous institutional change must involve programs in the most proximate sense, the question is then what makes it possible for institutional change agents to successfully put forward programs. Campbell (2004: 115) argues first that 'ideas . . . matter most for institutional change under conditions of great *uncertainty*' (emphasis in the original), especially in a *perceived* crisis. He argues that a key factor in shaping perceptions of events is the *interactions* that actors have with others.

Given the perception of crisis or uncertainty at senior levels in an institution, a number of conditions must then be in place for new programs to be taken up. First, the program must be *credible* to decision makers in the sense that it fits their dominant paradigm.[9] Second, policy makers must believe that the new program being offered is *effective* 'insofar as it promises a reasonable solution to a decision-making problem' (Campbell, 2004: 118). Finally, 'if decision makers perceive that an idea is effective . . . then they must also deem it *legitimate*,' i.e. it must be seen as resonating with prevailing public sentiments and it must be famed in ways that allow decision makers to legitimise it with constituents.

Taken together, Mahoney and Thelen's theory of gradual institutional change and Campbell's hypotheses about the conditions under which ideas can influence institutional change provide the framework for the analysis below. In the next section, I provide an account of the initial creation of a regulatory mechanism of support for network R&D and its subsequent expansion, based mainly on official documentation and interviews with key participants and industry observers (Annex 1). In Section 5, I then assess how far the theoretical arguments made above are supported by the evidence from these two episodes.

[9] Some crises are so extensive, deep and long that they call into question entire policy paradigms (Hall, 1993), but these are relatively rare episodes of major change involving 'critical junctures'.

4. The politics of niche creation: from the IFI to the LCNF

4.1. The Innovation Funding Incentive and Registered Power Zones

In 2000, support to innovation was not on the agenda at Ofgem (Bolton and Foxon, 2011). However, by 2004, two new mechanisms creating dedicated funding pots for R&D and deployment trials had been set up. One was the Innovation Funding Incentive (IFI), covering 'all aspects of distribution system asset management' (Ofgem, 2004: 48), which was capped at 0.5% of allowed revenue and available on a use-it-or-lose-it basis. Ofgem allowed 90% of the costs of IFI projects to be recovered in the first year of the price control, but this tapered off through the period to 70% in the fifth year, in order to incentivise early take up. The second mechanism was Registered Power Zones (RPZs) – a scheme aimed at demonstrating innovative solutions for the connection of new distributed generation (DG) on sections of network. DNOs were allowed additional revenue for each kW of DG connected, capped at a total of £500,000 per DNO per year. These mechanisms were small in relation to the size of total spend by DNOs, but they created a new niche of activity that led subsequently to a much larger scheme.

By the late 1990s, the regulatory regime for networks invented at the end of the 1980s was firmly established and largely seen as successful. The group that was most dissatisfied with the regime comprised developers of decentralised electricity generation, who were marginalised and received poor service from the distribution companies. Two successive working groups[10] bringing together Ofgem staff with a decentralised generation actor network were formed from the late 1990s onwards (see e.g. EGWG, 2001), but these working groups had little effect, and did not lead to technological or operational change. Instead, the origins of the IFI and RPZs lie with the arrival of a new Technical Director in 2001, an engineer with a background in distribution networks in the pre-privatisation period, who sat on Ofgem's senior management team.[11] Early meetings with DNOs revealed a "complete collapse of any form of R&D"[12] relative to the situation in the late 1980s. Companies were squeezing spending on R&D as an activity that had a relatively high risk and no certainty of returns within the regulatory period, with the likelihood that any high returns realised would quickly be clawed back, and which often involved going against established competitive procurement rules.

The diagnosis implied a change in the regulatory framework that could address some of these problems. However, this idea was immediately very "contentious" inside Ofgem, creating considerable "tensions" with the dominant group of economists.[13] The markets group in the organisation were "purist" in outlook, i.e. taking the 'Austrian' view that the cost-reducing incentives created by RPI-X should be sufficient in themselves to drive innovation in a similar way to market competition (Helm, 2003: 59). These economists worked with a simplified, 'black-box' view of innovation, which they saw as primarily supply-push; innovation would be undertaken by electrical engineering supply firms and DNOs would use new products if they were good. Above all, they regarded Britain's adoption of incentive regulation (in contrast to the rate-of-return regulation prevalent at the time) as "leading the world", and were strongly opposed to any interventions that amended or blunted the incentive structure, seeing these almost as "breaking the faith".[14]

Other economists in Ofgem took a more pragmatic view, and became convinced that the decline in R&D activity was a real problem. This group was more open to trying some form of support mechanism on a temporary basis and seeing how it affected R&D activity. However, the issue was so divisive at management level that no agreement could be reached. The Head of Networks then decided to refer the issue up to Ofgem's governing body, the Gas and Electricity Markets Authority, as a way of resolving the issue.[15] At the Authority level, while the pragmatic view prevailed, there was still strong dissent

[10] The Embedded Generation Working Group which operated up to 2001 and the Distributed Generation Coordination Group, which succeeded it.
[11] Interviews 1, 2 and 4.
[12] Interview 4.
[13] Interviews 2 and 4.
[14] Interview 4.
[15] ibid.

from some. Giving evidence on the schemes to the Energy and Climate Change Select Committee some years later, one DNO chief executive noted that:

> 'It was a huge change four years ago when the authority approved any form of mechanism for innovation . . . A lot of water has flowed under the bridge since then, but at that time there were mixed views and great caution among some senior members of the authority. Some people were very hawkish, asking why they should be doing it . . .' (Phil Jones in oral evidence to ECC SC (2010: Ev58)).

