

**CREATING NEW PATHWAYS IN PERIPHERAL REGIONAL
ECONOMIES: THE OFFSHORE WIND AND PRINTABLE
ELECTRONICS INDUSTRIES IN THE NORTH EAST OF ENGLAND**

Benjamin Fisher

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Centre for Urban and Regional Development Studies
School of Geography, Politics and Sociology
Faculty of Humanities and Social Sciences
Newcastle University

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ABSTRACT

This thesis contributes to the emerging body of work on evolutionary economic geography focused upon understanding how new growth paths emerge. Path creation is conceptualised as a latent element within a more open and dynamic understanding of path dependency. The approach moves beyond firm-centric accounts by identifying and explaining the multi-faceted nature and interplay of multi-scalar social and institutional agents, factors and conditions that shape mechanisms of path creation. This conceptual framework is utilised to compare, contrast and explain the processes underpinning the heterogeneous path creation and development of the offshore wind and printable electronics industries in the North East region of England. The empirical analysis illustrates the varied forms and interconnectivity of path creation mechanisms that shaped, and were shaped by, progressive phases of multi-scalar socio-institutional agents, contexts and policy interventions. Evolving from an episode characterised by the mindful deviation of entrepreneurs in firm *and* non-firm organisations, the printable electronics and offshore wind paths entered a period of rapid development stimulated by a decade of national state-led enabling frameworks, resources and contextual regional policy intervention. The momentum in the offshore wind path evolved to a point that demonstrated elements of path dependency and ongoing adaptation. Whereas radical shifts amongst multi-scalar state institutions removed the strategic niche environment incubating the printable electronics path, creating a policy vacuum leading to regression of the developing pathway. The path creation framework developed here demonstrates the importance and influence of multi-scalar actors, institutional contexts and contextual policy prescriptions in supporting and framing the tensions between enabling and constraining environments that shape path creation in episodic and temporary ways.

DEDICATION

For dad.

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Doctoral research is a laborious, intense and time-consuming personal expedition filled with equal amounts of enjoyment and exasperation. However, despite my own fulfilling but sometimes rocky journey to produce this thesis, it was by no means an individual exercise. Throughout the past five years, I have been offered a huge amount of encouragement, advice and support, both directly and indirectly, from a plethora of people. I therefore take this opportunity to thank all those who have influenced, shaped and supported the completion of this research.

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CHAPTER 1. PATH CREATION IN LOCAL AND REGIONAL EVOLUTION

1.1.1 Introduction

Over the last few decades, economic geography has increasingly incorporated theories, concepts, metaphors and mechanisms from evolutionary economics and other evolutionary forays to interpret, understand and explain path creation and changes to the economic landscape over time and across space (Boschma & Martin 2010). As part of an “evolutionary turn” (Coe 2011) within economic geography, much attention and debate has focussed upon the core concept and models of path dependency (*inter alia* David 1988; Arthur 1994) which illustrated the spontaneous emergence of new economic pathways that lock-in to stable trajectories until eventual decline (Grabher 1993). However, the continued inadequacy of path dependency theory in justifying “how new growth paths emerge” within conceptual models and empirical studies propelled emerging work in evolutionary economic geography to search for a deeper conceptual and empirical understanding of new path creation (Neffke *et al* 2011, p. 241). As a consequence, the notion and intentionality of path creation has become increasingly situated and understood within a more open and dynamic understanding of local and regional industrial evolution (Martin & Sunley 2006; Martin 2010).

Reflecting a shift from equilibrist-orientated models of path dependency towards understanding local and regional industrial evolution as a dynamic, complex and fluctuating process of renewal, adaptation and decline, attention within evolutionary economic geography approaches turned to understanding the mechanisms or drivers through which regions adapt and avoid negative lock-in (Martin 2010). The questions of: “how are new pathways created? Where do they come from? How are they selected?” had rarely been answered (Fornahl *et al* 2012). In parallel but interconnected, approaches to path creation moved beyond a concentration on the micro-behaviour of economic agents (Boschma & Martin 2007) towards incorporating a broader perspective on the importance of place, history and strategic agency in mediating and stimulating mechanisms of path creation and development in local and regional economic settings (Dawley 2013). To understand the concepts, mechanisms and unfolding of economic trajectories at a local and regional level, the focus turned to wider economic, political, institutional and social actors and structures that operated in territorially varied contexts which mobilised and provided “enabling” or “constraining” environments for new and emerging growth paths (Martin 2010).

Situated within a broader conceptual understanding of path creation and underpinned by theoretical advances of an evolutionary approach in economic geography, this thesis conceptually and empirically examines and analyses the evolutionary path creation and development trajectories of the offshore wind and printable electronics industries in the North East of England (hereafter called the 'North East'). To re-emphasise for the purpose of conceptual, empirical and methodological clarity, this thesis is concerned with the formative processes of path creation and development, and particularly the role, type and influence of key agents, causal factors, conditions and mechanisms that shaped, and were shaped by, broader socio-institutional, political and economic factors on the creation and developmental trajectory of the regional offshore wind and printable electronics pathways. The lens in which this thesis peered through began in 1978 and concluded in 2012. In so doing, reinforced by theoretical and methodological advances in evolutionary approaches to studying change over time and space, this thesis illustrates, empirically and conceptually, key moments and episodes in over 30 years of path creation and development activity in the regional offshore wind and printable electronics industries.

Through a focus on path creation and development in the offshore wind and printable electronics industry in the North East, this thesis contributes to a limited corpus of conceptual and empirical evidence that explain the creation of new pathways (Martin 2010). The thesis extends the scope of enquiry beyond typical and narrow empirical studies on advanced technology regions to a peripheral regional economy perspective by contributing, in its own small way, towards an improved and deeper understanding of the formative processes and causality of local and regional industrial evolution (Morgan 2012). Moreover, by positioning processes of path creation within a more open, dynamic and broader understanding of the multi-scalar institutional, political and economic actors, contexts and settings that shape, and are shaped by local and regional industrial evolution, the thesis provides greater clarity of the causal mechanisms, agents, factors and conditions that influence and determine the geographical variability of new paths (Simmie 2012).

The thesis contributes three distinct but interconnected additions to the present literature on path creation. First, the thesis contributes to a developing body of conceptual and empirical literature in understanding the candidate mechanisms for stimulating new growth paths (Martin & Sunley 2006; Boschma & Frenken 2009; Neffke *et al* 2011). By situating firm

level analyses of the offshore wind and printable electronics industries in the North East within their broader political, economic and socio-institutional contexts, the thesis offers further evidence of the characteristics, usefulness, operation, interconnectivity and causality of the mechanisms of path creation in explaining the developmental trajectory of two territorially specific and contingent, but distinctly different, growth paths in a peripheral regional economy setting (Garud & Karnoe 2003; Gertler 2010).

Second, this thesis builds on an emerging body of empirical studies by incorporating a broader perspective on the role and types of social and institutional agency “within and beyond the firm” (Pike *et al* 2009) involved in the creation and evolution of local and regional growth paths (*inter alia* Mackinnon *et al* 2009; Mackinnon 2012; Dawley 2013). Specifically, influenced by a deeper integration of geographical political economy and institutional approaches in evolutionary economic geography, this thesis redresses the relative neglect and complexity of multi-scalar institutional forms and organisations, and particularly the multiple roles of the state, quasi-state and knowledge-based institutional actors in mediating and stimulating the creation and development of local and regional growth paths (Mackinnon *et al* 2009; Coe 2011; Mackinnon 2012). Moreover, in recognising the role of extra-regional actors and relations in processes of path creation, the research contributes to a fuller understanding and explanation of the relationship, connections and interplay between multi-scalar political, economic, social and institutional agents, networks and linkages, and key actors, mechanisms and conditions that stimulate and shape path creation at a local and regional scale (Pike *et al* 2009; Coe 2011).

Third, this thesis considers the role and influence of strategic agency, and particularly the role of place-based economic development agencies and purposive policy intervention, to foster, stimulate and enable (or constrain) the mechanisms of path creation at a local and regional scale. In the past, local and regional economic development agencies have developed economic and innovation system-based strategies, mobilised resources and key actors, built formal institutional structures and stimulated knowledge-based innovation assets. More recently, “contextual” policy intervention based on the virtues of historical legacy and place-based industrial technology relatedness has come to the fore (Asheim *et al* 2011). However, the challenge has remained, particularly for less economically developed regions which often lack endogenous assets and related “absorptive capacity” (Cohen & Levinthal 1990), subjected to “structural and institutional failures” in the innovation system (Boschma 2009),

and constricted by power relations and shifting geometries between the nation state and local and regional policy actors, to understand, both empirically and conceptually, how localities and regions transfer from constraining to enabling environments, and what role local and regional policy intervention based on evolutionary principles can play in that process (Martin 2010).

The remainder of the chapter forms a guide to the text that follows. The following section in 1.1.2 introduces the conceptual framework which frames path creation as being situated, mediated and stimulated by a combination of territorial agents, mechanisms, historical legacies and place-based assets that are conditioned by multi-scalar socio-institutional contexts, political relations and macro-economic conditions. Section 1.1.3 integrates the conceptual path creation framework into an operational explanation to present a brief history of the North East by positioning the creation and development of the offshore wind and printable electronics industries in the context of the region's previous and pre-existing industrial structures, knowledge, competencies and assets. The aim of the research, which is to examine and analyse the path creation mechanisms, agents, causal factors and conditions in the offshore wind and printable electronics pathways in the North East over the corresponding temporal period, is then cogently specified and operationalised by positing a series of specific research questions in section 1.1.4. The final section in 1.1.5 situates the research study within the wider empirical, conceptual and theoretical discourse that follows.

1.1.2 Path Dependency: From Equilibrium to Dynamic Path Creation

Understanding and applying path creation to an interpretation of local and regional industrial evolution has embarked upon its own theoretical and conceptual journey. Initially, the progressive and contemporary interest in evolutionary theories and concepts related to path creation amongst economic geographers and policymakers originated out of early accounts of dominant technological and industrial patterns which interpreted the creation of new paths as chance acts, "historical accidents" (Krugman 1991) or serendipitous "windows of locational opportunity" (Storper & Walker 1989). Spontaneously emerging in places over time, new path creation was understood as a consequence of an improbable event that set in motion the long-run effects and irreversible lock in of a particular economic trajectory to which only an exogenous shock could disrupt the incumbent pattern or system (Bassanini & Dosi 2001). Whilst helpful to explain *ex-post* analyses, particularly related to suboptimal outcomes and

changes to the direction of a pathway, path dependency theory was criticised for offering a “passive”, equilibrist and static interpretation of the uneven geography of new path creation (Cooke 2010).

With little conceptual understanding of how new pathways were created and why they occurred in some places and not others within traditional path dependency theory, evolutionary approaches in economic geography turned to explore how regions adapted to lock-in or “de-locked” from existing path dependencies to create new growth paths (Martin & Sunley 2006). The early work of path creation theory focussed on the importance of strategic agency and the prominent role of entrepreneurs and firms to purposively “mindfully deviate” from existing path dependent trajectories to establish new economic pathways by shaping the local environment in accordance with their own needs (Boschma 1997; Garud & Karnoe 2011). More recently, evolutionary notions of variety, novelty, emergence and selection have joined traditional change mechanisms of indigenous creation and transplantation to explain the unfolding and uneven economic landscape over time (Martin & Sunley 2006; Boschma & Frenken 2009). As a consequence of the variability of mechanisms, settings and contingency in local and regional economies which shaped, and were shaped by, a combination of internal and external factors, path creation became increasingly understood as part of an open and dynamic “path as a process” approach (Martin 2010) which positioned the creation of new paths within the “ongoing, never ending interplay of path dependence, path creation and path destruction” (Martin & Sunley 2006, p.407).

Connected to a more exposed and varied interpretation of path dependency and local and regional industrial evolution, economic and evolutionary economic geographers began to focus on identifying the precise mechanisms or de-locking processes from which new paths were created (Martin & Simmie 2010). Martin & Sunley (2006) categorised five candidate mechanisms through which local and regional economies adapted and avoided negative lock-in situations: indigenous creation (of new paths), heterogeneity and diversity, diversification into technologically related industries, transplantation from elsewhere and the upgrading of existing industries. Setting to one side the extensive body of literature pertaining to the role of entrepreneurs and firms in the generation and exploitation of knowledge, technologies and innovation (*inter alia* Nelson & Winter 1982; Garud & Karnoe 2001), evolutionary economic geography research adopted a particular interest in the second and third strategies with the opportunity to conceptually align Schumpeterian (1942) notions of novelty and innovation

with variety, and particularly the concepts of related variety and path branching, by fostering interactive learning and knowledge spillovers to stimulate new combinations of economic activity (Boschma & Frenken 2011). Thus, when a region's sectors are neither overtly specialised nor diverse, but are instead related in terms of technological fields and knowledge bases, they possess related variety (Boschma 2009).

As part of the transition to a broader conceptual focus of path dependency in evolutionary economic geography, the role of history and place in the creation of new pathways and de-locking of existing trajectories was similarly redrawn. In its most general guise, the traditional equilibrium interpretation of path dependency stated that "history mattered" in conditioning the creation, development and outcome of particular pathways (David 1988; Arthur 1994). History served as a constraining process supporting lock-in by emphasising continuity rather than change in the evolution of the economic landscape (Martin & Sunley 2008). However, as part of a more holistic approach to path creation encompassing broader multi-scalar political, institutional and economic agents, factors and settings, the creation and variability of new pathways became increasingly explained by:

"the pre-existing industrial structure of a region or locality which does have an influence on whether a particular new industry develops there" (Martin 2010, p.6).

Thus, as a reflection of path creation remaining "latent in the process of path dependence", historical legacies and place-based assets explained why particular paths had grown in some places and not others (Neffke *et al* 2011).

Influenced by geographical political economy and institutional approaches in economic geography, path creation theorists and evolutionary economic geographers have most recently turned their attention towards the wider social and institutional environment and the influence of multi-scalar political, economic and socio-institutional actors, settings and factors in stimulating mechanisms of path creation and explaining the geographical variability and diversity of local and regional industrial trajectories (Mackinnon *et al* 2009; Mackinnon 2012; Cumbers *et al* 2013). At a local and regional scale, identifying, mobilising and converting the endogenous base, "recombining" (Martin 2010) historical assets and seizing advantageous place-based characteristics to match new technologies, industrial trajectories and market opportunities had taken on increasing interest and significance (Coe *et*

al 2004). Moreover, while notions of “place dependence” highlighted the important local and regional conditions of path creation (Martin & Sunley 2008), extra-regional actors, networks and institutions, particularly wider political economic relations, economic conditions and market forces, had become increasingly weaved into the path creation narrative in recognition of the important and influential functions they performed in shaping the economic landscape at the micro and meso-level (Mackinnon *et al* 2009; Pike *et al* 2009; Mackinnon 2010; Dawley 2013).

To combine many of the broader theoretical and conceptual ideas of path creation and local and regional industrial evolution incorporating history, place, strategic agency, variety, institutional structures and the external environment, Martin (2010) illustrated phases of local and regional industrial evolution as progressing from a “pre-formation” phase through to “path creation” and “path development” phases. The pre-formation phase was characterised by the domination of pre-existing technological and economic conditions. The path creation phase exhibited experimentation but also competition between different economic agents with the path development phase solidifying the pathway through combinations of local and regional increasing returns and network externalities (Martin 2010). This thesis draws heavily on Martin’s (2010) schematic model of local and regional industrial evolution throughout the text to describe, at a conceptual level, the evolutionary changes and dimension of the regional offshore wind and printable electronics pathways. In the context of Martin’s (2010) helpful conceptualisation of path creation within a more open and dynamic model of path dependency, the following section situates the path creation of the offshore wind and printable electronics industries in the context of the pre-formation phase and the pre-existing industrial base, assets and competencies endemic to the North East.

1.1.3 North East of England: Context, Historical Legacies and Place-Based Assets

The path creation and development of the offshore wind and printable electronics industries in the late 1970s occurred during, and in the context of, over a century of decline in the North East’s “sunset industries” (Marshall *et al* 1987). Prior to that, local and regional economic growth of the 19th century was built around “carboniferous capitalism” (Tomaney 2006), a geographical clustering and inter-sectoral dependence of industries comprised of iron, coal,

steel, heavy engineering and chemicals transforming the North East from a non-industrial economy to become the “workshop of the world” (McCord 1979; Hudson 2005). As a result:

“the combination of continuously growing markets and close interconnections between the inputs to and outputs from production processes in the North East had created a virtuous spiral of path dependent growth” (Hudson 2005, p.583)

Nevertheless, by the end of the 19th century and early part of the 20th century the sustained growth of the British Empire was coming to an end with the North East’s key industries exhibiting “functional lock-in” (Grabher 1993) and lacking the adaptive capacity to respond to technological changes and increasing forms of exogenous competition (Adger & Vincent 2005). The North East’s primary extractive and heavy engineering industries continued to experience steady rates of decline into the 1930s and 1940s, although industrial output did increase with demand during the wartime economy in a brief temporal period of “path renewal” (Hudson 1999). To stimulate new industrial pathways and prop-up ailing industries considered critical to national interests and economic output, the North East’s “problem region” status became subject to national state Keynesian policy including nationalisation of the North East’s “traditional” industries and regional policy intervention was directed towards the provision of infrastructure to support lagging industries (McCrone 1969). In short:

“the public sector had replaced private capital as the proximate guarantor of the region’s path dependent trajectory” (Hudson 2005, p. 583).

Consequently, coal-mining was nationalised in 1947 with steel and shipbuilding to follow later rendering the North East a “state managed region” (Hudson 1989; Tomaney 2006).

Despite the region experiencing high employment and productivity levels during the 1950s, by the mid-1960s the national economy had begun to falter in the face of increasing competition from advanced capitalist economies with nationalised sectors exhibiting features of “lock-in to negative path trajectories” (Grabher 1993). For the North East, the emergence of new centres of international production in coal, steel and shipbuilding highlighted the implications of shifting market dynamics on local and regional industrial paths. Furthermore, illustrating a lack of “institutional and innovation capacity” (Albrechts 2004), the North East

became susceptible to technological developments in alternatives to coal as an energy source, oil as a raw material for chemical production and variations to steel as an industrial composite (Hudson 2005). To combat systemic structural issues in the North East economy, regional governance and policy reinforced “political lock-in” (Grabher 1993) to tackle problems of deindustrialisation by increasing expenditure at the regional level in the form of infrastructure improvements, increasing grants to firms and establishing a regional tier of governance, albeit with little regional autonomy or power (Tomaney 2006).

Entering into the latter decades of the 20th century, the quantitative and qualitative picture of the North East’s previously stable and path dependent growth based on the primary and secondary industries had been replaced by a region locked-in to negative path and place dependant trajectories (Hudson 2005). Privatisation and associated rationalisation of the region’s traditional industries had caused mass unemployment, “institutional hysteresis” and proved unsuccessful in halting the pattern of deindustrialisation, leaving former sites of heavy industrial activity derelict and vacant throughout the North East (Setterfield 1993). Those specialised industries which had “made the North East” had become a matter of “heritage” by the early 1980s (Robinson 2002). Therefore:

“just as economic growth in North East England in the 19th century had been grounded in a supportive institutional formation, by the late 20th century its legacies and relict form constituted a barrier to a transition to a new regional growth trajectory” (Hudson 2005, p.587).

In the absence of capabilities to harness endogenous assets and resources to stimulate new forms of path creation and de-lock from negative path trajectories, multi-scalar policy intervention concentrated on the mechanisms of transplantation as the main industrial policy instrument to instigate new local and regional growth paths through the attraction of mobile exogenous manufacturing investment (Tomaney 2006). However, regional and national policy based on attracting and embedding inward investment in the North East served only to provide a proliferation of low-valued added activities and low-skilled occupations in terms of stage of production and location in global value chains (Hudson 2005). Consequently, the path creation of the offshore wind and printable electronics industries towards the latter end of the 1970s occurred during, and within the context of, a weak private sector characterised by a high-degree of external control in the manufacturing base (Smith 1979), a poor track-

record of indigenous creation (Storey 1982), low representation of research and development (R&D) institutions and activities in the region, and continuing overreliance on the public sector for local and regional economic growth (Buswell & Lewis 1970).

1.1.4 Research Focus: Printable Electronics and Offshore Wind Pathways in the North East

Within the context of over a century of decline in the North East's traditional industries and repeated failure of multi-scalar policy intervention aimed at creating, renewing and diversifying into new growth paths within the North East, the aim of this thesis is to investigate and analyse the evolutionary path creation and development trajectories of the offshore wind and printable electronics industries in the North East between 1978 and 2012. More specifically, this thesis is concerned with understanding the processes and causality of key agents, mechanisms, factors and conditions that shaped, and were shaped by, broader socio-institutional, political and economic factors and contexts on the path creation and development of both industrial trajectories. In so doing, the thesis contributes to an expanding body of research in understanding how new local and regional growth paths emerge (Martin & Sunley 2006) and what determines the long-term adaptive capacity of regions (Martin 2012) which represents "one of the most intriguing and challenging issues in the field" of economic geography (Neffke *et al* 2011, p.241).

As highlighted previously, the research focus of this thesis concentrated on three interconnected elements of local and regional path creation. First, moving beyond the micro-level of the firm, the thesis is specifically concerned with identifying the candidate mechanisms that shaped the evolutionary trajectories of the offshore wind and printable electronics pathways in the North East. Second, in understanding path creation within a broader perspective on the role, type and influence of social and institutional agency, the research focus explored and examined the role of multi-scalar institutional actors, factors and settings, and specifically the role of the state, knowledge-based institutional actors and external technological conditions, market pressures and regulatory environments in mediating and stimulating the mechanisms of new growth paths in the North East (Martin 2010; Coe 2011; Dawley 2013; Dawley *et al* 2015). Third, the thesis considered the function, influence and contribution of purposive and strategic local and regional policy intervention in constructing a supportive (or constraining) environment for the offshore wind and printable

electronics pathways to emerge and grow (Martin 2010). Accordingly, the following three research questions, gleaned from a combination of existing literature and insights, steered the enquiry:

1. Which mechanisms stimulated the path creation and development of the printable electronics and offshore wind pathways in the North East?
2. What has been the role and influence of multi-agents at multi-scalar levels in the path creation and development of the offshore wind and printable electronics industries in the North East?
3. What role has the state and policy performed in stimulating the candidate mechanisms of the North East's offshore wind and printable electronics pathways and what are the lessons learnt for future policymaking?

To frame the study and provide a granular level of evidence in response to the research questions under investigation, the offshore wind and printable electronics industries in the North East were identified as research objects of analysis. The identification and selection of the offshore wind and printable electronics pathways in the North East was a consequence of their contrasting origins, the heterogeneous technological and industrial composition of each pathway, and the focus and diversity of multi-scalar socio-institutional agents and policy intervention within local, regional and national settings to stimulate and support those emerging local, regional and national industrial growth paths.

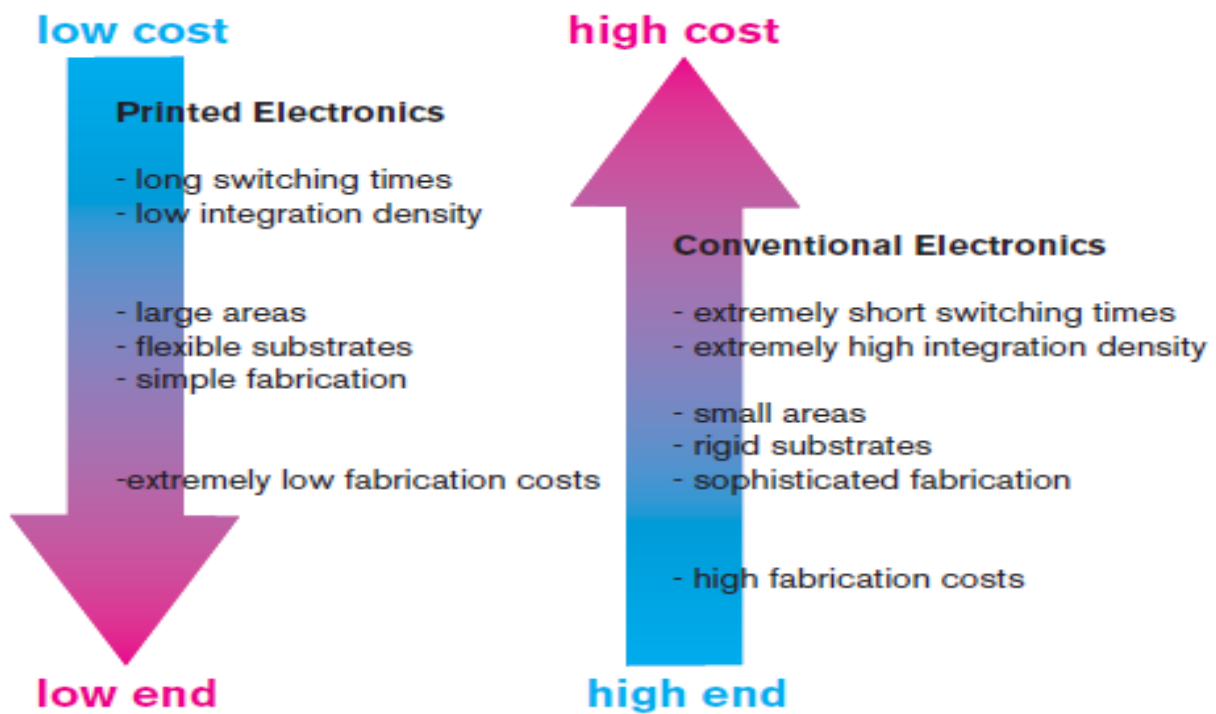
In the case of printable electronics, the new and emerging industrial growth path has been referred to as a “disruptive” technology capable of:

“wiping out silicon chip technology and completely sweeping aside existing traditional electronics industries” (House of Commons 2009b, p.30).

More specifically, the embryonic printable electronics technology and industry offers the capability of electronic materials, including organic and inorganic semiconducting devices, to be “printed” onto flexible substrates offering manufacturing efficiencies and accurate usage of materials (CST 2007). In short, the novelty in printable electronics resulted from the combination of two developments in the electronics industry: the use of printing techniques and “functional materials” to deposit electronic components; and production techniques that

permit the use of flexible surfaces (AIM 2009). As a result, in contrast to conventional electronic manufacturing of silicon-based electronic products requiring high cost materials, specialist factory equipment and manufacture onto rigid substrates, functional electronic materials are combined with established printing techniques to manufacture thin, lightweight, flexible and low-cost devices onto non-conventional flexible substrates in small production runs (King 2009) (see Figure 1.1).

Figure 1.1 Technological and Industrial Differences between Conventional Electronics and Printable Electronics

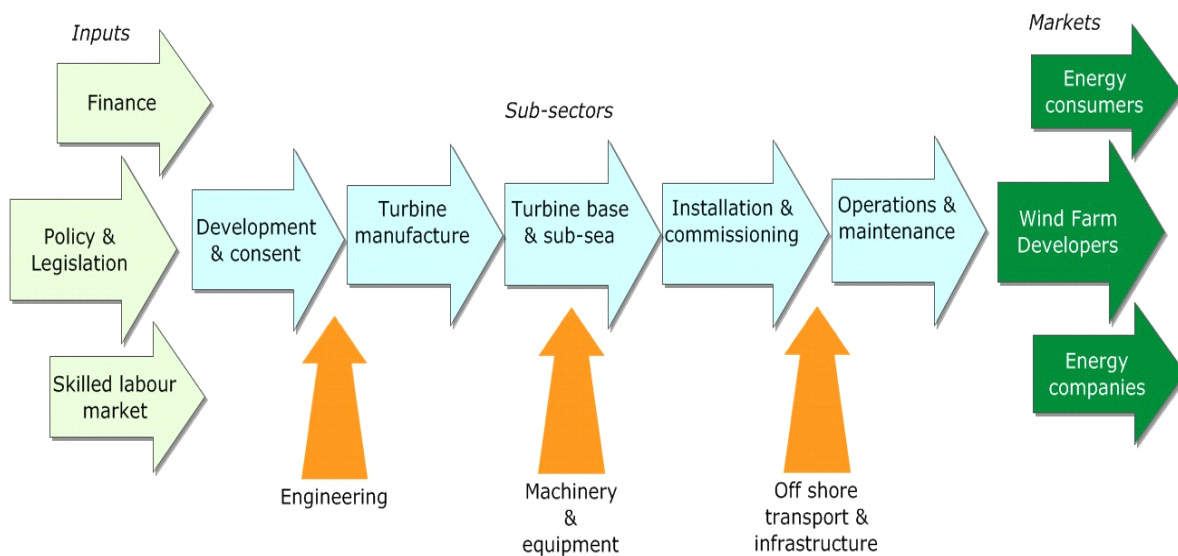


Source: Kempa 2008, p.4

Together, the application of combining functional materials and printing techniques to manufacture electrically-conductive materials onto flexible substrates has opened up opportunities to develop a range of new and/or reconfigured products, including: interactive electronic elements to paper; incorporation of radio frequency identification (RFID) tracking to products; electrical monitoring and sensing circuits to materials; manufacture of building materials with integrated photovoltaic modules; and ‘wearable electronics’ into clothing and textile products (Curling 2009).

In contrast to the convergence of printable electronics technology, the generation of electricity from offshore wind evolved out of incremental innovation steps replicated from the onshore wind industry (Musgrove 2010). To the present, the contemporary offshore wind industry remains conceptually segmented into a linear innovation value chain that can be compartmentalised into a series of sub-sectors, beginning with R&D, supply, fabrication and assembly of the offshore wind turbine, foundations and subsea cabling supported by tier 1 (supplying product or service to turbine manufacturers or construction contractors) and tier 2 (supplying component or machined parts to tier 1 suppliers) supply chain bases (Douglas Westwood 2006). The innovation and production chain culminates in the installation of the offshore wind turbine and associated ongoing operations and maintenance (O&M) activity (Technopolis 2008) (see Figure 1.2).

Figure 1.2 Conceptualisation of Activities in the Offshore Wind Industry

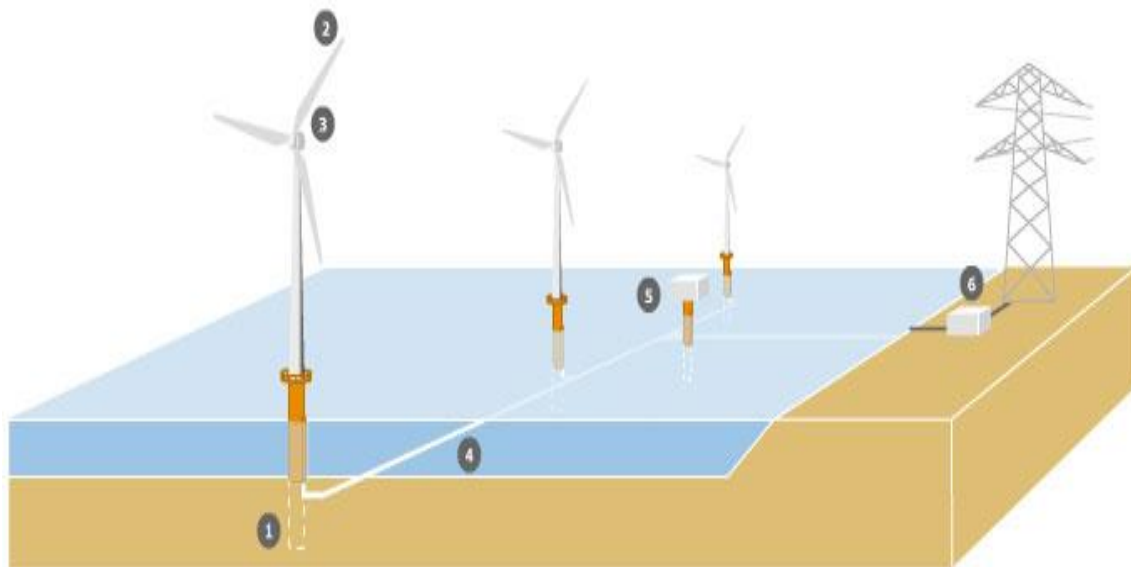


Source: Morgan *et al* 2010, p.6, adapted from BVG Associates 2009

In total, the development, deployment and operation of offshore wind farms consists of six interconnected technologies and processes (see Figure 1.3). To begin with, the subsea foundations (1) for the site of the offshore wind turbine are excavated and stabilised, allowing for the turbine base, nacelle (2) and blade (3) to be constructed and deployed. Simultaneously, during the preparation of the foundations, electrical subsea cabling is installed (4) that connects the offshore wind turbine with an offshore substation which

converts and directs energy generated from offshore wind sources onto an onshore electrical substation and onwards to the UK national electricity grid (6).

Figure 1.3 Process Flow Chain of Offshore Wind Industry



Source: ONE 2008, p. 3

Positioning the path creation of the offshore wind and printable electronics in the context and setting of the North East, the research utilised mixed methods approaches designed to undertake a backward extension of past and present actors in order to demarcate the key causal agents, mechanisms, settings and factors that influenced and shaped the evolutionary trajectories of the offshore wind and printable electronics pathways between 1978 and 2012.

1.1.5 Structure of the Thesis

Illustrating over 30 years of path creation and development activity in the offshore wind and printable electronics industries in the North East, the structure of the thesis has been chronologically segmented into three chapters reflecting three distinctive path temporal periods. The partitioning of each period highlighted empirical findings drawn out by the research methodology which connected the research objects with the research subject through key episodic “moments in time” (Dawley 2007) that influenced the quantitative extent and qualitative nature of the emergent pathways and their trajectories (Pike 2005). Therefore, the thesis begins in Chapter 2 by developing a conceptual framework which charts the historical interpretation of local and regional industrial evolution and situates the theoretical approach

of evolutionary economic geography within the context and understanding of local and regional growth paths. Adding further depth to the conceptual framework, the chapter revisits past conceptual models and explanations of path creation and reviews the current literature on mechanisms of path creation within local and regional economies. The remainder of Chapter 2 positions and connects local and regional industrial evolution and the mechanisms of path creation and de-locking to wider social and institutional agents and forces, and particularly multi-scalar political relations, state institutions and policy, in mediating, stimulating and setting the conditions for the emergence of novel growth paths.

Chapter 3 situates the theoretical and conceptual interpretation of path creation and evolutionary economic geography within emerging methodological frameworks for empirically analysing and understanding the evolution of the economic landscape over time. As such, the chapter illustrates the theoretical and practical considerations that shaped the methodological layers of the study based on adopting and incorporating a predominantly qualitative research design into a mixed-methods case study approach.

In Chapter 4, the thesis draws upon the theoretical, conceptual and methodological frameworks to empirically analyse the “path creation phase” of the printable electronics and offshore wind pathways in the North East between 1978 and 2000 (Martin 2010). In the embryonic offshore wind industry, the chapter analyses how the interchange between local entrepreneurial activities and national state-led strategic niche management opened up a window of opportunity for local firms to experiment and create a “demonstration effect” through which the North East’s path was created (Dawley 2013). Conversely, the chapter analyses how the nascent printable electronics industry entered a period of latent stasis following the path’s origins which was influenced by the absence of multi-scalar institutional, political and policy support, and shaped by external technology and market environments, until local entrepreneurial dynamics of firm and non-firm actors reconstituted the pathway at the end of the century.

Chapter 5 analyses the developing offshore wind and printable electronics pathways between 2000 and 2010 as both trajectories entered a phase of “path development” (Martin 2010). Specifically, the chapter details the key turning points and analyses how the expanding territorial pathways and path mechanisms of variety, branching and transplantation were

stimulated and accelerated by a decade-long period of intentional and strategic regional policy intervention from multi-scalar institutional and political actors.

Following a sustained period of institutional, political and policy activism related to the regional offshore wind and printable electronics pathways, Chapter 6 picks up the temporal thread from 2010 to 2012 in analysing the implications of a radical shift in the multi-scalar institutional and political environment combined to create a local and regional institutional and policy vacuum in the North East. Amidst the constrained conditions and setting, the chapter addresses the implications on the mechanisms which served to have little bearing on the path dependent and ongoing adaptation of the offshore wind industry but equally stalled and derailed the printable electronics industry, regressing the developing growth path back into the practices and conditions akin to its previous “path creation” phase (Martin 2010).

Chapter 7 draws the thesis to a conclusion by synthesising the empirical findings that illustrated the influential role multi-scalar institutional actors, factors and contextual policy performed in stimulating and supporting the diverse and interconnected mechanisms of the offshore wind and printable electronics industries in the North East. Connecting the empirics to theoretical considerations, the chapter positions the analytical interpretations of path creation in the North East’s offshore wind and printable electronics industries within broader conceptual explanations of path dependency and the theoretical discipline of evolutionary approaches in economic geography. Moreover, the chapter also highlights lesson learnt and poses some practical suggestions for practitioners and policymakers in utilising and applying evolutionary principles of path creation and local and regional industrial evolution in policy terms. The remainder of the chapter offers suggestions for future research endeavour in the field of new path creation, illustrates limitations to the research exercise and concludes with a metaphorical challenge to the adoption and application of “paths” as part of a wider theoretical reflection of path creation in explaining the unfolding and uneven character of local and regional industrial evolution (Deeg 2001).

CHAPTER 2. PATH CREATION AND EVOLUTIONARY ECONOMIC GEOGRAPHY

2.1.1 Introduction

The aims and objectives of this chapter are to frame the creation and development of new growth paths within the theoretical roots of evolutionary economic geography by outlining some of the current core theories, concepts and accounts which explain and understand path creation and the geographical unevenness of local and regional industrial trajectories over time and across space. In so doing, this chapter goes beyond microeconomic processes, though important in new path creation, to address the relative neglect in path creation literature of the wider agents, causal factors, mechanisms and conditions involved in shaping the geographical variability of new local and regional growth paths (Simmie 2012; Dawley 2013; Dawley *et al* 2015). By addressing path creation within a broader extra-regional economic, political and socio-institutional setting, the chapter directs attention to the crux of this thesis by providing context and substance to the important role institutional actors at multi-scalar levels, and particularly the role of political economic relations and policy, play in creating, mediating and stimulating mechanisms of local and regional path creation (Coe 2011).

Accordingly, the chapter begins in section 2.1.2 with a review of past theoretical interpretations and concepts of structural and temporal change that explain local and regional industrial evolution. Section 2.1.3 introduces theories connected with evolutionary economics and 2.1.4 examines the core theoretical strands adopted from evolutionary economics by economic geographers to form the basis for a new theoretical evolutionary economic geography approach. Within this context, the introduction of the term ‘pathway’ has entered economic geography literature under the original concept of path dependency theory which is explored in section 2.1.5. In sections 2.1.6 to 2.2.0, the literature review examines the chronological interpretation of path creation since the 1980s utilising increasingly broader concepts and a more holistic perspective to understand the unfolding patterns and geographical variability of local and regional industrial evolution. As a broader understanding of path creation has come to the fore, identifying, understanding and empirically testing the precise causal mechanisms through which new paths are created has remained limited

(Dawley 2013). To this end, section 2.2.1 illustrates a series of path creation mechanisms identified by economic geographers that drive path creation and explain the uneven patterns of economic activity. In sections 2.2.6 and 2.2.7, the narrative moves beyond existing firm-centric accounts to illustrate and examine the prominent interest amongst evolutionary economic geographers of the role, type and influence of socio-institutional agents, including geographical political economy approaches, in mediating and supporting the mechanisms of path creation. The penultimate section in 2.2.8 considers evolutionary theories, concepts and principles in the context of policy prescriptions for practitioners and policymakers to stimulate and create enabling environments for local and regional path creation. The chapter concludes in 2.2.9 with a brief synopsis and restates the gaps in the existing literature that the thesis will address.

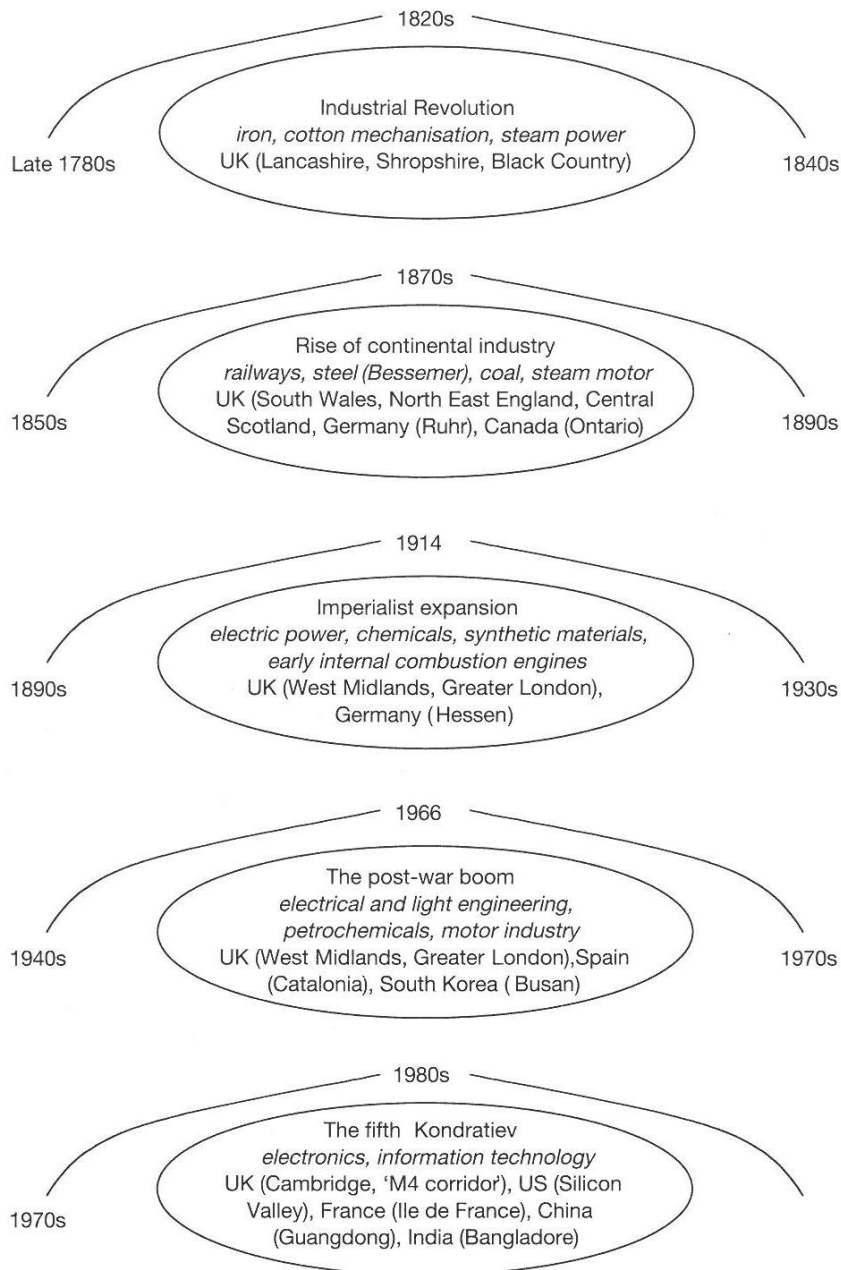
2.1.2 Background Context: Historical Theories of Local and Regional Industrial Evolution

The temporal nature of technological and industrial progress on the one hand, and economic growth and change on the other, has been a cause of interest amongst economic geographers since the early 20th century (Dosi 1982). The spatial implication upon local and regional economies has often been understood as part of wider historical and evolutionary processes that select, adopt and reject new technological and industrial trajectories. Economic geographers have developed and utilised the metaphors of “stages”, “cycles”, “waves”, “regimes”, “paradigms”, “trajectories” and latterly “paths”, to conceptualise the geographically uneven character of local and regional economic development (Pike *et al* 2006). The following section provides a brief summary of those past historical theories and concepts.

In “stages” theories, regions and nations were interpreted as moving through progressively more advanced stages of economic growth and development; from primary industries through to knowledge-based and quaternary forms of development (Clark 1939). However, the linear process proposed by stages theory failed to acknowledge the multi-directional logic of innovation, industries and local and regional economies that fail to follow sequential and identical patterns of development (Pike *et al* 2006). Echoing similar criticism to stages theory for its macro-level generalisations, Schumpeter’s (1934) theory of long “waves” explained economic flows as a progressive process of advanced innovation, entrepreneurial activity and

economic development. In sum, each temporal wave was superseded by a more advanced techno-economic paradigm (Kondratiev 1935; Sternberg 1996) (see Figure 2.1). Nevertheless, wave theories were critiqued for adopting an aspatial perspective by neglecting to recognise the economic and socio-institutional differences in local and regional economies.

Figure 2.1 Kondratiev Long Waves of Economic Growth

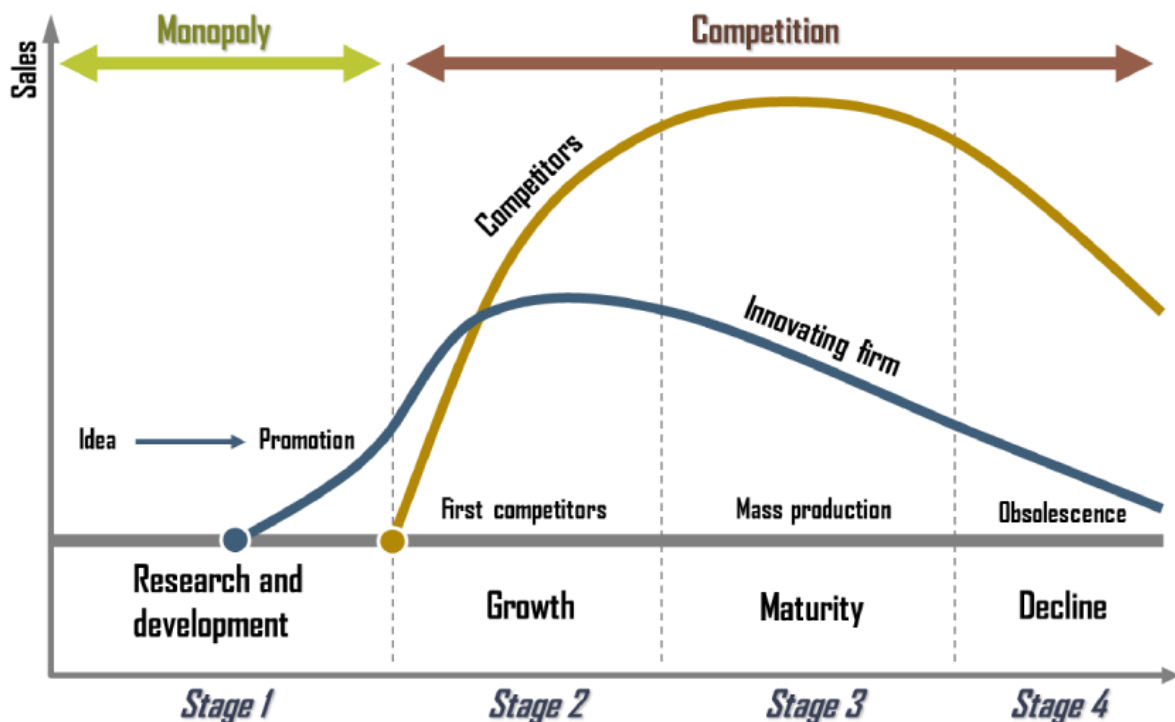


Source: Pike *et al* 2006, p. 83, adapted from Dicken 2003

Moving into the second half of the 20th century, further conceptual explanations for the cumulative and patterned character of local and regional economic development were sought

through the introductory notions of technological “regimes” and “cycles”. Inspired by the scientific writings of Kuhn (1962), Giovanni Dosi (1982) interpreted techno-industrial change on the basis that firms incorporated processes of knowledge and technology in order to stimulate industrial growth and develop new technological paradigms and trajectories. In a similar vein, the “product and industry life cycle” models focussed upon the temporal trajectories of local and regional industrial structures and their relation to local and regional development (Pike *et al* 2006). As highlighted in Figure 2.2, innovative firms introduced new products to the market while often retaining local proximity to key R&D functions and suppliers. As a result, an emerging market was created encouraging a growing number of firms to enter into the industry until maturity and standardisation when economies of scale led to decentralisation of underdeveloped localities (Storper & Walker 1989). Despite significant criticism of the product life cycle theory for offering a narrow a focus upon individual products rather than industries and markets (Schoenberger 1989), economic geography scholars, including Markusen’s (1985) “profit cycle theory” and Klepper’s (1997) examination of the U.S. automotive industrial life cycle, continued to utilise cycles theory as a useful conceptual model to explain the spatial evolution at a micro and meso level.

Figure 2.2 Industry Life Cycle Model



Source: Rodrigue 1998

Reflecting the transition away from stages, waves and cycles theories and their often deterministic perspective of technology and limited conceptualisation of innovation, the final theoretical metaphor to enter economic geography vocabulary in recent decades has been the notion of “paths” in explaining structural and temporal change via the core concept of “path dependency” (Sayer 1985). However, before examining the notion of paths within path dependency theory, the following section provides contextual background to the emergent approach of understanding path creation based on the combinatorial theories of evolutionary economics and economic geography.