The tensions at senior level and the fact that the case for new mechanisms had only just prevailed were reflected in the ambivalence of the language in the decision document for the 2005–2010 price control:

> 'Ofgem has . . . considered whether there is reason to suspect market failure in respect of R&D funding by DNOs. While this is not clear cut, it is possible that the regulatory system is perceived to be such that it undermines the commercial incentive to R&D that the patent system provides in other sectors' (Ofgem, 2004: 48).

In designing the R&D mechanisms, there was a need to engage and negotiate with the economists in Ofgem. A central concern was that companies would take advantage of the risk-mitigation that the mechanisms offered, and would simply take the revenue while not actually undertaking useful R&D.[16] Two steps were taken to address this concern: the Electricity Networks Association was asked to prepare an IFI Good Practice Guide,[17] and public reporting on funded activity using a prescribed format was required. Input into the design of the mechanisms also came from informal meetings with senior engineering staff in the DNOs and a relationship with a contact in a large electrical engineering manufacturing firm.

Once launched, the IFI quickly produced a response. Spending by DNOs under the IFI increased from around £2 million in 2003/04 to around £12 million in 2008 (Jamasb and Pollitt, 2008: 313), implying that there had been a back-log of R&D waiting to be done.[18] Spending then plateaued to 2011 and then declined as the successor LCNF scheme came in (see below). Positive feedback came not only from engineers but also from the senior management of DNOs and also internally from parts of Ofgem, including the Sustainable Development division established in 2009. By contrast, there was less take-up of the RPZs, with only a handful of schemes materialising in the price control period (Woodman and Baker, 2008: 4529; Bolton and Foxon, 2011: 17).

4.2. The Low Carbon Network Fund

The Technical Director left Ofgem in 2007, and the post was abolished, leaving no engineering representation at senior management level.[19] However, in 2010 a new mechanism for R&D and demonstration projects was introduced in the fifth distribution price control review, the Low Carbon Network Fund (LCNF). This was a competitive mechanism that allowed DNOs to bid for up to £500 million over 5 years (Ofgem, 2010), equivalent to 2.3% of allowed revenue, an order of magnitude larger than the IFI and a very substantial increase on levels of R&D spend a decade previously. It was closer to the RPZ concept than the IFI in that was aimed primarily at demonstration projects rather than basic R&D. There were two 'tiers' of funding, one allowing DNOs to recover most of the costs of smaller projects in allowed revenue, and another for larger projects in the form of a competitive fund of £64 million a year. Tier 2 funding requires DNOs to cooperate with ICT firms, suppliers, generators and consumers in projects. Essentially the same structure for RD&D funding will be continued into the next price control period (2015–2023).

---

[16] ibid.

[17] For the guide for electricity distribution networks see: http://www.energynetworks.org/electricity/engineering/research-and-development/innovation-in-electrical-distribution-networked-systems-a-good-practice-guide.html.

[18] IFI funding went to a wide range of projects. See http://www.smarternetworks.org/Project.aspx?ProjectID=737#downloads for full reports.

[19] Interviews 1 and 4.

The external and internal contexts for the LCNF were quite different from those at the start of the decade. Public concern about and media interest in climate change had grown sharply from 2004 onwards, culminating in the publication of the Stern Review in 2007 and the passage of the Climate Change Act, the consequent creation of the Climate Change Committee and the new Department of Energy and Climate Change in 2008. The now-defunct Sustainable Development Commission published a critical evaluation of Ofgem in 2007 which questioned whether the regulator had 'kept pace with the climate change imperative and whether the government framework within which it operates is fit for the challenge of moving to a completely decarbonised electricity system by 2050' (SDC, 2007: 6–8). There were calls by academics and think-tanks to increase the scale of funding (e.g. Pollitt and Bialek, 2008), to allow more collaboration across the value chain, with consumers, suppliers and ICT companies (Cary, 2010) and to do more to ensure that technical innovations developed under funding mechanisms were mainstreamed into investment programs (Bolton and Foxon, 2011). A Parliamentary Committee report called for a 'fundamental rethink' of the regulatory regime (ECC SC, 2010: 16). Successive governments also made several changes to the remit of Ofgem through legislation or guidance over the 2000s, intended to increase the attention given to climate change and decarbonisation of the energy system.

Within Ofgem, senior managers were increasingly reflecting critically on RPI-X.[20] The successes of cost reduction were celebrated, but the new concern was the need for investment in increasingly ageing networks, as well as the expectation that electricity networks would see increasing amounts of small scale distributed generation connected. There was a perceived need to specify more clearly the quality of service that network companies should be delivering as part of the "regulatory settlement as a contract".[21] Following work on a regulatory framework for the roll out of smart metres, to be implemented by energy suppliers, Ofgem was also increasingly paying attention to the opportunity and need to modernise networks and the importance of accelerating innovation in network planning and operation. Finally, those working on price control reviews saw that separate and different incentives schemes for opex and capex led DNOs to favour capital heavy solutions to network problems, potential distorting attempts to introduce smarter approaches.