2.1.3 The Rise of Evolutionary Economics

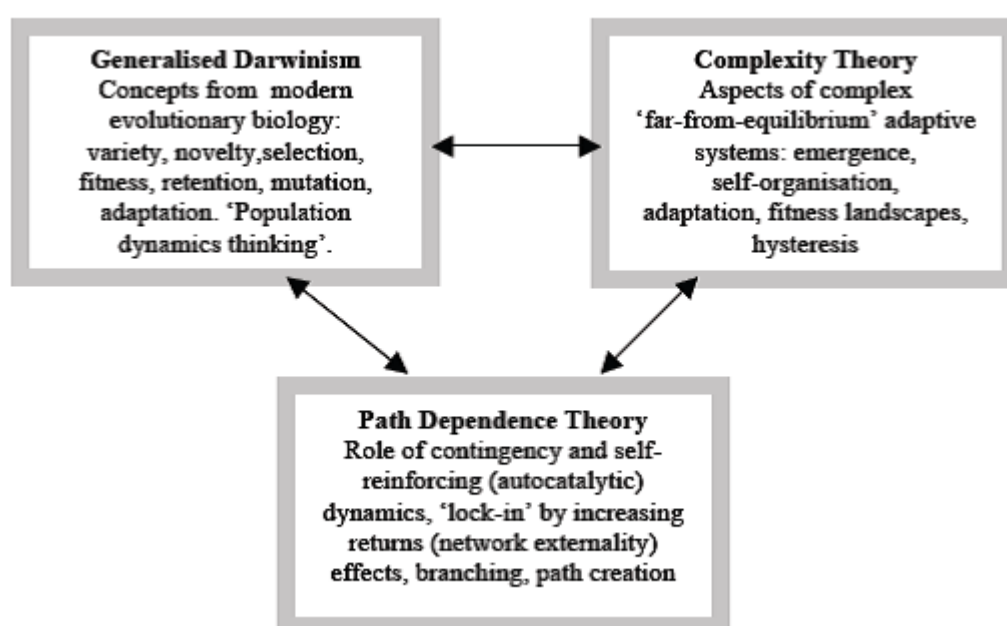
The history of evolutionary strains within economics can be traced back to the linkages made between economics and the concept of evolutionary biology advocated in Darwin’s (1859) seminal text *On the Origin of the Species by Means of Natural Selection*. Employing the core evolutionary principles of variety, selection, novelty and retention (replication), Neo-Darwinist approaches sought to apply the concepts of evolutionary biology to an interpretation of economic actors and their activity over time. Since Darwin’s contribution, evolutionary economic theory has been permeated by a number of prominent evolutionary economists, including Veblen (1898), Schumpeter (1942), Hayek (1944), and most recently, Nelson & Winter (1982). All have rejected neoclassical equilibrium models in favour of giving economic interpretation to the basic ideas of modern evolutionary biology and complexity science (Boschma & Martin 2007).

The key focus of evolutionary economics has been on the processes and mechanisms by which the economy “self-transforms itself from within” (Witt 2003). This has been particularly relevant to understanding the dynamic processes that jointly influence the behaviour of firms and the market environment in which they operate (Nelson & Winter 1982). Evolutionary economic theory therefore viewed and interpreted an economy as a dynamic environment, constantly dealing with irreversible processes and focussing on the generation and impact of novelty as the ultimate source of self-transformation (Essletzbichler & Rigby 2007). It is thus the creative capacity of economic agents and the innovative functions of markets that drive economic adaptation and evolution.

2.1.4 Evolutionary Economics and Economic Geography

As a result of increasing penetration of evolutionary economics-based concepts, approaches and terminology into economic geography to explain the spatial dynamics and competitiveness of economic activity, an “evolutionary turn” ushered in a new period of theoretical debate within economic geography (Coe 2011). At the heart of the new evolutionary economic geography approach involved the amalgamation of three theoretical frameworks: generalised Darwinism, complexity theory and path dependency theory (see Figure 2.3). In the context of integrating generalised Darwinism into an explanation of the unfolding economic environment, Witt (2003) identified two principal heuristic applications. First, the theoretical perspective applied the theory of natural selection to human economic behaviour on the grounds that economic phenomena resulted from human decision-making (Witt 2003). Second, Darwinian concepts, comprising novelty and fitness were increasingly incorporated into describing micro-level activities, including portrayal of the firm as an organisation based on “routines and rule-based behaviour” (Nelson & Winter 1982). More recently, the notions of variety and adaptation have taken on increasing prominence to conceptually describe the changing economic landscape over time and space (Witt 2003; Martin & Sunley 2006; Boschma 2009).

Figure 2.3 Three Theoretical Frameworks of Evolutionary Economic Geography



Source: Boschma & Martin 2010, p.7

The second theoretical framework incorporated and underpinning evolutionary approaches in economic geography was complexity theory. Described as complexity economics by Rosser (2009), complexity theory interpreted the economic landscape as an “open and complex adaptive system” which exhibited emergent self-organising behaviour and was driven by co-evolutionary interactions that, while dynamic, still displayed internal order (Pavard & Dugdale 2000). Moreover, Martin & Sunley (2007) described a complex system as one in which an economic system demonstrated openness, a distributed nature and representation, self-organisation, adaptive behaviour and non-deterministic characteristics. Despite ambiguities in the definition of “complexity” from different economic standpoints (see, for example, Potts 2000; Lawson 2003; Perona 2004) and assertion by Martin & Sunley (2007) that a socio-ontological approach should replace complexity thinking, complexity theory interpreted knowledge and organisational structures as co-evolving within the economic landscape.

Completing evolutionary economic geography’s tripartite theoretical framework, and the most often utilised notion within evolutionary approaches in economic geography, was the concept of path dependency. Path dependency theory originated from David’s (1985) and Arthur’s (1989) examination of technology and increasing-returns effects in which economic systems were interpreted as open systems that evolved in ways and trajectories shaped by past development paths. Thus, the concept of path dependency was considered:

“a probabilistic and contingent process [in which] at each moment in historical time the suite of possible future evolutionary trajectories of a technology, institution, firm or industry was conditioned by both the past and the current states of the system in question. The past thus sets the possibilities while the present controls what possibility is to be explored” (Martin & Sunley 2006, p.402).

Broadly speaking, path dependency referred to increasingly constrained processes that cannot easily be escaped. The combination of historical contingency and the emergence of self-reinforcing effects highlighted the core notion of path dependency: “lock-in” and the sequential patterns of activity and behaviour which became difficult to deviate and break from (Setterfield 1997) (see section 2.1.6).

In summary, economic geography adapted and applied evolutionary economic theory and its core concepts that were aspatial in formulation and outlook to spatial contexts and processes (Boschma & Martin 2007). In so doing, evolutionary approaches in economic geography began to focus specifically on path dependency theory, terminology and meaning associated with the notion of paths to illustrate and explain the evolution of the economic landscape (Boschma & Martin 2007).

2.1.5 Constructing a Definition: What is a Pathway?

Despite considerable literature on path dependency theory and more recently the notion of path creation, both of which are unpacked and explored in greater detail later in the chapter, neither theoretical concepts has provided a clear definition of what is denoted by the term “path”. In other words:

“it seems rather obvious that if we cannot make a clear distinction between change within a path and a change to a new path, then the concept itself is rather useless” (Deeg 2001, p.14).

According to Deeg (2001), paths were essentially institutional constructs that exhibited identifiable and predictable patterns, routines, knowledge and rules by individuals, firms or organisations within a given system. Therefore, adaptations to new situations that preserve elements of a path’s pre-existing logic constituted “on-path” or “bounded innovation” (Martin & Sunley 2006).

Paths exist in different economic arenas and at various different spatial scales and levels. At a micro-level, substantial literature has been compiled by economic geographers on routines and competencies within firms as characteristics of path dependency (see, for example, Nelson & Winter 1982; Boschma & Frenken 2003; Stam 2008). At a meso-level, studies have highlighted path dependent characteristics in clusters, labour markets, industries, networks and sectors (see, for example, Essletzbichler & Rigby 1997; 2005; Klepper 1997; Glaesar 2005; Neffke & Henning 2008; Giuliani 2010; Hassink 2010; Neffke *et al* 2011). Moreover, at a macro-level, institutional environments, spatial systems, trade cycles and technological shifts have all been identified as exhibiting path dependent patterns and traits (see, for

example, Hall & Soskice 2001; Essletzbichler & Rigby 2004; Hidalgo *et al* 2007; Lambooy 2010; Morgan 2011). However, in many respects, economic geographers embracing evolutionary principles remained in the embryonic stage of linking the research objects, subjects and levels together into a more comprehensive and holistic framework (Martin & Sunley 2014).

2.1.6 Path Creation

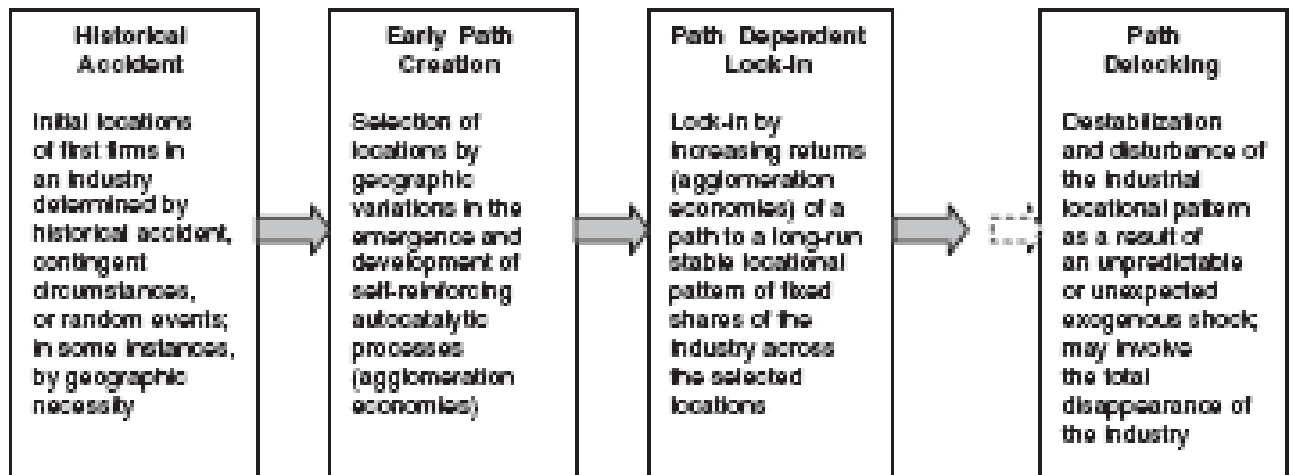
Since the explosion of interest in applying evolutionary economics to economic geography, path-related literature has featured prominently in the social sciences for its ability to conceptually examine the processes, mechanisms and causality of path dependency. However, in the past decade path dependency theory has been relegated by the notion of path creation in examining the “spatiality of economic novelty” (Boschma & Martin 2010, p.23). The key questions of “how are new pathways created? Where do they come from? How are they selected? and what pathways are actually evolving?” *inter alia* firms, industries, clusters, regional economies, have not been adequately answered (Fornahl *et al* 2012). It is in this context that the following section explores the key theoretical and conceptual accounts in understanding and explaining the creation of new local and regional industrial pathways, beginning with a reassessment of the original path dependency concept conceived by David (1985) and Arthur (1989).

2.1.7 Chance, Emergence and Path Dependency

The establishment of new pathways were initially interpreted as being through acts of chance, serendipity or “historical accident” (see, for example, Krugman 1991). Drawing upon Paul David’s (1985) famous account of the QWERTY keyboard, and later studies on the economic history of technology (see, for example, David 1988; 1992), the choice of the QWERTY design was a matter of historical accident in which a sequence of self-reinforcing irreversible steps resulted in “technological lock-in” (Grabher 1993) (see Figure 2.4). Considered a non-ergodic stochastic process, once the arrangement of keys had been contingently “selected” and reached equilibrium within market contexts the configuration of keys locked in manufacturers through a series of autocatalytic processes to a stable path dependent trajectory (Garud & Karnoe 2001). Moreover, consumers also became locked-in to the preferred arrangement highlighting the importance of social forces together with economic actors in the

stabilisation of a pathway (Meyer & Schubert 2007). To counter path dependent lock-in and institutional structures that inhibited the generation of novelty, only through an external shock can the technology, industry or industrial location pattern be disrupted or dislodged from its stable trajectory (David 1985).

Figure 2.4 Canonical Model of Path Dependency



Source: Martin 2010, p.5

The canonical model of path dependence emphasised how the adoption of new technologies was initiated through small random, chance moments which would lead to a path-dependant process creating long-run effects on the technological, industrial, institutional and spatial structure of an economy over time (David 1985). For economic geographers, the conceptual model translated into a dichotomy: regional economies were either on an upward curve characterised by ongoing renewal and high-growth, or on an unsuccessful path of stasis, lock-in and decline (Hasssink 2005; Karlson 2005). Indeed, for peripheral, old industrial regions and branch plant economies, local and regional economies were deemed to be lacking innovation capacity for endogenous path creation and renewal on the one hand, and dependence on external markets and extra-regional actors on the other hand (Steen & Karlson 2014). In short, the canonical model of path dependency provided a powerful perspective through which to highlight the importance of history and contingency in the lock-in to pathways (David 1988).

Extending the work of David (1985), Brian Arthur (1989; 1994) explained the creation of new industries as a path dependent process through two principal models: spin-off dynamics

and agglomeration economies. In the former model, a new industry would grow firm-by-firm through spin-off dynamics in which an entrepreneur from a previous firm would establish a new firm in the same industry, often in close geographical proximity (Arthur 1994; Agarwal *et al* 2004). The second model stated that the more start-ups in a new industry enter into a local and regional economy the stronger the impact of agglomeration economies (Boschma 1997). In both models, the location and spatial evolution of a new techno-industrial pathway followed a path dependant process in which a random decision or historical accident by a firm to locate in a particular locality would initiate increasing returns that would enact local and regional economic benefits (Krugman 1991). Geography and history were thus considered irrelevant in the emergence of new pathways (Boschma 1999). Increasing returns was understood to take many different types and processes of path dependence (historicity) including firm routines (Nelson & Winter 1982), learning which always favours the existing (Arthur 1999), institutional hysteresis (Setterfield 1993) and social embeddedness (Ghezzi & Mingione 2007) (Martin & Sunley 2006). In summary, small, arbitrary triggers that were hard to predict may set in motion mutations of institutional structures and organisational forms that were conceived through pure accident (Arthur 1989).

By the early 1990s, the creation of new paths of growth within path dependency literature was viewed as a result of serendipitous products of “windows of locational opportunity” (WLO) (Storper & Walker 1989). Similar to Arthur’s (1989) account, the WLO model originated from the California School in the 1980s which stated that new industries offered enhanced moments of locational freedom for each type of local and regional economy because new technologies, firms and industries represented a fundamental break from the past (Boschma 1997). Moreover, the spatial indeterminacy of a new techno-industry was likely to provide an opportunity for lagging regions to escape former exclusion effects, whilst leading localities were denied to reap the benefits from previous advantages related to former leadership positions in order to divert into new industrial fields (Storper & Walker 1989).

Rejecting Weberian location theory, which claimed that new industries would develop most rapidly in local and regional economies where their static, pre-given locational needs were most consistent with existing local factors, the WLO model stipulated that early-stage, technologically-based industries often had few established specific inputs so that they could invent their own input chains (natural resources, labour, capital etc.) and shape the local environment in accordance with their own needs (Boschma 1997). Therefore, new

technological trajectories were understood to emerge spontaneously and unexpectedly in space (Boschma 1997; 2004). In other words:

“the evolutionary approach argued that the selection pressure of existing spatial structures is rather weak when new industries emerge. Under certain circumstances there are good reasons to assume that place-specific features do not determine the location of new sectors. The environment is considered to be of minor importance at the initial stage of development of a sector where there exists a gap between the requirements of the new industry (in terms of skills, knowledge etc.) and its surrounding environment...windows of locational opportunity are open in emerging industries” (Boschma and Frenken 2003, p. 20-21).

The WLO model highlighted the opportunity for places to generate new economic pathways by “starting from scratch” (Boschma & Lambooy 1999). However, by the end of the 20th century the WLO model had been refined and extended (see, for example, Boschma 1997; Boschma & Van der Knaap 1997) to recognise that while new industries had the capability to generate and/or attract their own conditions of growth, new technologies, firms and industries required generic resources or basic variety for new path creation (Boschma & Lambooy 1999). Nevertheless, because every local and regional economy possessed generic factors and remained susceptible to external triggers, the establishment of new pathways was considered unpredictable in determining when and where new economic trajectories may or may not occur (Boschma & Frenken 2004).

Whilst path dependency theory and the WLO model proved useful concepts in describing the initial contingent effects played in the lock-in of path trajectories through processes of self-reinforcement, path dependency theory had little explanation for how a new pathway emerged, where it might take place or the causal factors behind the selection (Martin 2009; Fornahl *et al* 2012). Indeed, the canonical model of path dependency and WLO concept was considered the consequence and not the cause of new path creation (Cooke 2010).

Explanations for the emergence and spatial distribution of new economic activities as acts of chance failed to recognise the role of pre-determined human intervention and the intentionality behind innovations in purposefully creating new pathways (Sydow *et al* 2010). In this regard, human agency was thought to behave rationally within the confines of neo-classical and equilibrium-orientated thinking and secondary to the importance of

unpredictable, small events (Arthur 1999). As a seed of a new pathway within path dependency theory, chance and historical accidents were deemed “voluntarist” (Mackinnon *et al* 2009), lacking an understanding of the broader contextual relationship between structural forces and pre-existing variety (Boschma & Lambooy 1999; Mackinnon *et al* 2009) and antithetical to the fundamental concept and application of evolution (Martin & Sunley 2006). As a result, a new body of literature began to emerge reflecting the more basic principles of evolutionary economics based on the heterogeneity, variety, selection and emergence of strategic agency in creating, influencing and shaping the uneven geography of new path creation (Boschma 1999; Boschma & Frenken 2009).

2.1.8 Strategic Agency and Path Creation

In contrast to the early writings of David (1985) and Arthur (1989) and their emphasis upon chance in the emergence of new pathways, evolutionary economic geography thinking began to acknowledge the prominent role of strategic agency, and specifically the actions of entrepreneurs and firms, in the establishment of new path trajectories through adaptation to lock-in or the potential to “de-lock” from existing path dependencies (Martin & Sunley 2006). Focussing particularly on the role of the firm in processes of path creation, evolutionary economic geography became inordinately concerned with:

“the spatiality of economic novelty and how the spatial structure of the economy emerges from the micro-behaviour of economic agents” (Boschma & Martin 2007, p. 4).

In their seminal contribution to path creation theory, Garud & Karnoe (2001, 2003) adopted a socio-ontological perspective in attaching a prominent role to the importance of “knowledgeable agents” (Simmie 2012) and the “mindful deviation” of entrepreneurs in creating new techno-organisational development paths (Garud & Karnoe 2011). At the heart of new path creation were entrepreneurs, of various kinds, who created new pathways by utilising real-time influence to set new processes in motion (Garud & Karnoe 2001; Simmie 2012). To this end, events and occurrences that start off a new path of development include a large element of strategic purpose, reflexivity (Schon 1983) and deliberate action (Puffert 2001).

As highlighted previously, the early work of path creation theory focussed on how the spatial structure of the economy emerged from the micro-behaviour of individuals and firms through two core concepts: “real-time influence” and “mindful deviation” (Garud & Karnoe 2001; Boschma & Frenken 2006). In the case of real-time influence, the ability to control, mobilise and manipulate time as a resource provided an opportunity for strategic agency to wait or strike to realise options value in the purposeful creation of new pathways (Garud *et al* 1997). Indeed:

“path creation implicates all three moments of time; the past (as in the term ‘path’), the future (as in the term ‘creation’) and present (as in the conjunction of the two terms)” (Garud *et al* 2010, p.763).

By mobilising real-time influence and broader social dynamics, entrepreneurs and actors possessed the ability to organise ideas, people and resources to mindfully deviate from the existing path dependent order (Giddens 1984). Through mindful deviation and “human will”, strategic agency mobilised the past to actively pursue new economic pathways (Bassanini & Dosi 2000; Garud *et al* 2010) (see Table 2.1). In other words, traditional path dependency scholars viewed an entrepreneur as passively on the outside looking in, while proponents of path creation interpreted the entrepreneur to be situated on the inside actively looking out.

Table 2.1 Sociology of New Path Creation

Initial conditions	Path creation process	Path establishment process	Path dependence process	Path dissolution
Constructed by actors who mobilize events from the past.	Mindful deviation by embedded actors.	Emergent contexts for action. Self-reinforcing mechanisms are cultivated.	Lock-in as a temporary stabilization of paths in the making.	Continual possibilities for creative destruction.

Source: Simmie 2012, p. 757

Influenced by theories associated with the social construction of technology systems literature (see, for example, Bijker *et al* 1987), notions and processes of path creation became concentrated on the distribution and multiplicity of human agency in both contributing to the creation of new pathways, and in becoming embedded within a pathway as a result of involvement in previous historical developments. The strategic creation of a new path was thus enabled by knowledge, experience and competencies inherited from previous local paths. With respect to the path creation process:

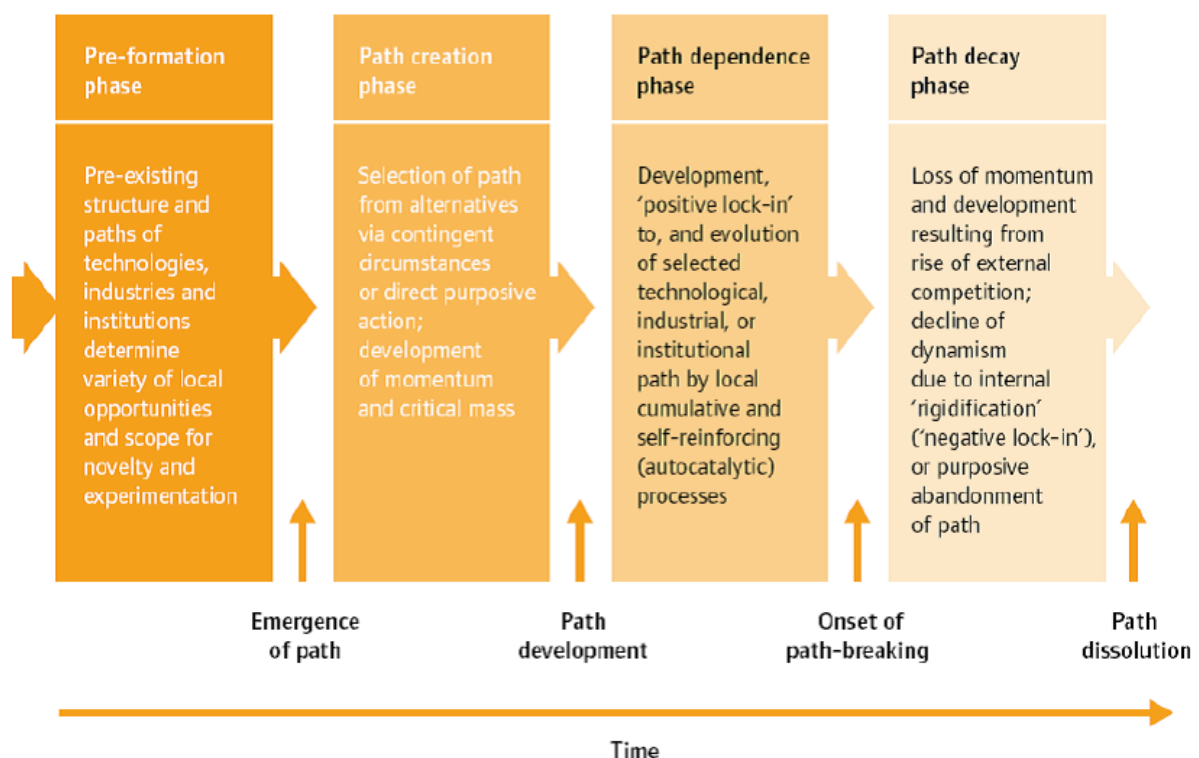
“initial conditions are not given but rather constructed by actors who mobilise specific sets of events from the past in pursuit of their initiatives...what is exogenous and what is endogenous is not given but depends on how actors draw and redraw their boundaries. Emergent situations are not “contingencies” but instead afford embedded actors the possibilities to pursue certain courses of action while making others more difficult to pursue. Self-reinforcing mechanisms do not just exist but are cultivated. Rather than lock-in there is ever the possibility of creative destruction...with those with the most to lose proactively making their own creations in order to survive” (Garud *et al* 2010, p. 769).

Thus, strategic agency and history influenced and shaped paths, whilst over time they themselves were shaped by the path. Therefore, entrepreneurs were viewed as embedded in paths but not completely constrained by them allowing strategic agency to enter into temporal processes of continual path creation, stabilisation and creative destruction (Schumpeter 1934; Schienstock 2007). In summary, path creation theory proposed to offer a strategic interpretation of history, a conceptualisation and active shaping of emerging structures and objects in the present, and an evocation of the future to construct history in a self-fulfilling manner (Garud *et al* 2010).

As a consequence of greater conceptual clarity and empirical findings to support understandings of path creation, evolutionary approaches in economic geography began to integrate ideas of strategic agency, variety and selection into more systemic meso-level approaches to local and regional industrial evolution (see Figure 2.5). Progressing forward from the original canonical model of path dependency, notions of purposive path creation became understood as part of a linear series of identifiable candidate phases of path dependency (NESTA 2008). Set within the conceptual framework, new path creation was

understood as beginning with a “preformation” phase in which pre-existing economic and technological conditions set the context and tone for novelty and experimentation (NESTA 2008). Such historical and place-based characteristics could include natural resources, surpluses of capital, skills, innovation capacity or networks (Coe *et al* 2004). Once a series of alternative paths and assets had been identified and harnessed, the industrial trajectory would transition to a phase of “path creation” through which the selection of a pathway would be “selected” either through contingent circumstances and/or by direct purposive action by economic agents. The chosen pathway would go on to enter a phase of positive path dependent lock-in until external competition, internal rigidities or abandonment of the pathway would lead to path decay in similar conceptual characteristics to that displayed in earlier product and industry life cycle models (Klepper 2001).

Figure 2.5 Path Dependency and the Creation of a New Technological and Industrial Pathway



Source: NESTA 2008, p. 13.

2.1.9 Path Creation and Interrelations with Path Dependency

The introduction and integration of human agency in creating and establishing new pathways resulted in evolutionary thinking entering a period of reflection and conceptual iterations of the binary distinctions between path creation and path dependency. Protagonists of the original path dependency theory continued to portray new techno-industrial developments as a non-purposive process in which initial conditions were given and novelty created serendipitously (see Table 2.2). In contrast, Garud & Karnoe’s (2001) notion of path creation emphasised the role of strategic change and deliberative action in which the initial conditions for the establishment of a pathway were constructed and contingencies contextually dependent upon how actors shaped, drew and redrew boundaries (Stack & Gartland 2003). In short, a “contested terrain” (Schienstock 1997) existed between path dependent evolution as an ergodic, closed system in which history or “past dependence” (Antonelli 1997) acted as a constraining structure on the one hand, and on the other, the importance of strategic agency to utilise history as heritage (Steen & Karlsen 2014) to react and adapt to external influences (Raven *et al* 2012), and emergent opportunities seized upon by entrepreneurs making use of existing resources (Isaksen 2011).

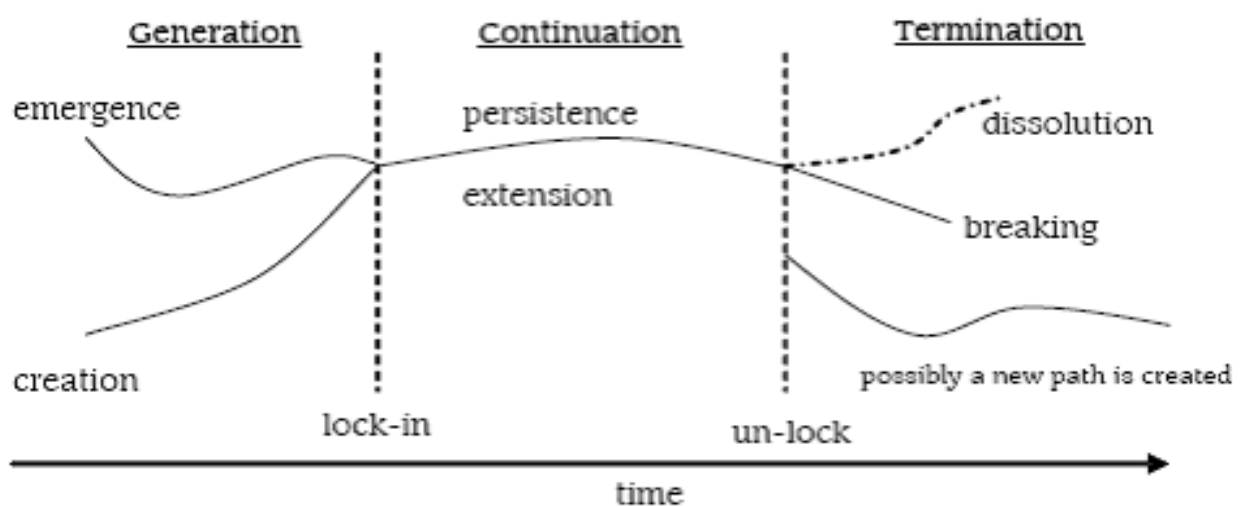
Table 2.2 Path Dependency versus Path Creation

Dimensions	Path Dependence	Path Creation
‘Initial conditions’	Given	Constructed
‘Contingencies’	Exogenous and manifest as unpredictable, non-purposive, and somewhat random events	Emergent and serving as embedded contexts for ongoing action
‘Self-reinforcing mechanisms’	Given	Also strategically manipulated by actors
‘Lock-in’	Stickiness to a path or outcome absent exogenous shocks to the system	Provisional stabilisation within a broader structuration process

Source: Garud *et al* 2010, p. 769.

Despite fundamental differences in the theoretical, conceptual and constitutional dimension of path dependence and path creation processes, evolutionary economic geographers sought to integrate both schools of thought into new conceptual paradigms for the explanation of new local and regional economic trajectories. For instance, Meyer & Schubert (2007) coined the term “path constitution” in which new pathways were conceived as a combination of emergent processes and intentional actions constituted through the mutual configuration of social, material and chance elements (Meyer & Schubert 2007) (see Figure 2.6). Indeed, the concept of emergence itself rather than creation or chance was proposed as a useful notion for understanding the initial traits that initiated the beginning and evolution of a new trajectory (Martin & Sunley 2007). In this regard, novel pathways were not characterised by one specific condition or pattern of development but generated a series of modes or orders which, once crystallised, selected and locked-in through phased borders of development until termination or the emergence of a new pathway (Martin & Sunley 2007; Meyer & Schubert 2007).

Figure 2.6 Path Emergence and Creation Modes in Path Constitution



Source: Meyer & Schubert 2007, p. 31.

Despite the introduction of strategic agency into the broader conceptual models of local and regional industrial evolution, the formation of new pathways remained consistent with the mechanisms of path dependency (Boas 2007). Schneiberg (2007) contested that pathways were not pure, settled or uniformed as conceptual models proposed. On the contrary, paths contained “structured diversity”, manifested in ambiguities, multiple layers, decomposable elements or competing logics that exhibited a fragmentation of successful, incomplete or

failed pathways (Schneiberg 2007). With this in mind, the binary distinctions between new path creation and adaptation on the one hand, and path dependent lock-in to obsolete technologies and organisational routines on the other, began to be theorised and explored as a continual interlinked process (Martin & Sunley 2006).

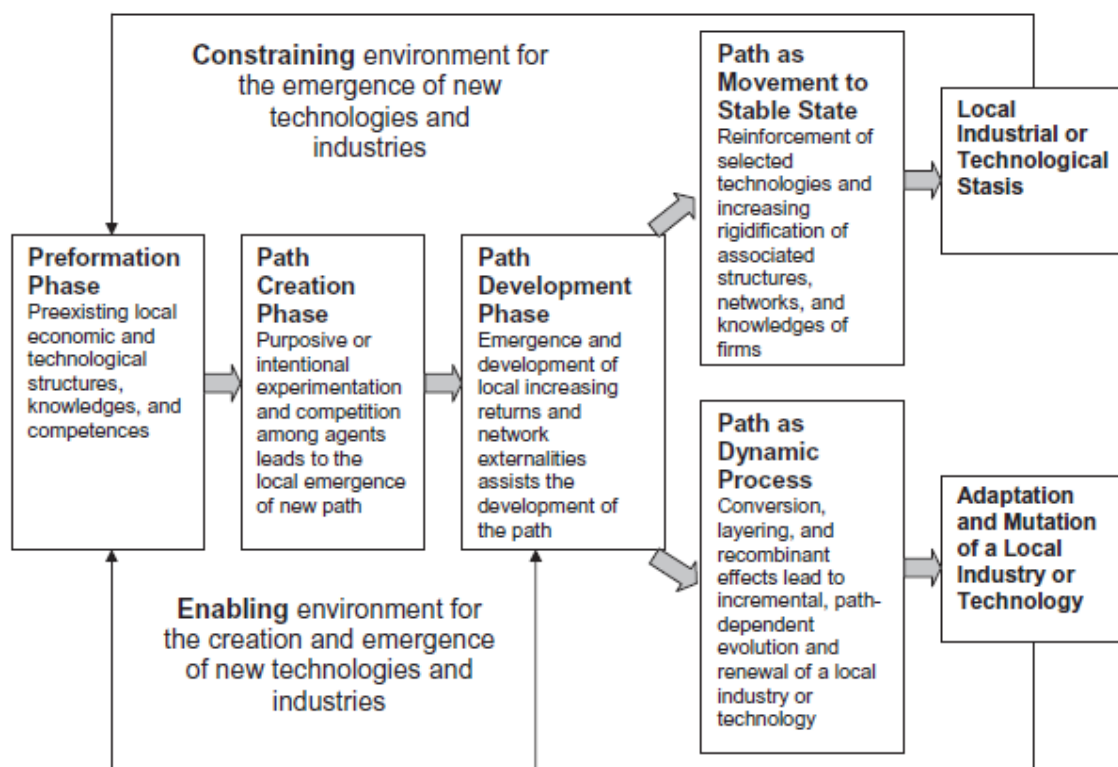
2.2.0 Path Creation as a Process

Despite increasing recognition of the role of multiple actors, mechanisms and contexts in the creation of new pathways, meso-level evolutionary approaches remained rooted in a linear, path dependent equilibrium model reminiscent of Markov processes and at odds with the open and dynamic nature of economic activity over time and space (David 2005; 2007). Inspired by notions of adaptive systems and the symbiotic relationship between local and regional institutional structures and broader technological and market-selection pressures (Simmie & Martin 2010), evolutionary economic geographers began to interpret economic evolution through a “path as a process” approach (Martin & Sunley 2006). From this perspective, the process of local and regional economic development was interpreted as an ongoing, never-ending interplay of “path dependence, path creation and path destruction” within the context of existing pathways which occurred at a variety of economic, technological and political scales against the backdrop of pre-existing social, institutional and economic systems and structures (Martin & Sunley 2006). Through evolving processes, path creation was considered to be latent in the process of path dependence in which all three concepts were complementary and continuously reinforced by each other (Sydow *et al* 2009).

With respect to understanding path creation as part of a continuous process influenced by broader social, institutional and market dynamics, Martin (2010) conceptualised an alternative path dependency model in which the development of a pathway progressed through candidate phases to reach either a stable, self-producing form symptomatic of lock-in with the previous canonical model of path dependency or a second pathway which would allow for incremental endogenous evolution and renewal (Grabher 1993). Adapted from previous meso-level approaches which highlighted the progress of paths evolving through sequential phases of development, Martin’s (2010) model of local and regional evolution highlighted the importance of the local environment in providing an “enabling” or “constraining” influence on the creation of new technologies and industries through processes of “layering, conversion and recombination” (see Figure 2.7). In the context of a local and

regional economy, layering referred to ongoing changes in the composition of a firm e.g. entrepreneurship, firm spin-offs, inward investment etc., or non-firm ecosystem e.g. new rules, procedures or institutional structures (Boas 2007). In conversion, local and regional actors' survival remained dependent upon instigating internal processes of change and innovation (Martin 2010). More recently, local capabilities of conversion have been captured in the concepts of “adaptation and adaptability” in the context of the resilience of local and regional economies (Pike *et al* 2010). Finally, recombination represents an opportunity for local and regional actors to recombine and redefine past and existing socio-political economic structures, resources and competencies in order to instigate change (Martin 2010).

Figure 2.7 Alternative Model of Path Dependency



Source: Martin 2010, p. 21.

Despite an increasing emphasis by evolutionary economic geographers on social and institutional contexts, factors, conditions and resources to explain the uneven nature of path creation and local and regional industrial evolution, notions of layering, conversion and recombination have remained conceptually abstract, difficult to empirically examine and have failed to explain how local and regional economies transition from constraining to enabling environments (Cumbers *et al* 2013; Dawley 2013). Indeed, Martin's (2010)

alternative model of path dependency still left many analytical and empirical issues of causality and agency in path creation unresolved (Dawley 2013). With this in mind, the following section seeks to explore the key path creation mechanisms that stimulate path creation, and in turn are manipulated and shaped by their positioning within broader multi-scalar economic, political and socio-institutional environments.

2.2.1 Mechanisms of Path Creation

During the past decade economic geographers have grappled with identifying, understanding and empirically testing the precise causal mechanisms and associated contexts through which new paths are created. Martin & Sunley’s (2006) path as a process approach identified five mechanisms through which local and regional economies adapted existing trajectories or de-locked to avoid negative lock-in to create new pathways: 1) indigenous creation; 2) heterogeneity and diversity; 3) diversification into technology related industries or related variety; 4) transplantation of new technologies, firms and industries from exogenous sources and; 5) upgrading of existing industries (see Table 2.3). Aside from transplantation, the other candidate mechanisms were relevant to path creation theory and the basic principles of evolutionary growth theory in that they exhibited self-transformation from within the internal system (Witt 2003). However, in the context of identifying the specific candidate mechanisms which stimulated the path creation and development of the North East’s offshore wind and printable electronics industries, the following section explores all five key theoretical and conceptual candidate mechanisms to provide a framework for later empirical investigation.

Table 2.3 Sources of New Path Creation

Sources of New Path Creation	Characteristics
Indigenous Creation	Emergence of new technologies and industries from within the region that have no immediate predecessors or antecedents there
Heterogeneity and Variety	Diversity of local industries, technologies and organisations promotes constant innovation and economic reconfiguration, avoiding ‘lock-in’ to a fixed structure

Transplantation from elsewhere	Primary mechanism is the importation of a new industry or technology from elsewhere, which then forms the basis of a new pathway of regional growth
Diversification into (technologically) related industries	Transition where an existing industry goes into decline but its core technologies are redeployed and extended to provide the basis of related new industries in the region
Upgrading of existing industries	The revitalisation and enhancement of a region's industrial base through the infusion of new technologies or introduction of new products and services

Source: Martin & Sunley 2006, p. 412.

2.2.2 Indigenous Creation

One of the principal mechanisms of path creation remains indigenous activity, with the emergence of new technologies and industries from within a locality or region possessing no immediate predecessors to past or pre-existing trajectories (Martin & Sunley 2006). At the crux of the production and transfer of new knowledge are firms as the main innovation actors in establishing new pathways (Patel & Pavitt 1997; Simmie & Martin 2010). According to Nelson & Winter (1982), firm behaviour remained guided and constrained by routines which demonstrated key neo-Darwinian processes of variation, selection, replication and retention that cognitively acted as a mechanism to coordinate the collective skills of employees and politically act as a mechanism of internal control (Boschma 2004; Boschma & Frenken 2006). In short:

“routines coordinate and control firm behaviour and thereby shape distinctive competitive advantages at the micro-level which unfold onto other spatial layers through processes of interaction” (Boschma & Martin 2007, p.541).

For Nelson & Winter (1982), firm routines were established and improved upon in the past, carrying with them path dependent properties (Boschma & Frenken 2009). Markets would

operate as selection mechanisms upon the heterogeneity of routines amongst firms resulting in systematic differences in the growth rates of firms (Nelson & Winter 1982). In order to escape from pre-existing, path dependent routines firms have to change their time-space distribution of activities (Boschma & Frenken 2003). By generating and supporting innovation, firms developed new pathways by selecting and adapting to new variations of fitter routines, while simultaneously catalysing the “shake-out” of existing firms with old or redundant practices (Klepper 1997). The geographical unevenness of innovation capacity within and between firms was due to the “absorptive capacity” (Cohen & Levinthal 1989) of firms to identify, interpret and apply relevant knowledge, which is shaped by different cognitive, social, geographical and institutional structures and contexts (Armstrong & Taylor 2000). Schumpeter (1942) described this process as “creative destruction” in which change, adaptation and new path creation was a consequence of firms seeking, developing and implementing new sources of novelty and innovation (Essletzbichler & Rigby 2004).

Since the seminal contribution of firm routines by Nelson & Winter (1982), economic geographers have identified other sources and processes of indigenous activity that explain the evolution of the economic landscape. Connecting to previous literature on path creation, strategic agency and entrepreneurship (see, for example, Garud & Karnoe 2001; 2010), the “will of the entrepreneur” was considered decisive in the creation of new techno-organisational development paths (Schienstock 2007). Entrepreneurs applied mindful deviation to uncouple from the constraints imposed by accepted approaches and articulated alternative routines and approaches that transformed the economic and spatial landscape (Garud & Karnoe 2001). Transformation was often an uneven process as, unlike neo-classical economics in which entrepreneurs and firms selected an optimum location based on the spatial margin of profitability (Boschma & Lambooy 1999), entrepreneurs exhibited “locational inertia” by utilising their existing (local) networks to seek partners, employees, suppliers and customers (Michelacci & Silva 2007), and remain close to family and friends for emotional rather than rational reasons (Dahl & Sorenson 2009; Stam 2011).

The evolution and spatial unevenness of entrepreneurial activity, firms and industrial dynamics was also understood as a result of the interaction between actors and the surrounding environment. Reflecting a path as a process approach (Martin 2010), local and regional economies possessed particular characteristics, resources and assets that facilitated or hindered entrepreneurial activity (Martin & Sunley 2006). Moreover:

“as entrepreneurs require resources to begin new ventures, and resources tend to concentrate in space, the probability of starting a new venture can be made dependent on territorial conditions” (Boschma & Frenken 2006, p. 6).

Thus, in a Lamarckian sense, human agency, in the form of entrepreneurs, firms and organisations adapted their behaviour to the external environment, while also adapting their environment in accordance with their own needs (Saviotti 1996). For instance, new innovation created within universities and/or research institutes generated opportunities for start-ups and spin-out enterprises (Noteboom 2000; Audretsch *et al* 2006). Whilst exemplified by, but not restricted to peripheral regional settings, local and regional economies that exhibited weak territorial innovation systems and displayed low levels of “institutional adaptive capacity” offered weakened potential to support indigenous creation into new economic trajectories (Albrechts 2004). Notwithstanding other candidate factors, including human capital and the physical environment, culture was also considered to provide an important explanation for the spatial variation in entrepreneurship, firms and industrial activities as, without the presence of entrepreneurial culture, local and regional economies became hindered in the development of new or related development paths (Saxenian 1994; Audretsch 2001; Stam 2011).

2.2.3 Heterogeneity, Related Variety and Branching

A possible source of new path creation identified by economic and evolutionary economic geographers was the diversification of local and regional industries, technologies, organisations and social networks through constant innovation and economic reconfiguration (Martin & Sunley 2006; Pike *et al* 2010). Evolving from the near century long debate between the binary distinctions of regional specialisation (localisation or Marshall Arrow Romer (MAR) externalities) versus regional diversification (Jacob’s externalities) (see, for example, Marshall 1890; Klepper 2001; Boschma & Wenting 2007; De Groot *et al* 2010), Jacobs (1969) seminal work in the 1960s viewed the diversity of local and regional economies as a key determinant in the generation of new pathways and economic growth (Saviotti 1996). Echoing Penrose (1959) and Romer’s (1990) new growth theory, Passinetti (1993) built on Jacobs (1969) initial work to conceptualise evolutionary growth theory which viewed variety as necessary for firms to innovate and diversify which would lead to enhanced

knowledge transfer and productivity growth in and between firms and sectors to create new industrial trajectories.

In the past decade, theories associated with diversity and evolutionary growth has been replaced by the evolutionary economic geography variant “variety” in explaining the creation of new pathways (Boschma 1999). At the crux of the increasingly utilised concept, championed in particular by the work of Ron Boschma (see, for example, Boschma 1999; 2004; Boschma & Frenken 2007; Boschma & Iammarino 2007), was the notion that local and regional economies with more diversified institutional structures were more conducive to innovate (Asheim *et al* 2007), induce knowledge spillovers that were geographically bounded (Feldman 1996) and thereby support transition from declining industries into new regional techno-industrial trajectories (Van Oort 2004). Instructive within the concept of variety was the importance of place-based contexts and competencies in which new paths latent within ongoing processes of path dependency presented redundant capacities which could act as the seed of new paths and slack capabilities which may prove useful in adapting to unexpected changes (Grabher 1993; Rantisi 2002). In other words:

“the industrial history of regions, and in particular the parts of technology space their portfolios inhabit will affect the way regions create new variety over time, and how they transform to restructure their economies” (Neffke *et al* 2011, p. 241)

A diversified (unrelated) economy brought opportunities for local and regional actors to generate, copy and modify products, process and services by providing a platform for unpredictable knowledge recombination to take place (Arthur 2009). In addition, an unrelated economy also served to offer a portfolio effect (Montgomery 1994) which could function as a “regional shock-absorber” (Essletzbichler 2007) by reducing the risk of over-reliance on a given technology or industry (Frenken *et al* 2007). Nevertheless, identifying the key actors and processes through which variety occurs, in certain places and at particular times, still required further investigation which lies at the heart of this thesis (Dawley 2013).

Intrinsically linked to the notion of diversification and stimulated by literature on technology relatedness, an additional and influential body of literature formed around the concept of “related variety” and “path branching” as a causal mechanism of new path creation (Boschma & Frenken 2011). The principle of the concept illustrated that local and regional economies

that neither exhibited Jacobian externalities (variety) nor MAR externalities (specialisation), but instead offered related characteristics in terms of knowledge base and technological fields, possessed related variety which stimulated new path creation, adaptation and enhanced regional growth (Frenken *et al* 2007) (see, for example, Klepper 2001; Frenken *et al* 2007; Boschma & Iammarino 2009; Boschma *et al* 2010). Therefore:

“if we can understand the emergence of a new industry in a region from the level of technological relatedness between the new industry and the existing industries in a region, you can understand how creative destruction occurs over time and space’ (Boschma & Frenken 2009, p.153).

Sectors may be technically related through producer-consumer relationships, production-system interdependencies, technological complementarities or technical interdependencies between firms (Boschma 1999). Accordingly, a strong link existed between related industries and the complementary knowledge base offering greater absorptive capacity via interactive learning and knowledge spillovers to occur that stimulated the generation of novelty and branching (Boschma & Iammarino 2009; Boschma & Frenken 2009; Neffke *et al* 2009).

Through technology relatedness and related variety, new industries were considered to branch out of old sectors or recombined from existing technology, knowledge and skills from multiple related sectors into new trajectories (Boschma & Frenken 2009). In order to stimulate branching, knowledge transfer between related sectors occurred based on four key processes: entrepreneurship e.g. spin-offs and start-ups (see, for example, Klepper 2001; Boschma & Wenting 2007); firm diversification e.g. new products, services etc. (see, for example, Kogut & Zander 1993; Wintyer & Szulanski 2001); labour mobility between firms and industries (see, for example, Almeida & Kogut 1999; Heuermann 2009); and social and professional networking (see, for example, Powell *et al* 1996; Ter Wal 2009). At the heart of related variety and path branching to create new pathways remained the importance of history and geography. Firms tended to diversify into technologically related fields that were shaped by their history, and in which, geographical and cognitive proximity ensured effective learning and knowledge spillovers between related firms and sectors (Jaffe *et al* 1993; Audretsch & Feldman 1996; Feldman 1999 Noteboom 2000). With this in mind, technology relatedness and proximity was understood to be fundamental in supporting path branching by harnessing revealed related variety (Neffke & Svensson-Henning 2008; Boschma & Frenken

2011) and Schumpeterian innovation to promote transversality among related industries (Cooke 2010). Nevertheless, despite helpful additional conceptual and empirical literature on the subject of related variety and path branching, evolutionary economic geographers continued to recognise the “strong need to determine through which mechanisms the process of path branching operates” which this thesis seeks to address (Neffke *et al* 2011, p. 261).

2.2.4 Transplantation

A fourth possible mechanism of adaptation and de-locking within local and regional economies was the “transplantation” or “invasion” of new novelty, firms and resources from exogenous sources (Castaldi & Dosi 2004). Alongside the evolutionary endogenous factors associated with path creation literature, transplantation referred to the importation, layering and diffusion of new technologies, firms, industries, organisational forms or institutional arrangements from exogenous sources into local and regional economies (Martin & Sunley 2006). Firms that access, absorb, learn and embed external knowledge through foreign direct investment (FDI) were able to create new products, processes and services (Blomstrom & Kokko 1998). A common explanation for the different receptivity of local and regional economies to create new industrial pathways was due to different levels of absorptive capacity within the existing institutional base (Niosi & Bellon 2002; Martin & Sunley 2006). More recently, transplantation as a mechanism of path creation became connected into emerging literature, including approaches associated with global production networks (GPN), which understood the evolution of the economic landscape in relation to broader extra-regional dynamics (Mackinnon *et al* 2009; Coe 2011). In this context, attention fell upon matching and harnessing local and regional assets to the strategic needs of transnational corporations (TNCs) or focal firms within a GPN by forging processes of “coupling” between those actors (Mackinnon 2012; Dawley 2013).

2.2.5 Upgrading Existing Technologies, Firms and Industries

The creation of new pathways also occurred through the revitalisation and enhancement of a domestic industrial base. Through the infusion of new technologies or by introducing new products and services, new pathways were created by “upgrading” industrial pathways to avoid negative local and regional lock-in (Martin & Sunley 2006). Underpinning a similar conceptual understanding to the upgrading of an industrial base, Bathelt & Boggs (2003)

proposed that local and regional economies “re-bundled” and integrated new resources into the regional production process and reconfigured existing resources, such as knowledge, to be used in different ways to serve different purposes (Bathelt 2009; Bathelt *et al* 2011). Thus:

“re-bundling is a process that readjusts existing and new, internal and external resources, to the needs of new socio-political and economic settings” (Bathelt *et al* 2011, p. 5).

Whilst upgrading and the other alternative mechanisms of new path creation focussed on endogenous and micro-economic processes, this thesis aims to unpick the processes and causality of local and regional path creation by situating the candidate mechanisms, and their interaction and interplay, within broader multi-scalar political, socio-institutional and economic actors, contexts and factors (Mackinnon *et al* 2009; Dawley 2013). Therefore, the following section addresses the neglected role of agency in the candidate mechanisms of new path creation by exploring the role of social and institutional agency, and particularly the multiple roles of the state, in stimulating and mediating the mechanisms and development of new local and regional growth paths.