As a result of these concerns, a major review of the regulatory framework (known as RPI-X@20) was launched by the Chief Executive in 2008 (Buchanan, 2008). This review ran alongside the development of the fifth price control review for electricity networks (DPCR5) and the partner running that review met regularly with the RPI-X@20 team. RPI-X@20 led in 2011 to the formation of a new regulatory regime for networks called 'RIIO' (standing for Revenue = Incentives + Innovaton + Outputs). This regime introduced a number of changes, but remained the basic structure of revenue cap regulation at its core.

Against this backdrop, proposals for an expanded innovation support scheme came from within the price control review team,[22] but also from an external Consumer Challenge Group set up in July 2008 as a 'critical friend' in the newly created Sustainable Development division.[23] These proposals recognised the precedent set by the IFI and RPZs, but in the new context, these were now viewed even within Ofgem as too tentative, too small and too focused on research projects divorced from business-as-usual network investment. In the words of one interviewee: "we needed a vehicle for risk-free learning and bringing it into BAU [business as usual]".[24]

Two changes were seen as necessary to move DNOs further through the innovation process and engage them in learning-by-doing. One was to push them to be more outward looking by requiring bids for LCNF funding to include partnerships with suppliers, ICT firms, local communities and universities. Indeed the original vision was that any organisation could apply for LCNF funding, not just DNOs. However, this approach proved to be legally problematic,[25] and DNOs remain the doorkeepers for R&D support. In this sense, while the LCNF allowed DNOs to explore the possibility of new

[20] Interview 5.
[21] Interview 6.
[22] ibid.
[23] Interview 3.
[24] Interview 6.
[25] Interview 5.

commercial relationships as well as new technologies, it did not open up protective space for innovation in institutional arrangements for providing networks services. Such innovation was suggested in the RPI-X@20 review (Pollitt, 2009), but was quickly criticised by the network industry (ENA, 2009b: 11). Competition for network services remains restricted to new network extensions, and there are only a handful of tiny independent DNOs at present.

The second change was to radically scale up the funding available. In the words of one interviewee, the scheme had to be sufficiently "juicy" and "super-charged" to engage the attention of the boards of DNOs rather than just engineering staff, and overcome the reluctance of companies to devote resources to non-core activities.[26] However, precisely because of the big increase in scale of funding and because Ofgem staff were now using "explicit language and rhetoric around failure"[27] in thinking about the innovation process, there was a considerable amount of scrutiny and challenge from GEMA. Their concerns included not only risk being borne by consumers but also the possibility that the competition element could lead to legal challenge, state aid issues and the assignment of intellectual property rights.[28] Ofgem staff had to go back to the Authority on several occasions before getting final approval for the scheme.

The LCNF has led to a step change in levels of R&D activity, and especially larger sale demonstration projects by companies. The Fund has accelerated learning and networking processes, and its requirement for the sharing of knowledge gained from trials has led to a website[29] and an annual conference, which is now a major event attracting several hundred participants. There is some evidence that it has also a significant effect on DNO thinking and culture, albeit varying between companies.[30] It has required DNOs to work together with suppliers, ICT firms, renewable generators and consumers on concrete demonstration projects. It has engaged network company board level interest in the smart grid agenda, and made DNOs aware of potential new commercial relationships and opportunities (for example, in demand response). However, whether the LCNF will actually lead to major changes in network investment and operation more widely remains to be seen. In their business plans for the new price control period to 2023, DNOs expect that savings from smart grid solutions against BAU approaches will lead to savings equivalent to less than 2% of allowed revenue (Ofgem, 2013). Ofgem has in turn said they will expect DNOs to realise roughly double this level of savings.

5. Discussion

How far are the events narrated in Section 4 consistent with the associations proposed by the theoretical frameworks outlined in Section 3? In the creation of new mechanisms for RD&D in Ofgem, institutional change has taken the form of 'layering', that is, the addition of new rules and objectives on top of existing ones. Thus support mechanisms for R&D have been added to rather than replaced incentive regulation. Such a pattern of change can also be found in other aspects of the evolution of network regulation, such as the introduction of new rules on output incentives or stakeholder engagement, which have been layered on top of the basic efficiency incentive. Even the move from RPI-X to RIIO retained the underlying model for cost minimisation at its core.

In Mahoney and Thelen's framework, institutional change is more likely to take the form of layering where the political context involves strong veto possibilities and where actors in an institution have less discretion in the interpretation and implementation of rules. The relationship between the electricity regulator and government at the point of its creation in 1989 was heavily influenced by the values of 'club' governance that dominated the British political, professional and civil service elites for most of the 20th century, i.e. discretion, limited public accountability and self-governance (Moran, 2003: 105–06). In the first electricity regulator there was an individual Director General and broad

[26] Interview 6.
[27] Interview 5.
[28] Interview 6.
[29] http://www.smarternetworks.org/index.aspx.
[30] Deasley et al. (2014: 29) report increased staff resources being allocated to innovation and organisational changes in UK Power Networks, for example.

powers subject to a 'light touch' legal framework. As a 2011 government review noted, the specification of Ofgem's duties has been "intentionally broad to allow the regulator flexibility" (DECC, 2011: 24) and this of course fits with the general approach of regulatory independence. Despite successive changes to the regulator's remit and duties, this relationship effectively leaves Ofgem to interpret policy, including trade-offs between policy objectives, in the way it chooses. Government can give guidance to Ofgem, but this guidance has "weak legal status" (DECC, 2011).

This relationship gives senior staff in the regulator considerable possibilities for veto. Successive governments did apply political pressure to Ofgem over the 2000s to take the low-carbon imperative more seriously, but they could not directly instruct or micro-manage an independent regulator. This is indeed why a series of changes to duties and guidance were introduced, as each in turn was seen to be ineffective. Arguably even Ofgem's major regulatory review in RPI-X@20 was driven more by internal concerns than by external demands (the government in fact hardly engaged either with the review or with DPCR5). Even when Ofgem has been under pressure from government to address a particular issue, it has retained the power to decide *how* it will do so. In terms of Mahoney and Thelen's central point, it is certainly the case that political pressure from governments, Parliament or other external actors cannot overcome Ofgem's veto on retaining what it sees as its core functions and rules, meaning in turn that these cannot be swept away and replaced with new ones. Only a dissolution and reinvention of the institutional relationship could do this.

By contrast with this high degree of discretion in the relationship between government and regulator, the aim of the architect of the system in the 1980s, Stephen Littlechild, was to get rid of discretion in the *application* of regulation. Littlechild rejected the American 'rate of return' (RoR) regulatory model, which he saw as providing no incentive for improving efficiency, in favour of RPI-X. However according to Moran (2003: 105), he was also sceptical of RoR regulation because it required the regulator to exercise discretion in making a detailed assessment of the asset base of the regulated companies and assessing what a 'fair' rate of return is, both of which open the regulator to capture. RPI-X regulation, by contrast, involves set methodologies and rules, for example for benchmarking company performance, assessing efficient investment, adding to the asset base, and setting the allowed cost of capital. While a degree of discretion was inevitable at some stages,[31] it is generally hard for actors in Ofgem to depart significantly from rules in most areas. Certainly, it would have been hard for actors in Ofgem to create significant support for R&D simply through bending the rules and incentives for expenditure. This implies that such support would need new rules in addition to the existing ones, i.e. layering.

Within this structural context, the agency and use of ideas by institutional actors or entrepreneurs then become important. The Technical Director of Ofgem in the early 2000s was the key institutional entrepreneur in the introduction of new rules for support to R&D. While he wanted to see change, he also wanted to preserve the wider regulatory institution, and believed in the basic efficiency incentive provided by RPI-X. He also sought to bring in new rules, as bending existing ones was not an option. In Mahoney and Thelen's schema, this characterises him as a 'subversive', a type of agent they associate with layering. Such agents are expected to work largely alone and 'under the radar', rather than seeking alliances with internal or external critics of the institution. However, this is only partly true in the case of the Technical Director. Initially, he did find himself isolated, but in developing proposals for new rules he had to build relationships with actors in external institutions, such as engineering staff in DNOs and contacts in supply firms. Even more importantly, he sought to build an internal advocacy coalition with the more pragmatic economists in the networks division of Ofgem, although not with complete success.[32]

This last point relates to Campbell's hypotheses about the use of ideas in institutional change. Campbell argues that for ideas to bring about institutional change, there has to be a perceived crisis or problem at senior levels in an organisation. To a large extent, this condition was not present in the Ofgem of the early 2000s in relation to innovation. While the Technical Director did identify a problem of moribund R&D early on, mainly through contacts with engineering staff in DNOs that others in

[31] Such as in setting the 'X' parameter that represents expected efficiency gains.
[32] Interview 4.

Ofgem did not have, he had to actively create perceptions of the problem inside the institution (and only partly succeeded). Following this, the Technical Director effectively offered a 'program', i.e. a specific cognitive idea about how to solve the problem, based on a particular view of the innovation process. He was also able to offer some analysis (commissioned by an independent consultant) of its effectiveness in lowering costs over time, but the case was based in part on the approach of trying out a mechanism and then assessing it rather than on hard evidence of effectiveness.[33] The challenge of legitimacy in relation to public sentiment was mainly about ensuring that the program did not add unreasonable costs for consumers, a challenge that was met through aspects of the program design. The more fundamental problem was that the program was not consistent with the intellectual paradigm that the dominant group of 'purist' economists were working within. This issue was never fully resolved, and in the end an appeal to senior actors operating within a more pragmatic paradigm was necessary.

This discussion points to the important implication that in any institutional setting, while there may be paradigms that are dominant at any one time, there are also likely to be a number of alternative paradigms (or varieties of the main paradigm) that institutional entrepreneurs can attempt to make their programs consistent with. Certainly the story of IFI is not a neat one of making a new policy fit the dominant paradigm, but rather a messier one of attempting to confront a dominant paradigm before seeking out consistency with an alternative at another level of governance.

Moving to the late 2000s, if senior managers in Ofgem did not perceive a *crisis* in network regulation they did perceive a set of *problems*, including capital bias in spend, a poorly defined regulatory contract and a slowness of network companies to respond to new agendas and technological possibilities. These actors also wanted to change the institutional rules without destroying the regulatory institution or its core objectives, but while they could also be labelled 'subversives' in Mahoney and Thelen's (2010) sense, they were of sufficient number and seniority that they had no need to work alone or 'under the radar'. A key reason for this was that the dominant economic paradigm in Ofgem had shifted over the 2000s.[34] A commitment to incentive regulation based on a simple belief in the power of cost reduction had given way to a more complex assessment, including the possibility of negative effects on quality of service and on innovation. This latter point was reinforced by the evidence that support mechanisms like the IFI could be effective in changing the levels of R&D undertaken by companies. A program for a bigger bolder innovation support mechanism was therefore more consistent with what had become a more pragmatic, less 'purist' paradigm and it was far easier to provide evidence of its likely effectiveness. In fact, most of the work in the case of the LCNF went into developing in such a way that it was consistent with public sentiments, i.e. that it should be constructed in such a way that it did not impose excessive risks and costs on energy consumers. With that gas and electricity prices increasing sharply between 2002 and 2008, it is not surprising that public sentiment came to the fore more strongly.