2.2.6 Path Creation and Social and Institutional Agency

The primary preoccupation and focus amongst evolutionary economic geographers exploring and examining path creation and local and regional industrial evolution has been the important role of entrepreneurs and firms in responding to market and selection pressures (Mackinnon *et al* 2009). However, threatened by an overreliance on narrow imported theories, conceptual frameworks and populist themes, an emerging narrative within evolutionary economic geography began to emerge through integrating notions of social agency, power relations and institutions (Hodgson 2006). Deriving from mainstream economic geography and associated institutional, relational and geographical political “turns”, including a greater acknowledgement that economic activity was socially and institutionally situated and enmeshed in wider structures of social, economic and political rules, procedures and conventions, evolutionary economic geographers began to incorporate a broader perspective and comprehension of the role and types of social and institutional agency involved in the mediation, creation and evolution of new local and regional growth paths (Martin 2000; Mackinnon *et al* 2009; Hassink & Klaerding 2012).

Despite recognising the role and influence of institutions in economics and geography as “both objective structures ‘out there’ and subjective springs of human agency” (Hodgson 2006, p. 6), evolutionary economic geography originally considered institutions within the context of path creation, adaptation and economic change as “orthogonal to organisational firm routines” and exerting a marginal role on technology development and industrial activities because of the “loose”, “non-binding” and “general characteristics of different institutional frames” (Boschma & Frenken 2009, p152-153). Fundamentally, institutions were “carriers of history” (Martin 2010) with path dependent properties acting as a constraining influence on strategic agency (Maskell & Malmberg 2007). However, recognising that social and institutional arrangements and actors at various spatial scales embody collective action that can constrain but also guide and liberate individual habits, preferences, values and action, proponents of a more open and dynamic understanding of path dependency started to integrate micro-level accounts of path creation into their broader social and institutional contexts and sets of social relations that shaped path creation. Thus, institutions were historically and geographically conditioned by the wider institutional environment and extra-regional relations offering the potential to shape and select technological change, whilst also recognising that institutional change itself was often required to enable the emergence of new industries and to revive maturing sectors (Lundvall 1992; Nelson 1993; Hodgson 2004; Hassink 2005; Coe 2011). Thus, the multiple roles and spatial scales of socio-institutional actors became an increasingly prominent focus amongst evolutionary economic geographers by mediating, stimulating and providing an “enabling” environment for local and regional actors to create and establish new developmental paths (Martin 2010).

As a consequence of widening the theoretical scope of evolutionary economic geography, the uneven developmental potential of local and regional economies to embrace and support mechanisms of path creation, adaptation and de-locking became understood as part of a wider set of processes and dynamic interrelations including knowledge and capital accumulation, spatial circuits of production, circulation, consumption and regulation (Hudson 2005), power (Hassink & Klaerding 2012), social relations, labour markets and relations, and multi-scalar governance arrangements (Mackinnon *et al* 2009; Pike *et al* 2009). Thus, the dynamic interrelations between agents *within* and *beyond* firms became of particular interest e.g. formal concrete organisations, such as research institutes or the influence of government policies (Amin 1999; Gertler 2005; Mackinnon *et al* 2009). To stimulate collective learning

processes between actors to catalyse emerging local and regional industrial growth paths, institutional structures were proposed to “co-evolve” in order to facilitate, create, reconfigure and regulate new path creation and de-locking mechanisms (Teubal 1997; Schienstock 1997).

In addition, extra-regional dynamics, including global innovation networks (GINs) (Cooke 2011), open innovation practices (Chesbrough 2003) and “ever-shifting market, competitive and regulatory environments” became increasingly recognised as influential in shaping the creation, development and adaptation of local and regional growth paths (Martin 2010, p. 22). In this respect, firms and non-firm actors at a local and regional scale remain subjected and influenced by broader processes of co-evolution or “path plasticity” (Strambach 2008) in which innovation, firms, markets and institutions combined to mediate and shape, and are shaped by, new economic pathways (Nelson 1995; Rao & Singh 2001; Boschma & Frenken 2006; Boschma 2008). Nevertheless, despite helpful contributions to the literature, further research remained necessary to understand and unpack how socio-institutional environments, and particularly the role of political actors and policy examined in the next section, provide the necessary enabling (or constraining) environments to mediate, support and envelop mechanisms of new path creation (Mackinnon *et al* 2009).

2.2.7 The Geographical Political Economy of Path Creation

Given the increasing attention of the role wider socio-institutional, economic and political forces play in moulding and stimulating new growth paths at the local and regional scale, geographical political economic approaches recognising the role and influence of political relations and multi-scalar state institutions in setting the enabling conditions to catalyse and incubate new path creation began to receive increasing attention amongst evolutionary economic geographers (see, for example, MacLeod 2000; Rao & Sing 2001; Spencer *et al* 2005; Hassink 2007; Martin 2010; Pike *et al* 2010; Simmie 2010). As such, the mechanisms involved in path creation:

“are not purely market branching processes but significantly intermediated by regional agencies” (Cooke 2010, p. 10).

Therefore, the creation of new local and regional industrial pathways remained “pre-eminently a political phenomenon” because support had to be mobilised for the goals,

authority structure, technology and clients embodied in the new form (Stinchcombe 1968, p. 35). Thus, the state at a local, regional and national level performed an important role in shaping the evolution of the economic landscape reflecting its possession of resources, institutional capacity and political legitimacy (Hudson 2005; Jones 2008). For instance, the path creation and evolutionary trajectories of the domestic U.S. and Danish offshore wind industries during the 1980s were stimulated and shaped by national industrial strategies that followed “breakthrough” and “bricolage” characteristics (Meyer & Schubert 2007) (see, for example, Musgrove 2010; Simmie 2010). The U.S. approach of breakthrough concentrated on long-term planning in combination with developing a competitive domestic market structure. In direct contrast, Denmark’s bricolage strategy proposed a loose coupling between technology and actors to create virtuous learning cycles of unplanned activity (Garud & Karnoe 2003). Similarly, peripheral local and regional economies seemingly without endogenous assets and lacking regional institutional capacity (Albrechts 2004), including the North East of England, had long been the objects of multi-scalar state-led policies to stimulate institutional change, promote innovation and de-lock from negative path trajectories (see, for example, Hudson 2005; Pike *et al* 2006; Boschma & Martin 2010; Simmie 2010; Dawley 2013).

Situated within the multiple roles of the state, quasi-state and local and regional policy interventions, evolutionary economic geographers turned to multi-level perspectives on systems innovation to champion for multi-scalar political actors to form “niches” within existing knowledge structures, networks and techno-economic paradigms in order to introduce new innovations to the market (Geels 2004; Cooke 2012). A niche may be defined as an application context in which the new product or technology remains temporarily protected from the standards and selection rules of the prevailing paradigm (Hoogma *et al* 2002; Markard & Truffer 2006). State actors and policymakers can mediate and enable the creation of novelty and new pathways through strategic niche management (Kemp *et al* 1998) by developing protected spaces to build a constituency behind new innovations and set in motion interactive learning processes and institutional adaptations (Simmie 2010). Once the original niche conditions enter a critical mass or tipping point via increasing diffusion of innovation, sufficient economic agents prepare to switch to the new technology or industry in the presence of existing externalities (Witt 1997; Simmie 2010).

Nevertheless, despite emerging empirical evidence that illustrate local and regional techno-industrial growth paths shape, and are shaped by, their multi-scalar socio-institutional and political economy context and setting, evolutionary economic geographers still need to:

“examine the strategic decisions made by policymakers, including the nation state, if we are to properly understand regional path creation” (Martin & Sunley 2006, p.427).

As a result, Mackinnon *et al* (2009) have argued for a theoretical redesign of evolutionary economic geography by integrating evolutionary and institutional concepts within a broader geographical political economy approach. In short: evolution *in* economic geography rather than *an* evolutionary economic geography (Mackinnon *et al* 2009). In the absence of connecting evolutionary and institutional concepts to the multiple roles of the state, quasi state, its governance arrangements and purposive policy interventions, evolutionary economic geographers continued to possess:

“little understanding of how regions diversify into new growth paths, and to what extent public policy may affect this process” (Asheim *et al* 2011, p. 894).

It is in this context that the final section explores the influence of evolutionary approaches in economic geography in formulating and delivering policy interventions to stimulate and support the mechanisms of path creation and local and regional industrial evolution.

2.2.8 Path Creation and Evolutionary-Informed Local and Regional Policy

Economic geography has long considered the roles and impacts of state agencies, national and sub-national governance systems and local and regional policy strategies in providing constructive conditions or an enabling environment for knowledge generation, innovation and new path creation to take place within local and regional economic settings. Since the conception and introduction of national innovation systems thinking by Lundvall (1992), policymakers have applied innovation systems thinking to a variety of territorial scales and concepts including regional innovation systems (Cooke *et al* 2000), innovative milieux (Camagni 1990) and learning regions (Asheim 1996). In each instance, the dynamics of the system, comprising organisations, universities, financial institutions, development agencies etc. mediate actors’ “relative capacities to generate new pathways or renew old ones” (Martin

& Sunley 2008, p. 189) through the complex relationships between the nature and types of economic variety, the absorptive capacity of strategic agency and the capability of the territorial innovation system to generate and exploit new knowledge (Simmie & Martin 2010). However, policies underpinned by territorial innovation systems approaches were criticised for typically proceeding on a vertically configured sectoral and cluster basis (Asheim *et al* 2011), and carrying inherently path dependant characteristics based on constant learning and knowledge accumulation (Cooke *et al* 1998).

In the context of a deeper understanding and integration of the influence of multi-scalar governance and power dynamics of political economy of local and regional policy on new path creation, evolutionary economic geography began to consider and apply the theoretical, conceptual and empirical understandings of local and regional industrial evolution to suggestive policy prescriptions for policy practitioners (Asheim *et al* 2007). In many respects:

“there remains a clear need for more research that seeks to uncover the varying ways, forms and levels of success in which state actors, such as policymakers, attempt to implement strategic agency and mindful deviation from established paths” (Dawley 2013, p.98).

To the present, drawing general policy prescriptions for state actors and policymakers has remained problematic because evolutionary theorising left room for small, random moments in time that can spontaneously instigate or change a developmental trajectory (Dawley 2007). However, existing evolutionary-inspired local and regional policy identified four basic principles that stimulated and supported path creation. First, policy based on evolutionary principles began on the basis that new developmental paths cannot always be planned or even foreseen (Boschma & Lambooy 2001). Therefore, a “picking the winners” policy approach remained impractical and adversative to the spontaneity of local and regional industrial evolution based on the premise that it remained hard to predict where, when and what the growth regions, technologies and sectors of the future might or might not be (Asheim *et al* 2007). With uncertainty over the formation of new technologies, firms and industries over time and space, state agencies and policymakers assisted processes of new path creation by acting as “adapters” rather than “optimisers” (Boschma 2004) of “promising targets” by

supporting mutual adaptive and co-evolving processes that enact in local, regional and national settings (Boschma 2014).

Second, policies and policy intervention based on evolutionary principles increasingly recognised the role, importance and conditioning of local and regional structures, institutions and activity laid down in the past (Rigby & Essletzbichler 1997; Neffke, Henning & Boschma 2008). In other words, local and regional policy prescriptions were not conformable to a “one size fits all” approach (Boschma 2004). Rather, the emergence of new paths were stimulated or enabled, at least in part, by the pre-existing resources, competencies, skills, decisions and experiences that were inherited from previous local and regional paths and patterns of economic development (NESTA 2008; Sydow *et al* 2010). Therefore, in contrast to revolutionary policymaking and an emphasis on a complete redesign and restructure of the institutional landscape, adopting an evolutionary regional policy and adaptation approach takes into account history and specific local and regional contexts as the starting point in formulating and delivering policy interventions (Boschma 2005) (see Table 2.4). As such:

“the degree and nature of policy intervention should be different in regions because their histories differ...[and] be based on the institutional history of a region and which type of intervention fits better a region’s situation (Boschma 2009, p.19).

With respect to notions of path creation and related variety, policymakers stimulated regional branching by supporting and connecting new sectors that have their roots in the regional knowledge base and complementary technological fields (Boschma & Frenken 2007; Neffke *et al* 2011). Thus, policies based on mediating and connecting technology relatedness and related variety offered the potential to broaden a local and regional sectoral base by fostering knowledge spillovers between those related sectors (Frenken *et al* 2005; 2006). Therefore, the basic thesis held that “history matters” (Boschma 1999) in generating and implementing local and regional policy interventions based on constructing regional advantage (CRA) (Asheim *et al* 2011) drivers to support processes of innovation, related variety and path branching (Noteboom 1997).

Table 2.4 Two Types of Evolutionary Regional Innovation Policy

Evolutionary type of policy	Revolutionary type of policy
Location-specific policy	Generic policy
Fine-tuning	Restructuring of institutional framework
Strengthening existing connectivity	Stimulating new connections
Benefiting from specialisation	Stimulating diversity
Few degrees of freedom	More degrees of freedom
Less uncertainty	More uncertainty

Source: Boschma & Frenken 2006, p. 17.

Third, and linked to the importance of a broader “contextual view” of policy intervention, place as well as history remained important in evolutionary-inspired policy prescriptions (Asheim *et al* 2011). Technologies, firms and industries evolve along relatively distinct pathways as different local and regional economies follow innovation trajectories conditioned by their history and geography (Dosi 1982, David 1975, Porter 1990; Rigby & Essletzbichler 1997, 2006). As such, all local and regional economies possess the potential for growth regardless of variations in the institutional, organisational and absorptive capacity based on the identification, connectivity and exploitation of strategic agency, actors and local and region-specific assets to build upon and deliver the “basic” conditions to foster learning, innovation and variety (Boschma & Lambooy 2001).

Fourth, reflecting the increasing attention amongst evolutionary economic geographers of the wider role of social and institutional agency in mediating and influencing processes of path creation, policymakers often lacked capacity to stimulate and mobilise agents to establish new growth paths (Mackinnon *et al* 2009; Morgan 2012). Therefore:

“whilst notions of place dependency rightly direct attention to local conditions of path creation, the approach also recognises that these factors are both historically and geographically conditioned by national state strategies and wider political economic contexts and socio-spatial relations” (Dawley 2013, p. 99).

Thus, local and regional policymakers and prescriptive policy interventions were placed in and sensitive to the interrelations between multi-scalar policy contexts and actors that shape the geographical evolution of local and regional economies (Pike *et al* 2009; Gertler 2010).

In summary, policymaking based on the principles of an evolutionary economic geography framework recommended a variety of policy interventions that stimulated and supported the creation of new technology, industrial and local and regional growth path trajectories (Lambooy & Boschma 2001). Underpinned by the inevitability that new innovation, firms and industries might locate and grow in unexpected places and spaces, policymakers and policy intervention to instigate the key agents, processes and mechanisms of path creation focussed upon creating niche conditions based on the identification of promising targets and underpinned by a “transversality” of innovation capabilities, related variety and path branching characteristics (Cooke 2012). Thus, prescriptive evolutionary-inspired policy interventions offered the potential to instigate processes of related variety and path branching in order to create new economic pathways (Boschma & Frenken 2007). Inherent within the emerging policy narrative was the importance of policymakers considering “contextual” policy interventions in identifying emergent growth paths by placing or selecting choices within a locality or regions historical and geographical environment (Asheim *et al* 2011). Nevertheless, whilst emerging policy prescriptions and options became attuned to the historical and geographical specificities of particular places, policymakers began to increasingly consider and incorporate broader social and institutional linkages, and interrelations at a variety of multi-scalar platforms, that shaped the evolutionary trajectory of paths at a local and regional scale (Gertler 2010).

2.2.9 Conclusion

The evolution of the local and regional economic landscape over time and space has been a long standing focus of interest amongst economic geographers. Following on from the integration of a number of historical theories and concepts to examine the creation and unfolding of new local and regional growth paths, the theoretical emergence of evolutionary economic geography opened up a further avenue of exploration in economic geography. In particular, by situating path creation within a more open and dynamic understanding of path dependency and local and regional industrial evolution, the present literature moved beyond firm-centric accounts by beginning to identify, incorporate and understand the multifaceted

nature and interplay of multi-scalar social and institutional agents, causal factors and conditions that stimulate and shape the mechanisms of path creation. However, as a relatively new theoretical and conceptual approach, the literature review also revealed a set of gaps or areas of expansion in the literature; three to be specific; that this thesis contributes towards. First, whilst Martin & Sunley's (2006) path as a process approach helpfully identified and described the candidate mechanisms that create new pathways, there remains little conceptual and empirical evidence of their interaction and inter-relations between the mechanisms within their broader political, economic and socio-institutional settings (Dawley 2013; Dawley *et al* 2015). This thesis provides a further layer of evidence that addresses the gap in the literature by utilising Martin & Sunley's (2006) conceptual candidate mechanisms of path creation to analytically explain the evolutionary trajectory of the offshore wind and printable electronics industries in the North East.

Second, the emerging narrative in understanding new path creation has placed a greater emphasis on situating local and regional evolutionary growth paths within their wider multi-scalar social, political, economic and institutional contexts. This thesis adopts Martin's (2010) open and dynamic alternative conceptual model of path dependency by contributing to a deeper and fuller analytical examination and explanation of the relationship, connections and interplay between multi-scalar political, economic, social and institutional agents, networks and linkages, and key actors, mechanisms and conditions that stimulated and shaped the path creation of the regional printable electronics and offshore wind industries (Coe 2011).

Third, scholars and policy practitioners have begun to consider the application of evolutionary-inspired policies into targeted and contextual policy interventions to stimulate and catalyse the mechanisms of path creation. However, a dearth of empirical and comparative studies exist in examining how local and regional economies transfer from constraining to enabling environments, and what role local and regional policy intervention has played in that process (Martin 2010). This thesis addresses this relative neglect by proving an analytical framework utilising existing theories and concepts inherent in evolutionary-inspired policy to an understanding of the role of state actors and policy in stimulating the mechanisms of new path creation and shaping the creation and development of the offshore wind and printable electronics industries in the North East (Neffke *et al* 2011).

CHAPTER 3. METHODOLOGY

3.1.1 Introduction

The principal challenge for research into path creation and local and regional industrial evolution within broader evolutionary approaches in economic geography is to consider “who”, “what” and “where” is evolving in the economic landscape and “why” (Martin 2010). Thus, research and analyses of the mechanisms, agents and conditions enabling new path creation remain “top of the agenda” for research in this field (Sydow *et al* 2010, p. 190). Accordingly, and related to the aims and research focus of this thesis, the purpose of the research was to trace back, identify and understand the key causal agents, processes, conditions and mechanisms within broader economic, institutional, social and political frameworks involved in over 30 years of path creation and development activities in the offshore wind and printable electronics pathways in the North East.

Underpinned by theoretical and conceptual advances and understanding of path creation, the overarching research framework was based on adopting and incorporating a predominantly qualitative research design into a plural methodological case study approach. The objective of this chapter is therefore to identify the practical and methodological considerations that shaped the research strategy and justified the mixed methods research approach adopted within epistemological, theoretical, ontological, methodological and analysis. Consequently, the chapter begins in 3.1.2 by placing evolutionary approaches in economic geography and research into path creation within its epistemological, theoretical and ontological roots. From this stated position, section 3.1.3 addresses the selection of utilising case study analysis to frame the research study and section 3.1.4 presents a justification of the predominantly qualitative mixed methods research approach taken due to the absence of available and reliable quantitative datasets. The methodological layers of the research progresses in section 3.1.5 with a review and justification of the methodological tools borrowed from quantitative and qualitative techniques, including the rearward generation of semi-structured interviews and the collection of secondary quantitative datasets, to support the research process. Section 3.1.6 illustrate the techniques utilised in post-fieldwork analysis on the empirical data, including connecting theorisation of the relations between path creation concepts and empirical material to identify process and causal outcomes in the regional printable

electronics and offshore wind pathways. The penultimate section in 3.1.7 reviews the research process and interpretation of the findings in relation to the positionality and reflexivity of the researcher. The final section in 3.1.8 provides a succinct conclusion of the research process.

3.1.2 Epistemological, Ontological and Theoretical Positioning

As an embryonic discipline of economic geography, evolutionary economic geography's philosophical origins lie in the natural sciences through its relationship with evolutionary economic theory. The epistemological position of evolutionary economic theory was therefore grounded in positivism through its explanation of human behaviour by, although not solely, quantitative means (Von Wright 1971). However, entering into the 21st century evolutionary economists began to reject neoclassical economics in favour of beginning to connect economic interpretation to the basic ideas of modern evolutionary biology, complexity science and path-dependency theory (Boschma & Martin 2007). Thus, evolutionary economic geography's epistemological roots were also grounded in interpretivism as a school of thought that reflected theoretical developments in a post-positivist world (Yannow 2004). Thus, in many respects the:

“ontological and epistemological differences between the (quantitative) core of EEG [Evolutionary Economic Geography] and other (qualitative) parts of economic geography are still considerable” and any “methodological rapprochement will be easier said than achieved” (Coe 2010, p.7)

Within this hybrid context, reflecting the relationship between the knower (researcher) and the known (participant), the epistemological approach adopted in the research was underpinned by “pragmatism” (Sunley 1996). Therefore, unlike positivism (quantitative) or interpretivism (qualitative) which interpreted social action as an objective or subjective point of view, pragmatism:

“debunks concepts such as ‘truth’ and ‘reality’ and instead focuses on ‘what works’ [in the rejection] of the either/or choices associated with the paradigm wars” (Tashakorri & Teddlie 2003, p.713).

The complex epistemological positioning of evolutionary approaches in economic geography within quantitative and qualitative arenas was similarly reflected in the ontological position held throughout the research exercise. Broadly speaking, evolutionary economic geography has been widely criticised for borrowing and applying conceptual notions from a variety of theoretically unrelated disciplines (*inter alia* Hodgson 1993; Lawson 2003; Hodgson & Knudsen 2006). Moreover, further evidence is required to demonstrate the ontological properties of path branching and de-locking mechanisms and to distinguish, and clarify, the relationship between each concept over space and time (Pike *et al*, forthcoming 2015). Nevertheless, the ontological position held throughout the research also followed a pragmatist approach weighted towards constructivism in which social phenomena and categories were not simply produced through social interaction but reflected evolutionary principles which were in a recurring state of flux (Bryman 2008).

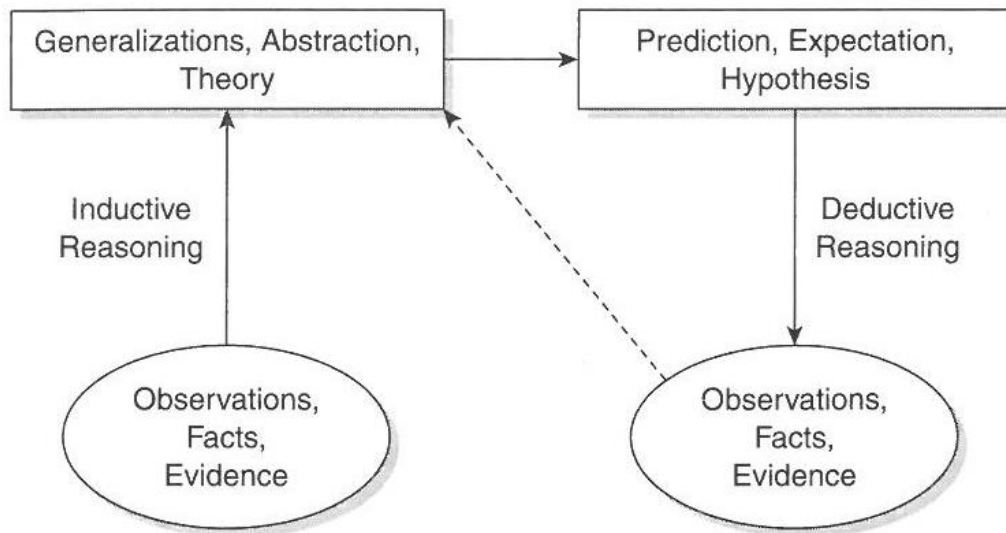
The methodological and analytical task of research in evolutionary economic geography remains to find ways of operationalising evolutionary concepts to inform theorisation of their relations and test their ability to interpret and explain empirical experiences (Pike *et al*, forthcoming 2015). Adopting and applying a hypothetico-deductive theoretical position, a number of evolutionary economic geography empirical studies have subjected data collection and analysis to applying the theoretical principles and conceptual models of variety, selection, lock-in, path dependency and others to interpret and understand the economic landscape as it unfolds over time and space (see Klepper & Simons 2000; Klepper 2001; 2002; Boschma & Wenting 2007; Henning *et al* 2009; Boschma & Ledder 2009).

However, the lack of definitional precision of evolutionary concepts and their specific explanation of the processes and causality of path creation matched to empirical data also present an opportunity to generate new conceptual models of path creation reflective of an inductive theoretical approach. Therefore, there is real value in exploring theoretically-informed empirical work and empirically grounded theorising as an inductive-deductive inter-play between theory and empirics (Peck 2005; Sunley 2008). Therefore, the theoretical position held throughout the research exercise adopted and applied an inductive-deductive research cycle (Tashakkori & Teddlie 1998) (see Figure 3.1) approach which can be understood as a process that:

”moves from grounded results (observations, facts) through inductive inference to general inferences, then from those general inferences (or theory, conceptual framework, model) through deductive inference to predictions to the particular (a priori hypothesis)” (Teddlie & Tashakkori 2009, p.26).