6. Conclusion

In this paper I have argued that the creation of protective space for innovation in electricity distribution networks in Britain over the 2000s is best seen as a political process involving gradual endogenous change within the regulatory institution. This change has taken the form of the 'layering' of new formal rules over existing ones, rather than displacement or informal drift. I have used a detailed account of

[33] Evidence gathering is particularly problematic in the area of innovation, as it requires supply chain companies to share insights about future products and their likely costs – both usually closely guarded types of information in a competitive market. This challenge was met by quite subtle means such as utilising the IET's building for meetings (neutral ground and a 'professional' context), by key advocacy behind the scenes by vendor representatives who saw the opportunity for positive change by being willing to accept some commercial risk, and by independent consultants providing reassurances of anonymity in data gathering (interview 4).

[34] Kern et al. (2014) argue, following Helm (2005) that a new energy paradigm became established over this period, because of shift away from liberalised markets to interventions on grounds of energy security and climate change mitigation. Here, the argument is that there was a shift *within* the nature of what remained a dominant paradigm of regulation based on a neo-classical economic theory of incentives.

how regulatory mechanisms for R&D and demonstration support were created to test two explanations of gradual change from the institutionalist literature. I have argued that this approach builds on existing theoretical frameworks for understanding the politics of niche creation in the socio-technical transitions school both by introducing more specific hypotheses about the nature of change and the role of ideas in institutional change, and by allowing a greater focus on the nature and role of actors.

Mahoney and Thelen (2010) argue that layering will tend to be found where an institution has many possibilities for veto in its political context, and where there is limited discretion in the implementation of rules. They also argue that layering will tend to be led by institutional entrepreneurs operating largely alone and 'under the radar' rather than openly challenging institutional power structures. The case of new R&D support mechanisms for electricity distribution networks provides some support for these arguments. Ofgem's high degree of discretion vis-a-vis government and other actors gives it multiple veto possibilities, while rules for applying regulation cannot easily be bent. However, the activities of the main institutional entrepreneur in the case of the early mechanisms (the Innovation Funding Initiative and Registered Power Zones) only partly fit the model. As Mahoney and Thelen's framework suggests, he sought to amend rather than overturn the regulatory framework. But contrary to the expectations of the framework, he had to form alliances with a group of 'pragmatists' in the regulatory organisation and its governing board, rather than working in isolation. With the second and larger innovation mechanism in the late 2000s (the Low Carbon Network Fund), the key change actors were senior managers, who proved to be simultaneously institutional incumbents and challengers. These findings imply that Mahoney and Thelen's characterisation of change agents associated with layering is too restrictive, and in particular does not accommodate the case where institutional incumbents also seek to drive change.

Campbell (1998, 2004) focuses on the role of ideas in institutional change, arguing that new policy 'programs' are more likely to be accepted where a crisis or problem is perceived, where the program is consistent with the dominant policy paradigm, and where is can be framed in such a way that it resonates with wider political narratives. In the case of the IFI and RPZs, the absence of innovation by network companies was not perceived as a problem, and the key institutional change agent had to work to build such a view within the organisation. His proposed program faced strong challenge from the dominant 'purist' economic paradigm, but found sufficient support from an alternative, more pragmatic set of ideas in Ofgem's governing body. Discursive theories of institutional change sometimes appear to conceive of single policy paradigms as monolithically dominant (e.g. Hall, 1993), but in this case there were a number of different variants of economics which change agents drew on. By the time that the LCNF was developed, the purist view had been moderated as attention shifted from cost-cutting to investment and quality of service. Consistency of the program with the policy paradigm was less of an issue than how the program resonated with public sentiment about energy bills, since electricity prices had risen sharply since the early 2000s. This finding suggests that the weight or importance of different types of ideas in determining the success of a new 'program' can change over time.

In terms of the existing literature of the politics of niche creation and development, this analysis confirms the messy and conflictual nature of these processes. However, it also shows the particularities of niche formation involved in an industry where returns are determined by a regulator. Both the establishment of the IFI/RPZs and the later expansion of R&D under the LCNF confirm Ulmanen et al.'s (2009) and Smith and Raven's (2012) emphasis on the importance of discourses or narratives, although the account here provides more detail on the interrelationship between the ideas associated with the niche, the wider perception of crisis, regime discourses, the nature of supporting evidence and the fit with wider public sentiment. Finally, the study adds a level of analysis linking 'layering' to certain actor attributes and modes of operation. Since niche creation is effectively almost always likely to take this form of institutional change, this additional dimension should be of use and interest to the study of niche politics more widely.

The understanding of innovation processes within Ofgem has evolved over time but remains incomplete. The need for a regulatory support mechanism for R&D, and now demonstration, has not only been recognised but apparently embraced. However, despite a shift away from a purist view of innovation based on Austrian economics to a more nuanced approach, it remains the fact that the dominant view (or hope) in Ofgem is that the incentive to reduce costs in the wider regulatory framework will

now be sufficient alone to drive network companies to take the lessons learned in LCNF trials and apply them in business-as-usual network planning, investment and operation. Whether this is so, or whether more assistance will be needed to persuade companies to cross what is the regulatory equivalent of the 'valley of death', remains to be seen. And indeed, in a regulatory context the valley is likely to be large, since unlike competitive contexts, niche markets cannot be used as an intermediate step with further opportunities for learning and refining between demonstration and mass deployment. The continuing absence of engineers (especially those with expertise in smart grid technologies) in senior, policy-shaping roles in Ofgem also arguably hampers the regulator's ability to negotiate a period of complexity and disruptive change. More widely, the mechanisms so far developed by the regulator have not been able to open up a space for institutional experimentation. Thus more radical ideas for making networks more contestable, for example by allowing buy-outs of parts of networks or the setting up of parallel networks and driving innovation through more direct competition were rejected in the main regulatory review in 2009.

Acknowledgements

This work was supported by The Engineering and Physical Sciences Research Council (EPSRC) [EP/K001582/1]. I am grateful to those people who agreed to be interviewed, to Catherine Mitchell, Caroline Kuzemko and Richard Hoggett for discussions on the issues raised in the paper, to participants at a workshop on the politics of protective space for innovation in Eindhoven in November 2013 and to anonymous reviewers on an earlier versions of this paper, and to Florian Kern for editorial advice. All errors remain my own.

Appendix A. Annex 1 – Interviews

The analysis in this paper is based in part on a number of face-to-face and telephone interviews with distribution network stakeholders, regulators and ex-regulators conducted over the period July 2013 to October 2014. These interviews were carried out as part of a larger project on innovation and the governance of electricity distribution networks in Britain. The interviews drawn on most directly for this paper, especially the account of events given in Section 4, are listed below. Face-to-face interviews were audio recorded (with exception of interview 5) and key points transcribed; telephone interviews were recorded in note form. References to events and issues were cross checked manually but not formally coded.

1. Independent consultant – 2 August 2013 (telephone interview)
2. Distribution network company senior engineer – 27 February 2014
3. Member of Ofgem Consumer Challenge Group – 5 August 2014
4. Independent consultant and former Ofgem senior manager – 15 September 2014
5. Ofgem senior manager – 6 October 2014
6. Ofgem senior manager – 6 October 2014 (telephone interview)

References

Abu-Sharkh, S., Arnold, R.J., Kohler, J., Li, R., Markvart, T., Ross, J.N., Steemers, K., Wilson, P., Yao, R., 2006. Can microgrids make a major contribution to UK energy supply? Renew. Sustain. Energy Rev. 10, 78–127.

Agrell, P.J., Bogetoft, P., Mikkers, M., 2013. Smart-grid investments, regulation and organization. Energy Policy 52, 656–666.

Baker, P., Chaudry, M., 2010. UK Energy Research Council Response to the PRASEG Inquiry – Renewables and the Grid: Access and Management.

Battilana, J., Leca, B., Boxenbaum, E., 2009. How actors change institutions: towards a theory of institutional entrepreneurship. Acad. Manage. Ann. 3 (1), 65–107.

Beland, D., 2007. Ideas and institutional change in social security: conversion, layering and policy drift. Soc. Sci. Q. 88 (1), 20–38.

Blanchet, T., 2015. Struggle over energy transition in Berlin: how do grassroots initiatives affect local policy-making? Energy Policy 78, 246–254.

Bolton, R., Foxon, T., 2011. Governing infrastructure networks for a low carbon economy: co-evolution of technologies and institutions in UK electricity distribution networks. Competition and Regulation in Network Industries 12 (1), 2–27.

Buchanan, A., 2008. Ofgem's "RPI at 20" Project, Speech at SBGI, 6 March 2008, https://www.ofgem.gov.uk/ofgem-publications/52152/ab-march-08.pdf.