Thus, in investigating the evolutionary processes, mechanisms and causal factors that underpinned the geography of path creation in the offshore wind and printable electronics industries in the North East, the theoretical position applied was one which sought to utilise existing conceptual models and theories of path creation, specifically those provided by Martin & Sunley (2006) and Martin (2010), to examine and understand the causality (from an interpretivism perspective) of the empirics, while simultaneously using specific observations based on empirical findings to propose broader generalisations and test the existing theory and concepts of path creation. In so doing, alternating between theory and empirics supported the conceptual robustness, theorisation, systematic analysis and explanation of the research object and subjects (Pike *et al*, forthcoming 2015)

Figure 3.1 The Inductive-Deductive Research Cycle



Source: Teddlie & Tashakkori 2009

3.1.3 Selecting and Applying a Research Design

Having examined the theoretical, epistemological and ontological utility to a study of the evolutionary path creation and development activities of the North East’s offshore wind and

printable electronics industries, the following section provides a rationale and justification for selecting case study analysis as the most suitable research design method (Diefenbach 2009). In simplistic terms, case study research is concerned with the complexity and particular nature of the case in question (Bryman 2008). A particular advantage of case study approach in understanding and “getting inside” (Clark 1998) processes and the causality of path creation is the ability to investigate, in a very detailed way i.e. using “thick description” (Geertz 1973), insights into a working historical social space by “closing in” on real-life phenomena as events have unfolded over time and history (Teddlie & Tashakkori 2009). Therefore, the research design approach utilising case study analysis was consistent with contemporary evolutionary approaches in economic geography that focus on processes of change, adaptation and renewal over longitudinal temporal periods (Pike *et al* 2012).

Borrowing from techniques associated with medical history, the research design was positioned as a retrospective case study which allowed for the research study to investigate and analyse “the relationship between one (usually current) phenomenon(s) or conditions and another (or several) that occurred in the past” (Mosby 2009, p. 344). Adopting a retrospective case study allowed the research to trace back and delineate the key causal agents, mechanisms, conditions and processes involved in over 30 years of path creation and development activity in the region’s offshore wind and printable electronics industries to explain how and why both pathways unfolded in a particular way over time and space (Pike *et al*, forthcoming 2015). In addition to the application of a retrospective case study, a comparative design approach was also incorporated into the research design recognising an increasing need within evolutionary studies to deliver empirical studies that are “more comparable, transparent and cumulative” (Boschma & Frenken 2009, p.156). In other words:

“social, economic and spatial phenomenon can be better understood when they are compared in relation to two or more meaningfully contrasting cases or situations” (Bryman 2008, p. 58).

The limitations of embodying the logic of retrospection and comparison into a case study analysis of the evolutionary path creation of the offshore wind and printable electronics industries relate to issues associated with reliability of the data, generalisability (positivism) and difficulty in transferring (interpretivism) empirical, theoretical and conceptual findings to

other empirical case study examples with identical research objects and subjects (interpretivism) (Flyvbjerg 2006).

3.1.4 Methodological Approach: Selecting and Applying Mixed Methods

In the past ten years evolutionary approaches in economic geography have built a strong pipeline of empirical research utilising longitudinal quantitative techniques (see, for example, Klepper & Simons 2000; Klepper 2001; Boschma & Wenting 2007; Neffke *et al* 2009; Boschma & Frenken 2010; Giulianin 2010). Amongst a number of benefits, the application of quantitative methodologies has been particularly useful in defining conceptual categories, articulating and testing hypotheses, and mapping patterns, features and regularities of evolutionary change over time and space (Pike *et al*, forthcoming 2015). However, as with typical criticism labelled at longitudinal quantitative techniques and analysis, such work has faced issues including integrating “fuzzy” (Markusen 1999) conceptualisations into appropriate proxy indicators, contextualising quantitative findings and establishing explanatory descriptions between statistical correlations (positivism) and causation (interpretivism) (Barnes *et al* 2003).

In contrast to the “emerging empirics of evolutionary economic geography which are largely quantitative” (Dawley 2013, p.99) in scope and output, research in evolutionary approaches in economic geography has slowly built a small body of qualitative studies (see, for example, Hassink & Shin 2005; Simmie & Martin 2010; Sydow *et al* 2010). In direct reverse to its quantitative alternative, qualitative approaches in evolutionary economic geography have provided fertile empirical studies by capturing conceptual notions of variety, heterogeneity and branching of evolutionary change, and identifying and interpreting causal processes and mechanisms (Pike *et al*, forthcoming 2015). As with other qualitative approaches in economic geography, the adoption of qualitative techniques has been weak in translating data into consistent categorisation in order to enable systematic comparison and analysis across time and space, and in the use of compare and contrast frameworks (Pike *et al*, forthcoming 2015).

Recognising the complementary benefits, rather than competing approaches, of applying quantitative and qualitative methodological constructs to evolutionary economic geography research, the research method utilised to investigate and examine the path creation of the

offshore wind and printable electronics industries in the North East was consistent with a mixed methods approach (Essletzbichler 2009). Thus, in many respects:

“the variant and emergent approaches to evolution in economic geography should employ plural methodologies better to engage and explain diversity, variety, heterogeneity and change in the economic landscape” (Pike *et al*, forthcoming 2015).

To provide a clear and consistent definitional use of the term mixed methods within the thesis amidst alternate definitions in methodological literature and practice e.g. multi-method design, mixed design etc. (Teddlie & Tashakkori 2009), a mixed method approach was reflective of:

“the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches e.g. use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques, for the purpose of breadth of understanding or corroboration” (Johnson *et al* 2007, p.123).

The overriding benefit of adopting methodological pluralism in evolutionary economic geography research would support a deeper explanatory grasp and understanding of evolutionary change in the economic landscape, while also transitioning beyond earlier twofold distinctions between “institutional” and “evolutionary” approaches that possessed specific and separate methodological approaches (Boschma & Frenken 2006, p.286).

Framed within a case study approach, the research design and methodological approach was originally based on the application of a uniformed quantitative and qualitative mixed methods approach. As such, the decision to incorporate “rich” (Parsons & Knight 1995) qualitative data into the research design reflected the principal research questions under investigation which aimed to capture and explain concepts of path creation and de-locking in the economic landscape over time (Boschma & Frenken 2007; 2010). Nevertheless, while recognising a qualitative approach would be superior to describe and explain “the sequence of individual and collective events, actions and activities [which] unfold over time and in context” (Pettigrew 1997, p. 338), the research design also sought to incorporate quantitative data sets in order to test existing hypothesises, causal effects (positivism) and support the identification of common patterns or irregularities (Massey & Meegan 1985; Atkinson & Hammersley

1994). However, the lack of available, reliable (positivism) and comparable longitudinal primary and secondary quantitative data limited the opportunity to apply a complete mixed methods design, offering inadequate statistical datasets through which to integrate, interpret and understand the relationship between causality (interpretivism) and effect (positivism) (see section 3.1.5). Therefore, illustrative of a pragmatic approach to mixed methods research based on the “desirability” (Greene 2008) to utilise both research paradigms and acknowledged deficiencies in the application of a complete QUAL + QUAN approach, the eventual research design adopted and applied to study the causal relations, mechanisms and factors in the regional offshore wind and printable electronics trajectories was predominantly qualitatively driven but designed to utilise quantitative data sources, when available and reliable (positivism) i.e. utilising a QUAL + quan design sequence (capitals reflecting dominant research design) (Morse 2003), synonymous with a parallel mixed methods research design (Lopez & Tashakkori 2006).

The amalgamation of both qualitative and quantitative methodological practices, albeit at different priority and sequential patterns, was synonymous with “triangulation” (see, for example, Campbell & Fiske 1959; Denzin 1978). However, because of the constrained nature of triangulation as a methodological design option (see, for example, Matthison 1988), the research design, methods and analysis were positioned and evaluated under the mixed methods notions of “complementarity” and “expansion” (Teddlie & Tashakkori 2009). For instance, the complementarity mixed method approach used to understand overlapping but also different facets of a phenomenon was applied to comprehend the relationship and connectivity between mechanisms of path creation in stimulating the offshore wind and printable electronics pathways (Greene 1987). Implementing an expansion mixed methods study, qualitative methods were used to assess processes and causality of multi-scalar actors, conditions, mechanisms and factors within the emergent regional offshore wind and printable electronics pathways by correlating, where possible, between the qualitative (causal) dimension of the trajectories and the quantitative programme outcomes and outputs (effect). Thus, having selected a parallel mixed methods design and expanded on the purpose of the research as grounded in complementarity and expansion rationale, the forthcoming section details the methodological tools and techniques used to generate research data, beginning with the decision to use a purposive sampling technique to conduct semi-structured interviews.

3.1.5 Research Methodology

In accordance with typical case study analyses, semi-structured interviews utilising a purposive sampling technique was selected as this approach “selected units based on specific purposes associated with answering the research study’s questions” (Clark & Creswell 2008, p.200). Indeed, adopting the semi-structured interview approach would yield the most information about the processes and causality of path creation and development in the region’s offshore wind and printable electronics industries through “close dialogue” with key agents and organisations in their institutional, sectoral and spatial contexts (James 2006; Teddlie & Tashakkori 2009). An initial sampling frame was generated as part of a “backward extension of institutional and organisational actors”, principally generated by utilising past knowledge, existing datasets and professional contacts held from working at One NorthEast (ONE), the Regional Development Agency (RDA) for the North East of England between 2004 and 2011 (Pike *et al* 2012). To ensure robustness and complete representation of actors across and embedded within the pathways, the sampling frame identified actors at multi-scalar levels from academia, industry, intermediary organisations and policy practitioners which were cross-referenced against existing databases and secondary data sources held and obtained from key North East-based organisational actors including the Northern Offshore Federation (NOF) Energy, the Centre for Process Innovation (CPI) and Tees Valley Local Enterprise Partnership (TVLEP).

In total, thirty-eight interviews were conducted with key actors, past and present, representing firm and non-firm organisations between 2010 and 2014 from across the offshore wind and printable electronics industries (see Table 3.1 & 3.2). The methodology was reminiscent of an “institutional genealogy” approach to uncovering and piecing together a qualitative dataset (Martin 2010; Pike *et al* 2012). Reflecting the decision to pursue a QUAL + quant research design, the interviews conducted were semi-structured in format with interviewees subjected to a series of pre-set, open-ended questions to encourage dialogue in order to offer greater insight and signposting to further supportive material (Patton 2002) (see Table 3.3). For instance, interviewees, on several occasions, offered a selection of undocumented and confidential information which served as a basis for future exploration. With the exception of four telephone interviews, the remaining interviews were conducted in person, typically lasting one hour per session, and predominantly undertaken within the organisational building of the interviewee. In each occasion, a sustained attempt was made to interview a senior

management representative from within the firm or non-firm entities recognising the importance of observing research objects and institutional behaviour through the eyes of “elite” interviewees (Neal & McLaughlin 2009).

To provide additional and complementary research data to the semi-structured interviews, historical secondary data was gathered and analysed. Secondary quantitative data pertaining, in the main, to firm-level datasets was collected from a number of sources including ONE, TVLEP, NOF Energy and regional multiplier organisations, including Energi Coast and the North East Chamber of Commerce (NECC). The reference to “core” firms throughout the thesis illustrated those firms whose primary activities were directly related to the offshore wind and printable electronics sectors e.g. wind turbine manufacturers, component suppliers etc. Nevertheless, the reliance on ad hoc secondary statistics within the research design and methodology was a consequence of recurring issues of data availability and quality within longitudinal analyses, with standard industrial classification (SIC) data unable to track, suitably categorise and keep pace with national and sub-national patterns of enterprise activity, employment and investment within the offshore wind and printable electronics industries over the temporal period (Boschma & Frenken 2007; Rigby 2007). Nevertheless, supporting secondary quantitative datasets was the collection and analysis of hundreds of documentary materials including: regional and national policy documents; corporate literature; media articles; industry reports; and internal ONE business case and funding proposals. In addition, biographical material, including photographs and previous biographical interviews, was accessed, where possible, to provide a contextual history and “life story approach” to the evolutionary trajectory of both industries (Bertaux & Kohli 1984).

To record collected data and ensure consistency of reporting, pre-arranged interviews utilised a digital tape recorder to capture verbal exchanges, unless the research participant requested otherwise. On those few occasions, more detailed handwritten notes were taken and often followed up with clarification by telephone conversation. Notes were also made during recorded interviews to serve a different purpose including recording perceptions, impressions and non-spoken gestures made by the research participant (Teddlie & Tashakkori 2009). All digital tape recordings were subsequently transcribed for respondent validation and analysis.

Table 3.1 Offshore Wind Interviewees

Organisation	Public/Private Ownership	Location of Organisation (Regional/National)	Position
Borderwind/ClipperWind Power	Private	Regional	Chief Executive Officer (CEO)/CEO
One NorthEast	Public	Regional	Head of Energy & Environment
One NorthEast	Public	Regional	Head of Innovation, Industry & Science
SMD Hydrovision/North East Local Enterprise Partnership (NELEP)	Private/Public	Regional	CEO/ Deputy Chairman
National Renewable Energy Centre (NaREC)	Public	Regional	Director of Technology & R&D
Shepherds Offshore Services	Private	Regional	Director of Business Development
Siemens Wind Power	Private	National	Business Development Manager
NOF Energy	Public	Regional/National	Deputy Director
Tees Alliance Group Energy Solutions/Energi Coast	Private/Public	Regional	CEO/Chairman
Newcastle University	Public	Regional	Deputy Director of Sir Joseph Swan Energy Institute/Professor of Energy
International Paint (AkzoNobel) Offshore Marine Division	Private	Regional	Business Development Manager
Northumberland County Council	Public	Regional	Area Regeneration Manager

CTC Marine	Private	Regional	Business Development Manager
McNulty Offshore	Private	Regional	Head of Commercial Development
Corus/Tata	Private	Regional	Business Development Manager
Alnmaritec	Private	Regional	CEO
Northumbrian Energy Workshop	Private	Regional	Former Director

Source: Author Interviews 2010- 2014

Table 3.2 Printable Electronics Interviewees

Organisation	Public/Private Ownership	Location of Organisation (Regional/National)	Position
British Printing Industries Federation	Public	National	Regional Director – North East
Mixicap	Private	Regional	CEO
One NorthEast	Public	Regional	Senior Specialist Advisor
Atmel Corporation/Centre for Process Innovation (CPI)	Public	Regional	Finance Director/Chief Financial Officer
One NorthEast	Public	Regional	Senior Specialist Advisor – Emerging Technologies
De La Rue	Private	National	Head of New Ideas
High Force Research	Private	Regional	CEO
One NorthEast	Public	Regional	Innovation Manager

Durham University	Public	Regional	Head of Business Development
CDDC/Business Durham (NETPark)	Public	Regional	Director of Business & Investment
PETEC (CPI)	Public	Regional	Director of PETEC
PETEC (CPI)	Public	Regional	Business Development Manager
DuPont Teijin Films	Private	Regional	Chief Scientific Officer
Durham University	Public	Regional	Professor of Physics
Thorn Lighting	Private	Regional	Research Team Lead – OLED and PLED Division
BIS/Technology Strategy Board	Public	National	Head of Electronics & Photonics
3M	Private	National	Head of Technical R&D
CENAMPS	Public	Regional	Former CEO
Merlin Flex-Ability	Private	Regional	CEO
Faraday Printed Circuits	Private	Regional	Sales Director
Northern Way	Public	Regional	Senior Specialist Advisor
INEX (Newcastle University)	Public	Regional	Head of Business
Polyphotonix	Private	Regional	CEO
Durham University	Public	Regional	Emeritus Professor of Chemistry

Source: Author Interviews 2010- 2014

Table 3.3 Pre-Prepared List of Semi-Structured Interview Questions

1.	Please tell me about the origins of your company/organisation?
2.	How would you describe the beginnings and evolution of the North East's offshore wind and printable electronics industries?
3.	Can you identify any particular patterns of firm and/or industrial activity?
4.	Can you identify any prominent individuals/firms/organisations internal or outwith of the North East that have had a significant bearing upon the North East's printable electronics and offshore wind industries?
5.	What role have local and regional institutions (ONE, centres of excellence, universities etc.) played within your company/organisation and the wider regional offshore wind and printable electronics industries?
6.	What role has the UK Government played in shaping your company/industry?
7.	What role has local, regional and national policy played in supporting or constraining the sectors?
8.	What local, regional and national policies can stimulate and support the two industries in the future?
9.	Is the North East's offshore wind and printable electronics a new pathway or a branching of an existing pathway?

Source: Author Interviews 2010- 2014

The collection of secondary quantitative data was recorded onto two electronic spreadsheets in order to analyse historical longitudinal patterns of industrial activity along and across both pathways. In addition, impromptu interviews, such as everyday conversations, often taking place at chance encounters, did not have the benefit of tape recorded discussions.

3.1.6 Post-Fieldwork: Analysis

As highlighted at the beginning of the chapter, one of the analytical challenges faced in undertaking research into local and regional path creation utilising an evolutionary economic geography framework is to consistently marry the theoretical concepts of path creation, variety, branching and others, into the empirical material to draw out specific understandings and explanation of the processes and causal mechanisms in a local and regional context (Pike *et al*, forthcoming 2015). The opposite is also true of applying an inductive theoretical

approach. To provide clarity and consistency throughout the research process, Martin & Sunley's (2006) conceptual candidate mechanisms and definitions were adopted and applied to the analysis. Similarly, at a meso-level, the empirical findings were compared and contrasted with Martin's (2010) schematic model of local and regional industrial evolution to describe, at a conceptual level, the evolutionary changes and dimension of the regional offshore wind and printable electronics pathways.

From establishing an analytical framework in which to evaluate the multi-scalar and multi-agent dynamics of path creation activity, the empirical material was subjected to a series of post-fieldwork analytical techniques. To begin with, semi-structured interviews were transcribed in full. Through the application of content analysis, responses were extracted related to "who", "what", "how", "when" and "why" both pathways were formed. Singular words and prominent phrases or quotes from interview subjects were aggregated into pre-conceived conceptual categories and activities e.g. indigenous creation, branching, historical legacy, place-based assets, state involvement and policy etc. (Holsti 1969). With respect to the collection of data referring to when key "moments in time" unravelled, the empirical findings presented in catalogued form were further segmented based on temporal occurrence rendering three temporal episodes or phases of investigation i.e. 1978-2000, 2000-2010 and 2010-2012, in the evolutionary trajectories of the offshore wind and printable electronics industries in the North East (Dawley 2007).

The selection of a retrospective case study allowed for a backward extension of the secondary quantitative data and its analytical integration with the historical qualitative analysis of secondary sources and in-depth engagement with relevant actors from the past and present (Pike *et al*, forthcoming 2015). In a similar pattern to the analytics applied to the semi-structured interviews, the predominantly firm-centric numerical data sourced from multiple locations were inputted on to an electronic spreadsheet and ordered according to a series of predetermined categories e.g. year of firm formation, original activity of business, type of firm (spin-off, start-up, transplantation) etc., mirroring empirical analyses applied in past quantitative evolutionary economic geography studies (see, for example, Henning *et al* 2009; Boschma & Ledder 2009). Statistical analytical techniques including path analysis and path co-efficient, while potentially useful, were not applied because of the unreliability (positivism) of the quantitative data sources (Dodge 2003). The remaining secondary sources of quantitative and qualitative data were systematically reviewed and compartmentalised

according to the purpose of the document e.g. economic strategy, national policy document etc., the categorisation of the activity e.g. firm diversification, indigenous creation, recombination etc., and the temporal period in which it was produced and/or occurred.

3.1.7 Researcher Identity, Positionality and Reflexivity

Connecting back to an epistemological position based on pragmatism, the research design, process and interpretation of the empirical findings was influenced and shaped based on a self-conscious awareness of the position and dynamic relationship between the researcher and the researched (Chiseri-Stater 1996). With regard to the research design and methodology, the identification and selection of the offshore wind and printable electronics industries as research topics of investigation was inherently connected to the policy practitioner occupation held by the author at ONE between 2004 and 2011. Within the context and timing of ONE's role in facilitating and supporting path creation of the printable electronics and offshore wind pathways in the North East during the first decade of the 21st century (see subsection 5.2), the author's position as a "research insider" (Robson 2002) provided a number of distinct advantages in designing and conducting the research. First, the author was able to leverage situated knowledge during the temporal period of employment in order to enhance the richness and diversity of the data (Haraway 1998). Second, the author was able to tap into an established network of "corporate" interviewees held by the author which enabled a more comfortable and open dialogue with interviewee subjects (Neal & McLaughlin 2009). Third, the occupational position at ONE provided the author with access to influential "gatekeepers" within both firm and non-firm organisations at multi-scalar levels which the author would have otherwise not been able to cultivate or had access to e.g. senior Technology Strategy Board (TSB) personnel (Bryman 2001).

The positionality of the author during the research process allowed for access and evaluation of research subjects which supported the granularity of the research data but also came with its potential criticism over the level of critical distance exhibited between the author and the research topic and subjects throughout the research process (Adler & Adler 1994). While recognising the impossibility of remaining "outside" a subject matter, particularly when conducting and analysing qualitative research, during the period of data collection interviewees were reminded of the aim, purpose and proposed output of the research at the beginning of each semi-structured interview, which was influenced but ultimately detached

from the author's own occupational position at ONE (Denzin & Lincoln 1994). To highlight critical distance between ONE and the research object of analysis, the thesis investigated and charted the path creation of the offshore wind and printable electronics pathways in the North East pre and post-RDA. As such, the research process illustrated and reflected on the role of a variety of multi-scalar agents and identities, aside from ONE's influence and interventions, within and across different temporal episodes and settings, in shaping the corresponding industrial pathways. In summary, throughout the research process the author recognised the construction of knowledge and interpretation of empirical findings to be a process of co-production, in keeping with epistemological approaches held by mixed methods researchers and disrupting the common and supposed dualism between being a research insider *or* outsider (Geertz 1973). Therefore, by illustrating and providing a statement on the positionality and pragmatic approach of the author during the research process, this section has sought to address any charge of bias towards the research design, methodology, analysis and write-up, and provide a level of critical reflection on the situatedness of the author's generation and interpretation of knowledge over time and social space.

3.1.8 Conclusion

The research methodology and analytical findings represented a small but important contribution to the growing body of largely quantitative empirical research on path creation by providing a more nuanced account of the processes and causality of the key agents, mechanisms, factors and conditions which stimulated, supported and enabled path creation of the North East's offshore wind and printable electronics industries (Coe 2011; Boschma *et al* 2012). In particular, this research contributes to a small nucleus of research which has attempted to weave mixed methods approaches into a longitudinal study of path creation and local and regional industrial evolution (see, for example, Rigby & Essletzbichler 2006; Dawley 2013). By contributing to an existing narrow body of empirical work, the research strengthens comparative research which remains critical to ensure that:

“empirical studies focussing upon geographical differentiation, diversity and heterogeneity in the economic landscape can be systematically compared and cross-referenced over space and time to yield deeper insights and challenge the robustness of emergent theoretical explanations” (Pike *et al*, forthcoming 2015).

Set within a mixed methods approach, the analytical framework contributes an original dimension to utilising case study analysis within the theoretical approach of evolutionary economic geography by comparing and contrasting the offshore wind and printable electronics industries within the same place and over an identical time period.

CHAPTER 4. PATH CREATION OF OFFSHORE WIND AND FLEXIBLE ELECTRONICS INDUSTRIES IN THE NORTH EAST

4.1.1 Introduction

Building on the conceptual advances and understanding of path creation by situating the notion within a more open and dynamic understanding of path dependency and local and regional industrial evolution, this chapter analyses the “path creation phase” of the flexible electronics and offshore wind industries in the North East of England (Martin 2010). Identifying the precise moment in time a given technology-based industrial pathway transitions from pre-formation to path creation phase remains a subjective interpretation. However, connecting to the methodological approach utilising mixed methods to unearth “who” and “what” is evolving in the local and regional economic landscape and “why”, quantitative and qualitative data pointed to two critical historical junctures in the path creation of the regional offshore wind and flexible electronics industries. The first was the discovery of a technology and process to manufacture organic polymer materials onto substrates by the Emeritus Professor of Chemistry at Durham University in 1978. The second was the formation of the Northumbrian Energy Workshop (NEW) workers cooperative in the same year. Accordingly, the lens in which the temporal period investigates began in 1978 and charts the transition to the path development phase beginning in 2000, illustrating the prolonged and complex nature of forming new developmental pathways (Simmie 2012).

The chapter commences in Chapter 4.1 by retracing the footsteps and setting the background context through which key multi-actors at multi-scalar levels initiated and entered a period of path creation in the regional offshore wind and flexible electronics pathways. Having provided a summary account of local and regional industrial early stage evolution in the offshore wind and flexible electronics industries, Chapter 4.2 addresses the processes of path creation by unpacking the candidate mechanisms and causal drivers that catalysed both pathways. Within the context of the role, types and influence of social and institutional agency involved in path creation, Chapter 4.3 explores the influence of national institutional actors, settings and factors in the stimulation and mediation of both pathways during the time period. Similarly, but reflecting multi-scalar institutional contexts, Chapter 4.4 addresses the role of local and regional institutions, including the state, knowledge-based organisations and

local and regional policy, in providing an enabling and constraining environment for the North East's offshore wind and flexible electronics pathways to emerge. To conclude, Chapter 4.5 draws the analysis of the temporal episode to a close by summarising the empirical evidence and placing the findings within the context of the three key research questions under investigation.