Campbell, J.L., 1998. Institutional analysis and the role of ideas in political economy. Theory Soc. 27 (3), 377–409.
Campbell, J.L., 2004. Institutional Change and Globalization. Princeton, NJ, Princeton University Press.
Cary, R., 2010. Future Proof: An Electricity Network for the 21st Century. Green Alliance, London.
Deasley, S., et al., 2014. How Could Electricity Demand-Side Innovation Serve the Electricity Customer in the Longer Term? Paper 11, GB Electricity Demand – Realising the Resource, Sustainability First, London.
Department of Energy and Climate Change (DECC), 2009. Smarter Grids: The Opportunity. DECC, London.
Department of Energy and Climate Change (DECC), 2011. Ofgem Review: Final Report. DECC, London.
Department of Energy and Climate Change (DECC), 2013. The Future of Heating: Meeting the Challenge. DECC, London.
Embedded Generation Working Group (EGWG), 2001. Report into Network Access Issues, http://webarchive.nationalarchives.gov.uk/20100919181607/http:/www.ensg.gov.uk/assets/21_10_2002_main_report.pdf
Energy and Climate Change Select Committee, Second report of session 2009-10, Volume I, HC194-1 2010. The Future of Britain's Electricity Networks.
Energy and Climate Change Committee, Local Energy, Sixth report of session 2013-14, Volume I, HC180.
Energy Networks Association (ENA), 2009a. ENA's Response to Ofgem's Working Paper 3 – Regulating Energy Networks for the Future: RPI-X@20, Delivering Desired Outcomes: Who Decides What Energy Networks of the Future Look Like?, http://www.energynetworks.org/modx/assets/files/news/consultation-responses/Consultation%20responses%202009/ENA_response_Ofgem_RPI-X@20_working_paper_three_1Sept09.pdf
Energy Networks Association (ENA), Submission from Energy Networks Association to Ofgem's RPI-X@20 project, 13 November 2009, http://www.energynetworks.org/modx/assets/files/news/consultation-responses/Consultation%20responses%202009/ENA_response_Ofgem_RPI-X@20_emerging_thinking_consultation_13Nov09.pdf 2009b. Where Should RPI-X@20 be Heading?
Fouquet, R., 2010. The slow search for solutions: lessons from historical energy transitions by sector and service. Energy Policy 38, 6586–6596.
Geels, F.W., Schot, J., 2007. Typology of sociotechnical transition pathways. Res. Policy 36, 399–417.
Geels, F.W., 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Res. Policy 31 (8/9), 1257–1274.
Geels, F.W., 2010. Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. Res. Policy 39, 495–510.
Geels, F.W., 2014. Regime resistance against low-carbon transitions: introducing politics and power into the multi-level perspective. Theory Cult. Soc. 31 (5), 21–40.
Greenpeace, 2005. Decentralising Power: An Energy Revolution for the 21st Century. Greenpeace, London.
Hall, P.A., 1993. Policy paradigms, social learning and the state. Comp. Polit. 25, 275–296.
Helm, D., 2003. Energy, the State and the Market: British Energy Policy Since 1979. Oxford University Press, Oxford.
Helm, D., 2005. The assessment: the new energy paradigm. Oxford Rev. Ec. Policy 21 (1), 1–18.
Hughes, T.P., 1983. Networks of Power: Electrification in Western Society 1880–1930. Baltimore, John Hopkins University Press.
Institute of Engineering and Technology, 2009. Response to Ofgem RPI-X@20 Working Paper 3: Delivering Desired Results – Who Decides What Energy Networks of the Future Look Like?, http://www.ofgem.gov.uk/Networks/rpix20/WorkingPapers/Documents1/IET%20comment%20on%20RPI-X@20%20-%20wp3%20-%20FINAL.pdf
Institute of Engineering and Technology, 2013. Electricity Networks: Handling a Shock to the System, http://www.theiet.org/factfiles/energy/elec-shock-page.cfm
Jamasb, T., Pollitt, M., 2008. Liberalisation and R&D in network industries: the case of the electricity industry. Res. Policy 37 (6–7), 995–1008.
Kemp, R., Schot, J., Hoogma, R., 1998. Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. Technol. Anal. Strateg. Manage. 10, 175–195.
Kern, F., 2011. Ideas, institutions and interests: explaining policy divergence in fostering system innovations towards sustainability. Environ. Plan. C: Gov. Policy 29 (6), 1117–1134.
Kern, F., Kuzemko, C., Mitchell, C., 2014. Measuring and explaining policy paradigm change: the case of UK energy policy. Policy Polit. 42 (4), 513–530.
Kern, F., Howlett, M., 2009. Implementing transition management as policy reforms: a case study of the Dutch energy sector. Policy Sci. 42, 391–408.
Kingston, C., Caballero, G., 2009. Comparing theories of institutional change. J. Inst. Econ. 5 (2), 151–180.
Lehtonen, M., Nye, S., 2009. History of electricity network control and distributed generation in the UK and Western Denmark. Energy Policy 37, 2338–2345.
Mahoney, J., Thelen, K., 2010. A theory of gradual institutional change. In: Mahoney, J., Thelen, K. (Eds.), Explaining Institutional Change: Ambiguity, Agency and Power. Cambridge University Press, Cambridge.
McDonald, J., 2008. Adaptive intelligent power systems: active distribution networks. Energy Policy 36, 4346–4351.
Meadowcroft, J., 2009. What about the politics? Sustainable development, transition management and long term energy transitions. Policy Sci. 42, 323–340.
Meadowcroft, J., 2011. Engaging with the politics of sustainability transitions. Environ. Innov. Soc. Transit. 1, 70–75.
Moran, M., 2003. The British Regulatory State: High Modernism and Hyper-Innovation. Oxford University Press, Oxford.
Ofgem, 2004. Electricity Distribution Price Control Review: Final Proposals. Ofgem, London.
Ofgem, 2009a. Regulating Energy Networks for the Future: RPI-X@20 Principles, Process and Issues. Ofgem, London.
Ofgem, 2009b. Regulating Energy Networks for the Future: RPI-X@20 Working Paper 2 Innovation in Energy Networks: Is More Needed and How Can This be Stimulated? Ofgem, London.
Ofgem, 2010. Low Carbon Networks Fund Governance Document v.1. Ofgem, London.
Ofgem, 2013. Assessment of the RIIO-ED1 Business Plans. Ofgem, London.
Pérez-Arriaga, I., Ruester, S., Schwenen, S., Batlle, C., Glachant, J.-M., 2013. 'From distribution networks to smart distribution systems: rethinking the regulation of European DSOs' THINK Topic 12, http://www.eui.eu/Projects/THINK/Documents/Thinktopic/Topic12digital.PDF
Peters, B.G., 2012. Institutional Theory in Political Science, third ed. London, Continuum.

Pieltain, F.L., Gomez, T., Cossent, R., Mateo Domingo, C., Frias, P., 2011. Assessment of the impact of plug-in electric vehicles on distribution networks. IEEE. Trans. Power Syst. 26 (1), 206–213.
Pollitt, M., 2009. 'Does electricity (and heat) network regulation have anything to learn from fixed line telecoms regulation?' Background Paper for RPI-X@20 Review, Available at: https://www.ofgem.gov.uk/ofgem-publications/52033/telecoms-pollitt.pdf
Pollitt, M., Bialek, J., 2008. Electricity network investment and regulation for a low-carbon future. In: Grubb, M., Jamasb, T., Pollitt, M. (Eds.), Delivering a Low-Carbon Electricity System. C.U.P., Cambridge, pp. 183–206.
Pudjianto, D., Djapic, P., Auinedi, M., Kim Gan, C., Strbac, G., Huang, S., Infield, D., 2013. Smart control for minimizing distribution network reinforcement cost due to electrification. Energy Policy 52, 76–84.
Ruester, S., Schwenen, S., Batle, C., Pérez-Arriaga, I., 2014. From distribution networks to smart distribution systems: rethinking the regulation of European electricity DSOs. Util. Policy, http://dx.doi.org/10.1016/j.jup.2014.03.007.
Sansom, R., 2010. RPI-X@20 emerging thinking on A new regulatory framework for energy networks. In: Presentation at Ofgem Academic RPI-X@20 Workshop, March 2010, Available at: http://www.ofgem.gov.uk/Networks/rpix20/Workshops/Documents1/Academic%20workshop%20Robert%20Sansom%20slides.pdf
Scrase, I., Smith, A., 2009. The (non-)politics of managing low carbon socio-technical transitions. Environ. Polit. 18 (5), 707–726.
Shaw, R., Attree, M., Jackson, T., 2010. Developing electricity distribution networks and their regulation to support sustainable energy. Energy Policy 38, 5927–5937.
Shove, E., Walker, G., 2007. CAUTION! Transitions ahead: politics, practice and sustainable transition management. Environ. Plann. A 39, 763–770.
Smart Grid GB, 2012. Smart Grid: A Race Worth Winning? A Report on the Economic Benefits of the Smart Grid, http://smartgridgb.org/benefits-of-smart-grid/item/2-smart-grid-development-saves-billions-when-compared-to-cost-of-conventional-technologies.html
Smith, A., Stirling, A., Berkhout, F., 2005. The governance of sustainable socio-technical transitions. Res. Policy 34, 1491–1510.
Smith, A., Voβ, J.-P., Grin, J., 2010. Innovation studies and sustainability transitions: the allure of the multi-level perspective and its challenges. Res. Policy 39 (4), 435–448.
Smith, A., Raven, R., 2012. What is protective space? Reconsidering niches in transitions to sustainability. Res. Policy 41, 1025–1036.
Smith, S., 2010. 'RPI-X@20' Beesley Lecture, Available at: http://www.rpieurope.org/Beesley.shtml
Strbac, G., Gan, C.K., Aunedi, M., Stanojevic, V., Djapic, P., Dejvises, J., Mancarella, P., Hawkes, A., Pudjianto, D., Le Vine, S., Polak, J., Openshaw, D., Burns, S., West, P., Brogden, D., Creighton, A., Claxton, A., 2010. Benefits of Advanced Smart Metering for Demand Response based Control of Distribution Networks. Energy Networks Association, London.
Streeck, W., Thelen, K., 2005. Introduction: institutional change in advanced political economies. In: Streeck, W., Thelen, K. (Eds.), Beyond Continuity: Institutional Change in Advanced Political Economies. Oxford University Press, Oxford, pp. 1–39.
Sustainable Development Commission (SDC), 2007. Lost in Transmission? The role of Ofgem in a changing climate. SDC, London.
Tsebelis, G., 2002. Veto Players: How Political Institutions Work. Princeton University Press, Princeton.
Ulmanen, J.H., Verbong, G.P.J., Raven, R.P.J.M., 2009. Biofuel developments in Sweden and the Netherlands: protection and socio-technical change in a long-term perspective. Renew. Sustain. Energy Rev. 13, 1406–1417.
Unruh, G., 2000. Understanding carbon lock-in. Energy Policy 28, 817–830.
Ward, J., Phillips, R., 2014. The Electricity Demand-Side and Local Energy: How Does the Electricity System Treat 'Local'?, Paper 10, GB Electricity Demand Project, http://www.sustainabilityfirst.org.uk/docs/2014/Sustainability%20First%20-%20Paper%2010%20-%20How%20Does%20the%20Electricity%20System%20Treat%20%27Local%27%20-%20January%202014.pdf
Willis, R., 2006. Grid 2.0: The Next Generation. Green Alliance, London, http://www.green-alliance.org.uk/resources/Grid%202%200.pdf
Wilson, I.A.G., Rennie, A.J.R., Ding, Y., Eames, P.C., Hall, P.J., Kelly, N.J., 2013. Historical daily gas and electrical flows through Great Britain's transmission networks and the decarbonisation of domestic heat. Energy Policy 61, 301–305.
Woodman, B., Baker, P., 2008. Regulatory frameworks for decentralised energy. Energy Policy 36, 4527–4531.
Xenias, D., et al., 2014. Smart Grids in the UK: Literature Review. Report UKERC/WP/ES/2014/001, UK Energy Research Council, Available at: http://www.ukerc.ac.uk/support/RF3LSmartGrids