4.1.2 Creating New Growth Paths: The Emergence of the Offshore Wind Industry in the North East

The Northumbrian Energy Workshop (NEW) was established in Hexham, Northumberland as a private enterprise in 1978 drawing together a variety of engineers and scientists recruited mainly from Newcastle University, regional marine engineering companies and local business associates. Initially established as a "lifestyle" business, NEW invented, sold and distributed small-scale energy systems producing electricity from water, sunlight and wind, including ground source heat pumps and small-scale domestic housing wind turbines to North Africa (CEO Borderwind, Author's Interview 2011). NEW was "unquestionably the first renewable energy business of its kind" in the UK (Former Director NEW, Author's Interview 2011) to introduce novel, radically different innovations into the marketplace demonstrating the characteristic hallmarks of creative destruction (Schumpeter 1942). By the mid-1980s, NEW had accumulated significant knowledge and experience in managing wind turbine power system projects that the firm was contracted as technical and engineering consultants to British Petroleum (BP), Shell, Plessey and the United Nations Development Programme (UNDP) to support the installation of micro-wind turbine systems for remote telecommunication and power supplies in Wales, the Shetland Islands and Ronda on the South coast of Spain (Former Director NEW, Author's Interview 2011). Despite demonstrable business growth and increasing employee numbers to fifteen in order to service a pipeline of domestic and international projects, NEW ceased operations in 1989 due a weak domestic market dominated by state nationalised companies and large private firms that monopolised UK government contracts. Moreover, a lack of fiscal support mechanisms in the initial path creation phase highlighted the importance of market incentives and "national framework conditions" in stimulating new industrial growth paths (Martin & Sunley 2008; CEO Borderwind, Author's Interview 2011).

The closure of NEW led to the spin-out of two new enterprises: Econnect and Borderwind. Both firms were formed in 1989 by six ex-members of NEW and co-located company premises in Hexham, Northumberland. In that instance, Arthur's (1994) spin-off model which proposed that existing firms gave birth and transferred routines to new enterprises that locate in close geographical proximity to the (former) parent company in order to enhance innovation held credible theoretical weight. Whilst Econnect concentrated on electrical engineering services to the broader renewable energy sector, Borderwind was founded by the Chief Executive Officer (CEO) and three ex-employees to exploit the technical knowledge acquired and transferred from NEW, alongside contributions from the regional science base and private sector firms, to become project developers for wind energy projects in the UK (Patel & Pavitt 1997; CEO Borderwind, Author's Interview 2011). In the case of the CEO of Borderwind, the theoretical binary distinction between "innovator" (Schumpeter 1975) as an actor for the recombination of knowledge versus "entrepreneur" (Garud & Karnoe 2001) as a key change agent acting upon and commercialising knowledge is helpful but less unequivocal in empirical terms (Anderson 2011). Borderwind and Econnect also reiterated the importance of history and geography in the location decisions of entrepreneurs. Both firms and their founders were established in close proximity to their previous employers and demonstrated bounded rationality by utilising personal connections, situated in socially embedded local networks, to encourage and facilitate cooperative learning, knowledge exchange and technological development (Sorenson & Stuart 2001; Boschma & Frenken 2007; Toke 2011).

The decade between the early 1980s and early 1990s witnessed large-scale, multi-megawatt (MW) onshore wind turbines successfully deployed in Denmark, Sweden, Germany and Spain, stimulating indigenous industries in the latter three markets. Indeed, the dominance of Danish regions in the wind power sector was due to a cocktail of positive growth factors including strong state deployment incentives, carefully targeted industrial policies and local ownership of wind farms with support from communities of actors (Munksgaard & Morthorst 2008; Cooke 2010). Although operating an alternative state fiscal mechanism to Denmark and other competing European nations, to follow suit the UK Government introduced the Non-Fossil Fuel Obligation (NFFO) in 1990 in support of UK renewable energy projects. As one of the first successful applicants, Borderwind secured a power purchase contract from NFFO in round two of the open tender process and together with financial assistance from European structural funding became project developer of the Blyth Harbour Wind Farm in 1992 (CEO Borderwind, Author's Interview 2011; Dawley 2013) (see Figure 4.1). Featuring

nine 2.7 MW onshore wind turbines supplied by Belgian wind turbine manufacturer WindMaster, the Blyth Harbour project represented the UK's first semi-offshore wind farm demonstration project "placing the North East at the forefront of the emerging national wind energy industry" (Head of Energy and Environment ONE, Author's Interview 2011).

Figure 4.1 Blyth Harbour Wind Farm



Source: Heys 1995

Following the semi-offshore installation along the harbour pier at Blyth, and inspired by the development of the world's first offshore demonstration wind farm in Vindeby, Denmark where 11 Bonus 450 kilowatt (KW) offshore wind turbines were deployed between 1.5 and 3km off the North-West coast of Lolland, Borderwind began initial dialogue with the UK Crown Estates, the custodians of the UK seabed and foreshore, on the feasibility of deploying wind turbines offshore (see Table 4.1). Observing technological, industrial and political developments in Holland, Sweden and particularly Denmark, which included a second offshore demonstration site at Tuno Knob wind farm, the UK Government Department for Trade and Industry (DTI), UK Crown Estates and a handful of interested private sector firms, including Borderwind, rekindled their interest in offshore wind. As a consequence, led by the DTI, firm and non-firm actors began to investigate the practicability of deploying offshore wind turbines off the UK coastline, including undertaking a compatibility review of existing

national electricity grid networks, planning consent processes, state fiscal support mechanisms and identification of prospective institutional and corporate investors (CEO Borderwind, Author’s Interview 2011).

Table 4.1 Total Installed Global Offshore Wind Capacity 1991-2000

Location	Country	Online	MW	No	Rating	Distance to coast (km)	Water depth (m)
Vindeby	Denmark	1991	4.95	11	Bonus 450kW	2.5	3 – 5
Lely (Ijsselmeer)	Holland	1994	2.0	4	NedWind 500kW	0.75	5 – 10
Tunø Knob	Denmark	1995	5.0	10	Vestas 500kW	6	0.8 - 4
Dronten (Ijsselmeer)	Holland	1996	11.4	19	Nordtank 600kW		
Gotland (Bockstigen)	Sweden	1998	2.5	5	Wind World 500kW	3	6 - 8
Blyth Offshore Wind Farm	UK	2000	4	2	Vestas 2MW	0.8	6 - 11

Source: Renewables UK 2012

By the mid-1990s, the UK Crown Estates and DTI were considering two national offshore wind demonstration sites: Scroby Sands off the Norfolk coast and Blyth in Northumberland. Through extensive consultation with the UK Crown Estates and DTI, Borderwind had positioned themselves as principal developer for the Blyth Offshore Wind Farm in the North East by forming a consortia of project partners, including securing co-investment by Powergen Renewables, sub-sea engineering solutions provided by Shell Renewables and deployment, installation, O&M services supplied by NUON UK (CEO Borderwind, Author’s Interview 2011). To finance the project, Borderwind was again successful in securing power purchase contracts through round four of the NFFO scheme and secured the remaining project finance through a European Regional Development Funding (ERDF) grant. By 2000, Borderwind and its consortium of partners had commissioned and installed two Vestas 66m diameter machines 1km off the coast of Northumberland (CEO Borderwind, Author’s Interview 2011) (see Figure 4.2). Consequently, Blyth Offshore Wind Farm became the

North East and UK's first offshore wind demonstration project. Moreover, Blyth Offshore Wind Farm generated significant local, regional and national industrial interest in offshore wind stimulating macro-political support, via the UK Crown Estates and DTI, to initiate a formal process from the beginning of the century to allocate future offshore wind farm sites in UK waters in order to accelerate the UK's existing 1GWh of electricity generated by offshore wind (DECC 2011a; Musgrove 2011).

Figure 4.2 Blyth Offshore Wind Farm



Source: Black 2009, p.32

4.1.3 Creating New Growth Paths: The Breakthrough of the Flexible Electronics Industry in the North East

Amongst a number of pioneering academic, scientific and industrial discoveries in flexible electronics throughout the 20th Century, many of the fundamental theoretical and practical principles of the technology can be credited to the Emeritus Professor of Chemistry at Durham University (Emeritus Professor of Chemistry Durham University, Author's Interview 2013). In collaboration with Professor's Richard Friend, Donald Bradley and Dr. Jeremy Burroughes from the Cavendish Laboratory, Cambridge University, the Emeritus Professor of Chemistry invented the first polymer light emitting diode (PLED) in 1978 restating the notion that "inventors" rather than "entrepreneurs" are often pioneers of new technologies and

industrial pathways (Simmie 2012). Previous to that, the Emeritus Professor of Chemistry had worked at Durham University since 1965 initially accepting an organic chemistry lecturing position in the Chemistry department (Emeritus Professor of Chemistry Durham University, Author's Interview 2013). Termed the "Durham Precursor Route", the Emeritus Professor of Chemistry and colleagues discovered a process of manufacturing polyacetylene, an organic polymer capable of exhibiting high degrees of electrical connectivity (Grubbs *et al* 2005; Emeritus Professor of Chemistry Durham University, Author's Interview 2013). The discovery led to a granted patent, a published paper in the 4* star journal Nature, which has remained the most cited paper in the field of organic semiconductors, a series of guest lectureship opportunities throughout the globe, particularly at the Max Planck Institute for Polymer Research in Mainz, Germany which, at the time, was the world's leading research organisation in basic polymer micro-electronics, and amplified interest from the global electronics community in the potential to produce organic electroluminescence from polymers (PELG 2012; Emeritus Professor of Chemistry Durham University, Author's Interview 2013). The invention of PLED technology possessed potentially radical innovation qualities reflecting a symbolic "gale of creative destruction" (Schumpeter 1932) by which established silicon-based, semiconductor path dependencies could be potentially terminated, or at least severely weakened, and new products and processes set in motion to generate "paradigmatic change" (Dosi 1982; 1988; Cooke 2012).

Despite the "path discovery" at Durham University, the financial cost of producing polymer substrates capable of harnessing an electrical current remained prohibitively high for industry during the 1980s and 1990s. Basic fundamental science in electrical polymers continued at Durham University by the Emeritus Professor of Chemistry and internal colleagues until the Professor of Physics joined Durham University in 1987. In 1988, the Professor of Physics brought together the University research base from the institution's chemistry, physics and electrical engineering departments to establish the Photonics Materials Institute (PMI). Within the PMI, the OEM research group was established under the strategic and operational direction of the Professor of Physics and quickly gained international recognition for expertise in understanding the spectroscopy or measuring the optical properties of conductive and luminescent polymer devices (PHS Consulting 2008; Professor of Physics Durham University, Author's Interview 2011). As a result, the OEM research group began to work with a number of multinational corporation(s) (MNC) original equipment manufacturing (OEM) partners including Philips, Covion and Sony Europe, which had begun to initiate

small-scale global R&D programmes to develop lighting technology (PHS Consulting 2008; Professor of Physics Durham University, Author's Interview 2011). The accounts from the Emeritus Professor of Chemistry and Professor of Physics at Durham University demonstrated the varied forms of strategic agency that instigated new pathways outside of the micro-level dynamics of the entrepreneur and firm (Simmie 2012). Indeed, the scientific discovery and invention of polymer electronics at Durham University also demonstrated the importance of recombining knowledge from related scientific disciplines, insights and past experiences. In other words, polymer electronics was a direct product of the “adjacent possible”, which referred to new science and innovation topics that became directly achievable from previous and existing sets of knowledge and skill sets (Kauffman 1995).

Despite the scientific promise of flexible electronics, the regional technology and industrial pathway failed to “take-off”. The principal reason remained the inability to dislodge the established, incumbent dynamic random-access memory (DRAM) silicon-based semiconductor technology (Dawley 2007). Moreover, polymer electronic technology also required high composite material costs and offered poor absorptive capacity amongst local and regional industry that continued to display an incomplete understanding of the technical processes required for scale-up to mass production (Cohen & Levinthal 1990) Through a combination of continual technological change, globalised production practices and market demand producing year-on-year double digit growth (Morgan & Sayer 1988; Dicken 1998):

“the global semiconductor industry had been the dominant technology of the last three decades, extending its transformative influence into all branches of the economy”
(Dicken 2003, p.353)

Further technological development and continuing “on-path” (Martin & Sunley 2006) adaptation followed into the mid- to-late 1990s as the semi-conductor and conventional electronics industry entered the fifth cyclical upturn in the modern integrated circuit industry driven forward by demand for new personal computers (PCs) (Dawley 2007).

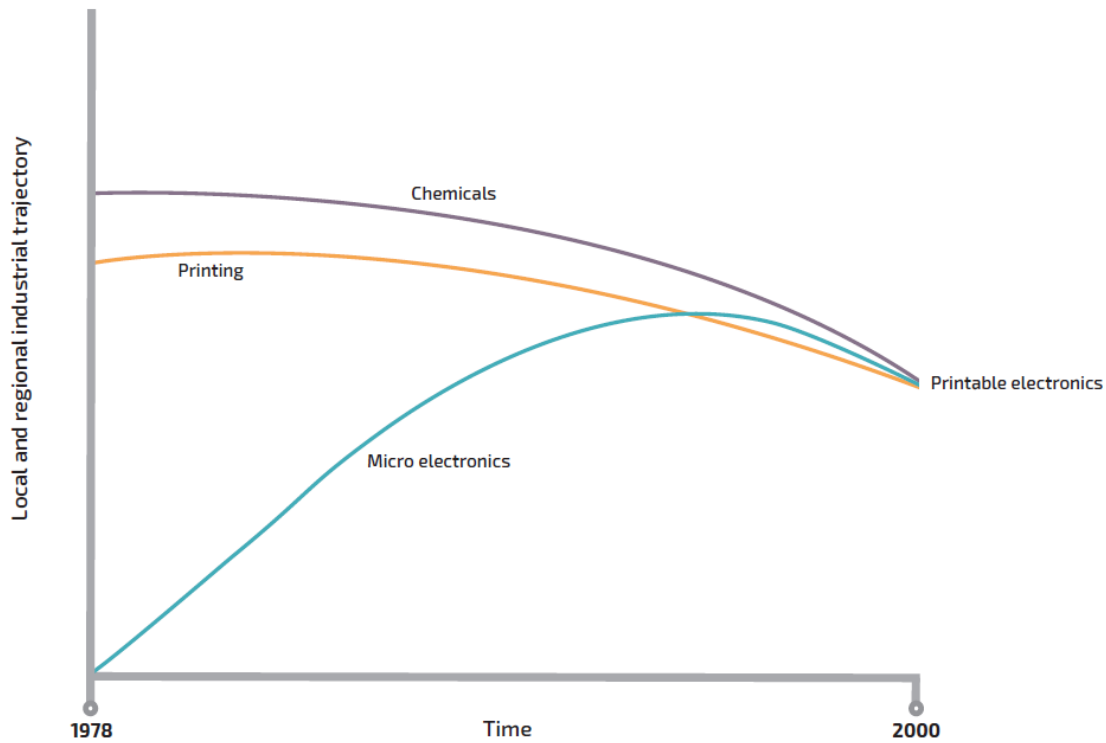
Whilst the North East's flirtation with the semiconductor industry led to fluctuations in the entry and exit of micro-electronics firms primarily through exogenous transplantation (see Chapter 4.2), the requirement to converge, multiple co-existing techno-industries from the North East's electronics, chemical and printing industries to create new and/or reconfigure

existing flexible electronics products failed to occur (Research Team Lead Thorn Lighting, Author's Interview 2012). In the process industries, the strategic decision by Imperial Chemicals Industries (ICI) to divest from Billingham and Wilton, Teesside in the mid-1990s led to the firm selling off its assets to MNCs including AstraZeneca, AkzoNobel, Huntsmann and DuPont. Only the management buy-out (MBO) of ICI's advanced materials division by Epigem in 1995 and acquisition by DuPont in 1998 retained polymer electronics in Teesside but both would prove important interventions in the future trajectory of the pathway (Chief Scientific Officer DuPont Teijin Films, Author's Interview 2011; Epigem 2012). However, the divestment of ICI's base, fine and speciality chemicals divisions in Teesside led to a gradual decline in production output, a loss of technical R&D functions and an increase in unemployment within the regional chemical sector (ADL 2002). Similarly, following national trends which had witnessed the relocation of printing firms to low-cost overseas locations and changing consumer patterns following the rise of the internet and virtual media, the North East's printing industry experienced a steady rate of decline with 478 printing companies located in the region in 1981 reduced to 336 by 2000 (BPIF 2012; Regional Director British Printing Industries Federation, Author's Interview 2012). In other words:

“most regions are not technologically homogenous, but contain bundles of overlapping technological and industrial trajectories. The interplay of these bundled technological trajectories unfolds into a regional development path. A crisis or rupture within one technological trajectory may or may not cause a major sectoral crisis in a given region, depending on the importance of that technological trajectory to the given region” (Bathelt & Boggs 2003, p. 278).

Therefore, rather than convergence and “re-bundling” (Bathelt *et al* 2011) of existing assets and resources to the novel flexible electronics industrial pathway in the North East, the region's electronics, printing and chemicals industries followed independent “sub-optimal path dependent trajectories” (Vergne & Durand 2010) through the remaining period of the 20th Century conditioned by extra-regional market dynamics and constrained by limited indigenous adaptive capacity (Martin 2010) (see Figure 4.3).

Figure 4.3 Divergent Techno-Industrial Trajectories in the North East Flexible Electronics Pathway



Source: Author 2014

Since the initial discovery of conductive polymers at Durham University and the fluctuation in the regional industrial trajectories of the printing, electronics and chemicals sectors in the two decades that followed, the flexible electronics pathway in the North East remained in a latent period of stasis within existing path dependencies until its reconstitution in 2000 (Martin & Sunley 2006). Pivotal to the (re)formation of the path was the Professor of Physics at Durham University and the OEM research group which, by 2000, had executed a portfolio of global lighting projects with MNCs including Philips, Osram and Novaled. Indeed, several of Durham University's MNC clients connected the OEM research group to Cambridge Display Technology (CDT) and Plastic Logic, two leading flexible electronics firms that had spun-out from Cambridge University (Professor of Physics Durham University, Authors Interview 2011). Importantly, the flurry of spin-out activity in Cambridgeshire and increasing interest amongst leading global firms led the Professor of Physics at Durham University to devise the notion and opportunity to create a flexible electronics industry in the North East based on the expertise at Durham University, existing micro-electronics research activity at Newcastle University's School of Electrical, Electronic and Computer Engineering, and a handful of private sector actors, particularly in the process industries sector, which at that

time were exploring new market opportunities in order to obtain first mover advantage in novel chemical materials and remain globally competitive (Professor of Physics Durham University, Author's Interview 2011; Director of Technology & R&D NaREC, Author's Interview 2011).

To kick-start the pathway, the Professor of Physics at Durham University utilised professional intra-regional networks to broker a meeting between the Chief Scientific Officer at DuPont Teijin Films, the Finance Director at U.S semiconductor firm Atmel Corporation and the Head of Innovation, Industry and Science at ONE, on the proposal to establish a new technology-based pathway in the North East (Finance Director Atmel Corporation, Author's Interview 2012). In that instance, the "triple helix" of regional industry, academia and policy actors was demonstrable in recombining knowledge, stimulating interactive learning, supporting innovation and networks to begin mobilising resources and agents towards collective action (Etkowitz 1993; Bathelt & Boggs 2003; Boschma & Ter Wal 2007). For the variety of firm and non-firm actors, the rationale was simple:

"we intended to leverage the academic expertise at Durham University and, to a certain extent, Newcastle University in service deposition technology, to create spin-out enterprises similar to Cambridge University's technology transfer and local economic development model...with related industries in the North East, the idea germinated that you could recycle skills in old industrial sectors where the competencies were appropriate for a new industry" (Professor of Physics Durham University, Author's Interview 2011).

As a result of pockets of academic excellence, industrial interest and lobbying by prominent local and regional business leaders, flexible electronics was recognised as an emerging regional economic opportunity by ONE, with the RDA committing to investigate future niche market opportunities and possible regional policy interventions to support the nascent pathway (Head of Innovation, Industry and Science ONE, Author's Interview 2011).

4.1.4 Summary: Divergent Origins of Path Creation

The path creation of the flexible electronics and offshore wind industries in the North East followed contrasting industrial trajectories. In rejection of the linear model of path

dependency, the discovery by the Emeritus Professor of Chemistry at Durham University and “star scientists” at Cambridge University in 1978 failed to lead to the take-off of the regional flexible electronics pathway (Zucker 2006). On the contrary, the flexible electronics industry exhibited characteristics of an “intermittent pathway” in which the initial revolutionary discovery of PLED at Durham University was followed by a dormant period in the industrial pathway re-enforced by multiple divergent pathways all exhibiting lock-in to path and place dependent trajectories (Grabher 1993). Reflecting theories associated with the canonical model of path dependency and the generation of new pathways, an external shock to the dominant semiconductor-based microelectronics system occurred through overcapacity in the global supply of DRAM electronic chips resulting in the shake-out of uncompetitive firms (David 1988). However, the external shock failed to dislodge the dominant industrial pathway. Through the work of the OEM research group at Durham University and purposive intervention by several regional firm and non-firm actors intent on seeking to create and establish new industrial growth trajectories within the North East, the regional flexible electronics pathway remained latent within existing path and place dependencies until its reconstitution in 2000 based on a combination of existing regional firm and industrial capabilities, academic credentials and technological diversification into new topics related to existing scientific disciplines (Heimeriks & Boschma 2012).

In contrast to the formation of the flexible electronics pathway which was originally predicated on academic discovery and exhibited characteristics of “railroadization” or the opening up of a new developmental pathway, the birth and evolutionary trajectory of the regional offshore wind industry was based on the entrepreneurial activities of NEW and the parallel undermining of existing industrial trajectories (Cooke 2010). Through incremental innovations, NEW went on to design, prototype and deploy an array of micro-wind turbine systems. As the “common ancestor” (Lieberman & Montgomery 1988) of the regional offshore wind pathway, through the early experiences of NEW and reflecting the localised and cumulative nature of innovation and technological change, Borderwind was established in a period when the global wind industry had begun to show signs of growth, partly as a consequence of external shocks to the dominant carbon-based energy system in the form of oil and gas price hikes and increasing lobbying by environmental campaigners on climate change and global energy usage (Freeman 1995). Nevertheless, the UK offshore wind industry remained on a “slow burn” throughout the 1990s despite the introduction of state policy support through the NFFO fiscal mechanism. As one of a handful of companies to

secure initial NFFO funding, Borderwind explored the practicability of deploying large-scale onshore wind turbines with the UK's first onshore wind farm demonstration site at Blyth Harbour in 1992. Utilising the knowledge and skills gained from Blyth Harbour Wind Farm, existing physical infrastructure at Blyth Harbour and leveraging state political actors to secure further NFFO funding, Borderwind installed the UK's first offshore wind farm at Blyth Harbour in 2000 placing the North East at the forefront of a new regional and national offshore wind pathway.

4.2. MECHANISMS OF PATH CREATION

4.2.1 Introduction

The emergent flexible electronics and offshore wind pathways in the North East had predominantly been influenced, stimulated and shaped by local and regional actors as opposed to extra-regional political, economic and socio-institutional factors, actors and conditions. As a consequence of the primarily endogenous path creation processes, the offshore wind pathway had initially been stimulated by the indigenous firm activities of NEW and the flexible electronics pathway by pioneering academics at Durham University. Within the context of the North East providing an enabling institutional environment for the germination of both pathways, the following section unpacks and analyses the causal processes in the path creation phase of the offshore wind and flexible electronics pathways in the North East by providing an additional granular level understanding of the characteristics, operation and interrelations of the preliminary candidate mechanisms (Martin & Sunley 2006).

4.2.2 Indigenous Creation

As illustrated in Chapter 4.1, the origins of the offshore wind pathway were credited to indigenous firm dynamics and the pioneering entrepreneurial activities of the founder and CEO of Borderwind, and former NEW worker. The CEO of Borderwind himself pointed to the influence of Professor's Alan Jack and Bill Hills at Newcastle University in the 1980s that were amongst a number of UK-based scholars that identified the potential contribution offshore wind could make to the UK energy mix (CEO Borderwind, Author's Interview 2011). However, it was the CEO of Borderwind, who was neither an engineer nor scientist

but “entrepreneur and amateur renewables enthusiast” (CEO Borderwind, Author’s Interview 2011) who mobilised time, internal technical expertise of fellow NEW members in mechanical and electrical engineering, and projected the future growth potential of the wind energy market to innovate, prototype and eventually deploy small-scale wind systems on a global scale (Dawley 2013). Therefore, the role of experienced entrepreneurs in processes of path creation became clear as they draw upon and mobilise existing knowledge, experience, networks and resources to transition between old and the development of new local and regional pathways (Martin & Sunley 2006).

The market potential of wind energy coupled with a “personal belief in the region” (CEO Borderwind, Author’s Interview 2011) led to the formation of Borderwind, incorporating established firm routines, behaviour and competencies taken from NEW through the transfer of existing human resources, skills, technology and different types of knowledge e.g. know-how, know-what etc. (Nelson & Winter 1982; Lundvall & Johnson 1994; Martin & Sunley 2008). In this regard, the founder and CEO of Borderwind was an example of an entrepreneur and key agent of path creation who, through ongoing layering (Martin 2010), reused knowledge, competence and skills gained from practice to exploit new opportunities (Karlsen 2011). As highlighted previously, Borderwind was established in Hexham to remain in close geographical proximity to previous and current local and regional actors highlighting the localised dynamics of entrepreneurs in sharing resources, building up respect, mutual trust relations and tacit knowledge sharing to support processes of innovation and learning (Morgan 1997; CEO Borderwind, Author’s Interview 2011). The pattern of localised, indigenous firm dynamics was also evident in the example of Newcastle-based Northern Engineering Industries Plc who entered into a joint venture (JV) agreement with Sir Robert McAlpine & Sons Ltd to create start-up company Vertical Axis Wind Turbines (VAWT) Ltd. VAWT utilised past organisational routines and experience inherent with evolutionary notions of reproduction and inheritance, combined with collaborative R&D activity with Borderwind, to go onto manufacture and deploy a series of onshore wind turbines in the UK (Klepper 2001; Musgrove 2011; CEO Borderwind, Author’s Interview 2011).

In the absence of sustained market demand amidst the continuing monopoly of existing fossil fuel-based industries in energy markets, the purposive actions of Borderwind to construct and operate Blyth Harbour Wind Farm and Blyth Offshore Wind Farm demonstrated “a willingness to take risks and show tenacity in creating a new industry” within the confines of

existing dominant path dependent techno-industrial trajectories (CEO Borderwind, Author's Interview 2011). The entrepreneurial endeavour displayed by Borderwind and nascent commercial opportunities within the UK offshore wind industry directly led to the start-up of North Sea Logistics in 2000 which was established primarily to provide O&M services to Blyth Offshore Wind Farm (North Sea Logistics 2000). In sum, the account of Borderwind and the Blyth Offshore Wind Farm demonstrated the key role entrepreneurial actors played in recombining knowledge, capabilities and networks in fostering strategic niche opportunities in the path creation of the offshore wind sector in the North East (Garud *et al* 2010; Dawley 2013).

In the embryonic flexible electronics industry in the North East, the discovery of polymer organic electroluminescence by the Emeritus Professor of Chemistry at Durham University and colleagues in Cambridge was pioneering in the creation of the pathway. Indeed, the breakthrough reflected the notion that science represents an adaptive and co-evolving process that comprises of a collection of individuals and institutions collaborating and contributing to a common body of knowledge (Wagner 2008; Heimeriks & Boschma 2012). Moreover, the discovery of the Durham Precursor Route was considered critical for paving the way for future applications in visual displays, new forms of lighting through light emitting polymers, intelligent labels and tags, and for solar and fuel cell technology (Director of PETEC, Author's Interview 2011; Research Team Lead Thorn Lighting, Author's Interview 2011). Nevertheless, the generation of novelty alone by strategic agency did not lead to a new local and regional industrial pathway as presented by some advocates of path creation theory (Garud & Karnoe 2001). Rather, it required further intervention by the Professor of Physics at Durham University, along with technological innovation within both academia and within the firm level brought about by changing market, social and institutional dynamics over several decades, to reform the pathway. In short, both academics were vital in the creation of the regional flexible electronics industry as without the "technological discovery" by one (Emeritus Professor of Chemistry) and the "entrepreneurial tendencies" of the other (Professor of Physics), the path which (re)assembled in 2002 may have either remained latent in existing path dependencies or otherwise perished (Professor of Physics Durham University, Author's Interview 2011).

4.2.3 Variety and Related Variety

Empirical evidence pointed to the origins of the offshore wind pathway in the North East to be primarily driven by entrepreneurial indigenous activities but later tentatively supported by the candidate mechanisms of related variety (Boschma & Frenken 2007). The initial path creation activities of Borderwind and their associated local and global supply chain of firms used to construct, deploy and operate Blyth's onshore and offshore wind farm's highlighted the commercial opportunities available to North East and UK firms seeking to diversify into new market opportunities (CEO Borderwind, Author's Interview 2011). As a demonstration project, Blyth Offshore Wind Farm acted as a catalyst for a number of local and regional companies with related technology, skills and experience from existing industries to explore diversification opportunities into the embryonic offshore wind pathway (Boschma & Frenken 2011). For instance, following two decades as a subsea engineering and equipment supply manufacturer to the oil and gas industry, Soil Machine Dynamics Hydrovision (SMD) branched into the offshore wind industry in the late 1990s through the modification of the firm's remote operated vehicles (ROV), deep sea trenching and cable installation capabilities (CEO SMD Hydrovision, Author's Interview 2012). Similarly, the pattern of related diversification was reflected in established engineering, fabrication and subsea engineering firms, including McNulty Offshore, JDR Cables, HTB Electrical, MPI Offshore, Jordan Engineering and The Engineering Business, beginning to supply products and services to the emerging industry by leveraging existing resources and infrastructure from previous temporal industrial episodes to enter into the sector (NESTA 2008). In the context of branching, the firms displayed a high-degree of cognitive proximity in order for companies with related variety to understand and implement external stimuli similar to their own knowledge base (Noteboom 2000). As a result, the formation of the regional offshore wind pathway identified the importance of place-based contexts and connections between the dynamics of technological relatedness and the focus on entrepreneurs as key agents in the deliberate pursuit of new paths (Garud & Karnoe 2001; 2010).

In the flexible electronics industry, the opportunity for local and regional firms to diversify and branch into the regional pathway remained limited. Reflective of the overall global technological and industrial trajectory which remained rooted within academia, only ICI's Conductive Components Division could call upon over 50 years' experience in materials science, polymer R&D and significant corporate resources to begin exploring R&D and

commercial opportunities to enter into the emerging industry trajectory (Chief Scientific Officer DuPont Teijin Films, Author's Interview 2011). Indeed, the consolidation of ICI's entire plastics division from Welwyn Garden City, Hertfordshire to Wilton, Teesside in 1983 resulted in over a decade of industrial R&D programmes into polymer applications (Chief Scientific Officer DuPont Teijin Films, Author's Interview 2011). For the printing industry, the integration of new electro-conductive materials and new process development into existing capital equipment, standardised fabrication techniques and rigid substrates meant North East-based printed circuit board (PCB) firms, including Faraday Printed Circuits, Northumbria Circuits, ISN and Welling, were incapable of innovating and lacking the absorptive capacity, financial capital and risk appetite to diversify into the pathway (Sales Director Faraday Printed Circuits, Author's Interview 2011). As a consequence, the majority of North East-based firms that supplied semi-conductor materials, electronic components and PCB's remained embedded in global micro-electronic supply chains and despite the global silicon chip crash of 1998 remained technologically locked-in to existing path dependencies that remained manipulated by external market environments (Hassink 1999; CEO Merlin Flex-Ability, Author's Interview 2011).

4.2.4 Transplantation

The rapid growth of the global silicon-based semiconductor industry led peripheral regions, including the North East, to concentrate regional policy and interventions on attracting and embedding new rounds of semiconductor and downstream microelectronics investment within host economies (Amin *et al* 1994; McClean *et al* 1998; Mackinnon & Phelps 2001). Post-1985, 23% of new jobs created in the region were in electrical and electronic manufacturing receiving investment from Far Eastern companies including Sanyo and Samsung (Hudson 1997). Indeed, between 1993 and 1998 the North East attracted twenty-one semiconductor inward investments including a number of flagship "performance plants", such as the £1.13bn Siemens Microelectronics plant in North Tyneside, Tyne & Wear and the Fujitsu microchip plant in Newton Aycliffe, County Durham (Pike *et al* 2006; Dawley 2007; ONE 2011a). The notable exception was the acquisition of ICI's polymer business by DuPont in a \$3bn deal in 1997 creating one of the world's leading plastic substrate manufacturers of flexible electronics products, and which would go onto play an important role in the future developmental trajectory of the industrial pathway (Chief Scientific Officer DuPont Teijin Films, Author's Interview 2011). However, the example of DuPont signified an anomaly in

the pattern of exogenous transplantation into the North East flexible electronics pathway with the dominant global semiconductor industry occupying the focus of multi-scalar state actors and direct local and regional FDI policy interventions to attract firms from the global microelectronics industry (Pike *et al* 2006).

Despite the positive net effect of Blyth's onshore and offshore wind demonstration sites, and associated stimulus from national institutional actors and emerging policy in support of the offshore wind pathway (see Chapter 4.3), the embryonic episode in the global offshore wind industry offered limited inward investment potential for the North East (CEO Borderwind, Author's Interview 2011). In the absence of a critical mass of offshore wind turbine OEMs, and those that were in existence including Vestas, Micon, Windpower Flowind and Gamesa remaining rooted in their domestic markets and preferring to export wind turbines rather than invest in manufacturing sites in overseas territories, the North East continued to secure exogenous investment from the wider carbon-based engineering, machinery and fabrication supply chain base predominantly as a result of the discovery of a number of oil and gas fields in the North Sea e.g. Oseberg oil and Troll gas field (1979), Miller oilfield (1983), Alba field (1984), Smorbukk field (1984) and Heidrun oilfield (1985). Through commercial licensing opportunities connected to oil and gas discoveries in the North Sea and a recovering global oil and gas market (Price 2006), the North East attracted branch plant investments from heavy engineering and fabrication firms, including European Marine Contractors, Deutsche Babcock and Dunlop Coflexip, that would prove to be important branching targets for later developmental phases of the offshore wind pathway (Phelps 1993; ONE 2011a). For the regional offshore wind pathway, the inability to transplant new technologies and firms into the nascent trajectory was inherently tied to broader extra-regional market dynamics, an absent commercial market and the relative success of regional institutional actors in securing and embedding upstream oil and gas supply chain inward investment projects from an increasingly burgeoning global oil and gas market.

4.2.5 Summary: Indigenous Creation, Variety and Path Creation

Adopting and applying Martin & Sunley's (2006) candidate mechanisms of path creation as part of a deeper conceptual interpretation of local and regional industrial evolution, the purpose of the chapter was to analyse the causal candidate mechanisms which stimulated and shaped the offshore wind and flexible electronics trajectories in the North East between 1978

and 2000. In offshore wind, the interconnected indigenous activities of NEW and Borderwind via the transition of firm-specific routines, inter-firm labour mobility and the continuation of multi-scalar socio-institutional networks was pivotal in the formation of the pathway (Kogut & Zander 1993; Almeida & Kogut 1999; Ter Wal 2009; Boschma & Frenken 2009). At the heart of indigenous firm endeavour was the entrepreneurialism displayed by the CEO of Borderwind who mobilised ideas, people and resources to mindfully deviate from existing path dependent trajectories in pursuit of a new economic pathway (Schumpeter 1934; Garud & Karnoe 2001). In the context of history and the spatial dynamics of entrepreneurship, the “locational inertia and past experience” of entrepreneurs to deliberately create and exploit novelty was critical in the early developmental stage of the pathway (Klepper 2007; Boschma & Wenting 2008). As a consequence of Borderwind’s role and impact upon the origins of the regional offshore wind pathway, the North East’s offshore wind growth path exhibited geographically concentrated spillover effects with local and regional businesses from technologically related industries beginning to explore diversification and branching opportunities as a net result of Borderwind’s initial foray into the offshore wind market (CEO Borderwind, Author’s Interview 2011).

Unlike the creation of the offshore wind industry which was largely attributed to indigenous firm activities and the exploits of one key entrepreneur, the candidate mechanisms that created and established the regional flexible electronics pathway followed a different trajectory. As such, a new technological pathway was discovered by the Emeritus Professor of Chemistry in 1978 based on Durham University’s inherent “analytical knowledge base” and the capability to recombine past and present related scientific topics into a novel technological path (Heimeriks & Boschma 2012). However, a combination of technological lock-in and established market dynamics based on the incumbent semiconductor industry led the technological discovery to become a latent path buried within a dominant path dependent trajectory (Sydow *et al* 2009). Connected but independent to the adjacent possible, processes of firm branching and transplantation transpired *ex-post* of the paths origins with only ICI, and later DuPont Teijin Films, diversifying into the regional flexible electronics pathway during the temporal episode (Boschma & Frenken 2009; Research Team Lead Thorn Lighting, Author’s Interview 2011).

4.3. NATIONAL INSTITUTIONAL ACTORS, CONDITIONS AND FACTORS IN PATH CREATION

4.3.1 Introduction

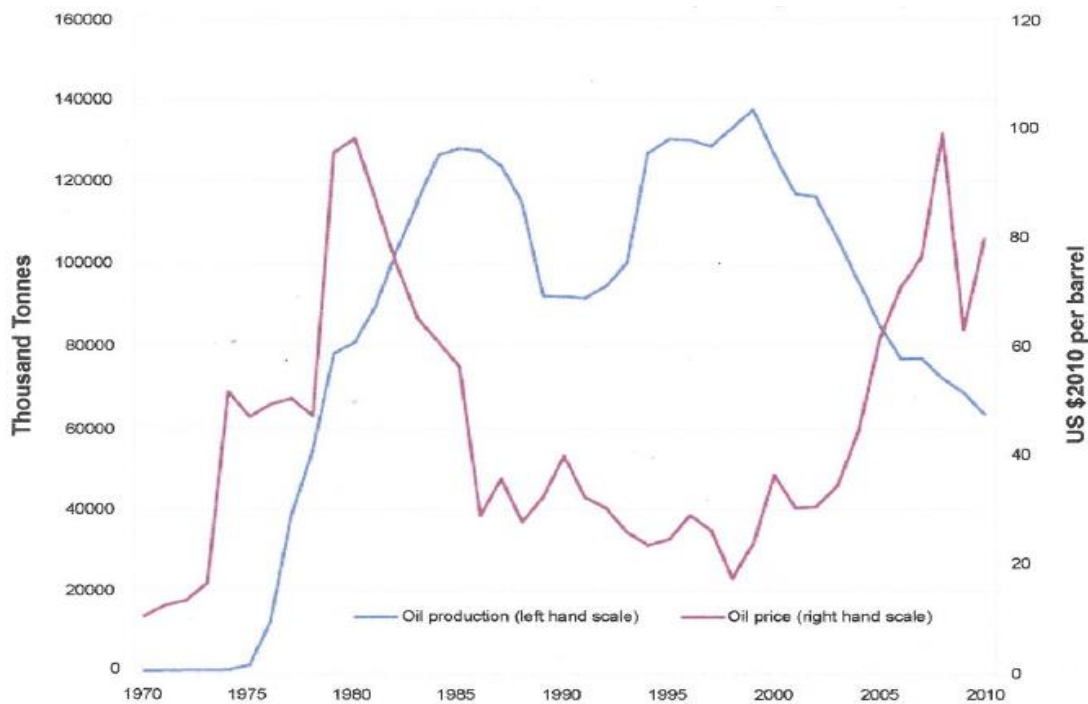
As illustrated in Chapters 4.1 and 4.2, the nascent offshore wind and flexible electronics pathways in the North East had formed as a consequence of the actions of local and regional firm and non-firm strategic agents mobilising history and place-based assets to create a new regional pathway whilst subsequently de-locking from existing path dependencies (Martin 2010). However, restating the role, type and influence of multi-scalar social and institutional agents in mediating the unfolding of new developmental pathways, the mechanisms of path creation were correspondingly shaped by extra-regional actors, factors and contexts. In particular, the offshore wind pathway in the North East entered, and was supported by, sporadic periods of national state-led “strategic niche management” (Schot 2008; Cooke 2012). On the basis that the mechanisms of path creation are subject and conditioned by wider national socio-institutional, economic and political relations, the following section unpacks the role, function and influence of national institutional actors, and particularly the national political economy, on mediating the creation and unfolding of the offshore wind and flexible electronics pathways in the North East.

4.3.2 National State Policy and Regulation of the UK Offshore Wind Industry

The international oil shocks of 1973 and 1979 following the geopolitical crisis in the Middle-East temporally destabilised the existing dominant global nuclear and fossil fuel-based pathways bringing alternative forms of energy to the forefront of international political debate (Jamison & Laessoe 1990) (see Figure 4.4). As postulated in original path dependency theory, external crises disrupt existing transactional networks releasing resources to create new opportunities for growth and break deep-rooted path dependencies (Bassanini & Dosi 2001; Bathelt & Boggs 2003; Jovanovic 2009). To counter the overreliance on coal, oil and gas, the latter two energy sources linked to the perceived depletion of fossil-fuel reserves in the North Sea, the UK Government established the Department of Energy (DoE) in 1974 with an explicit mandate to explore alternative forms of energy, including wind power. Beginning in earnest in 1979, UK state industrial and R&D programmes initially concentrated on “determining the technical and economic feasibility of wind power technology” (Bullen *et al*

1987, p. 216). Convinced of the UK’s offshore wind resource following initial technical evaluation studies, the UK Government syphoned off income from North Sea oil revenues towards initiation of a two-phased wind technology development and demonstration programme, beginning with the design, build and testing of a 60m diameter LS-1 3MW onshore demonstration wind turbine in Orkney, Scotland (Price 2006). The second strand of the DoE’s wind energy programme was to assess the engineering aspects of siting and installing large numbers of offshore wind turbines. However, despite favourable offshore wind farm estimates, including the proposal to establish an offshore wind demonstration farm in the coastal zone around the Port of Tees in Teesside, the incumbent Conservative Government instead embarked upon national state energy and industrial policy committed to increasing competition of nationalised industries, increasing domestic nuclear power capacity to 15,000MW and initiating a sustained investment in the coal industry (Price 2006; Pearson & Watson 2010; Professor of Energy Newcastle University, Author’s Interview 2011).

Figure 4.4 UK Crude Oil Production and Oil Prices, 1970-2010

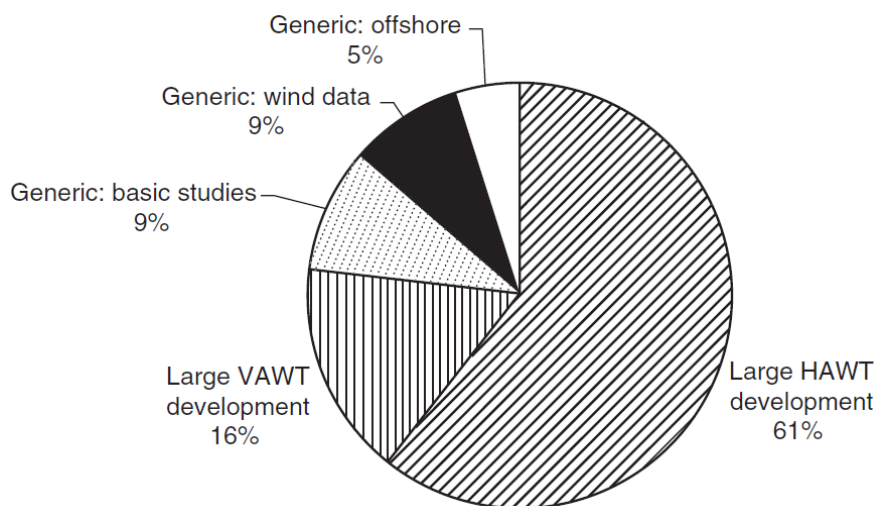


Source: Pearson & Watson 2011, p.4.

Despite prolonged but limited state expenditure of approximately £17m by the DoE in the UK’s wind energy programmes of the 1980s, wind energy failed to escalate with offshore wind classified as a “long-shot technology” (Musgrove 2010, p.155) (see Figure 4.5).

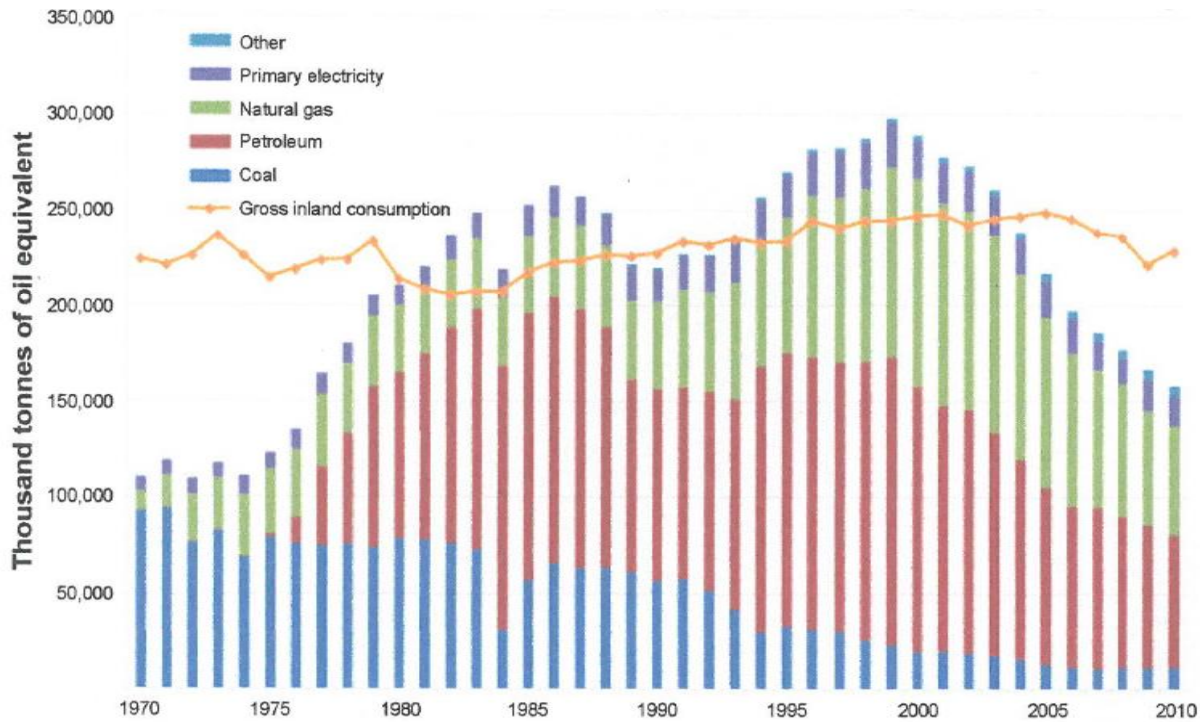
External to the North East, global oil prices had stabilised to pre-1973 levels and continued to be supported by path dependant lock-in of substantial historical subsidies to the incumbent fossil fuel-based energy system (Fuchs & Arentsen 2002; Doornsbosch & Knight 2008) (see Figure 4.6). In retrospect, the temporal episode reflected a period of “path renewal” in the oil and gas industry (Steen & Karlsen 2014). Moreover, individual producers of electricity utilising wind turbines connected to the national electricity grid were discouraged because of high and varied property taxes with only electricity utilities allowed to own and operate wind turbines (Musgrove 2010). The threat posed by global warming and climate change had also still not been widely recognised (Musgrove 2010). By the mid-1980s, an increasingly neo-liberalist Conservative Government under the ascendance of Thatcherism began to roll back the state as part of a “two nations” political strategy in response to the accelerating decline of the UK economy in an emerging era of globalisation (Hudson & Williams 1995; Hudson 1997). As a consequence, the national coal, oil and gas industries were rationalised, and eventually privatised, with the electricity industry prepared for privatisation by the end of the 1980’s (Pearson & Watson 2011).

Figure 4.5 UK Department of Energy Total Expenditure on Wind Energy R&D, 1979-1986



Source: Price 2006, p.231.

Figure 4.6 UK Production and Consumption of Primary Fuels and Equivalents, 1970-2010



Source: Pearson & Watson 2011, p.19.

Entering into the 1990s, the continued decline of domestic coal production and the liberalisation and extension of competition in the electricity sector, oil industry and the “dash for gas” as part of a fundamental shift from national vertical industrial policies (*inter alia* sector-based, industry supply chains etc.) and discredited efforts to “pick winners” (Mandleson 2008, p.1) in the 1960s and 1970s towards broad horizontal policies (*inter alia* markets, infrastructure, R&D etc.) (Chang *et al* 2013) opened up a market opportunity for firms and consumers in the North East to begin exploring alternative forms of energy generation and supply (Sadler 2001; Pearson & Watson 2011; CEO Borderwind, Author’s Interview 2011). For instance, the creation of national state-led market niches, exemplified by the authorisation of the UK Government’s Central Electricity Governing Board (CEGB) to allow citizens as well as industry to generate electricity from wind energy sources had opened up opportunities for the emergence of new local and regional renewable energy pathways (Simmie 2012). Having cast a watchful eye over the emergence of domestic wind industries in Denmark and Germany, which had been politically stimulated through a variety of state supply-side fiscal mechanisms e.g. Erneuerbare-Energien-Gesetz feed-in-tariff in Germany, the Conservative Government resurrected its interest in wind energy in the early 1990s (see

Figure 4.7). To seed and stimulate the market, the NFFO scheme was introduced which utilised a levy on the premium price output from nuclear power stations to finance a range of renewable energy initiatives, including nine onshore wind projects between 1990 and 1998 (Mitchell & Connor 2004).

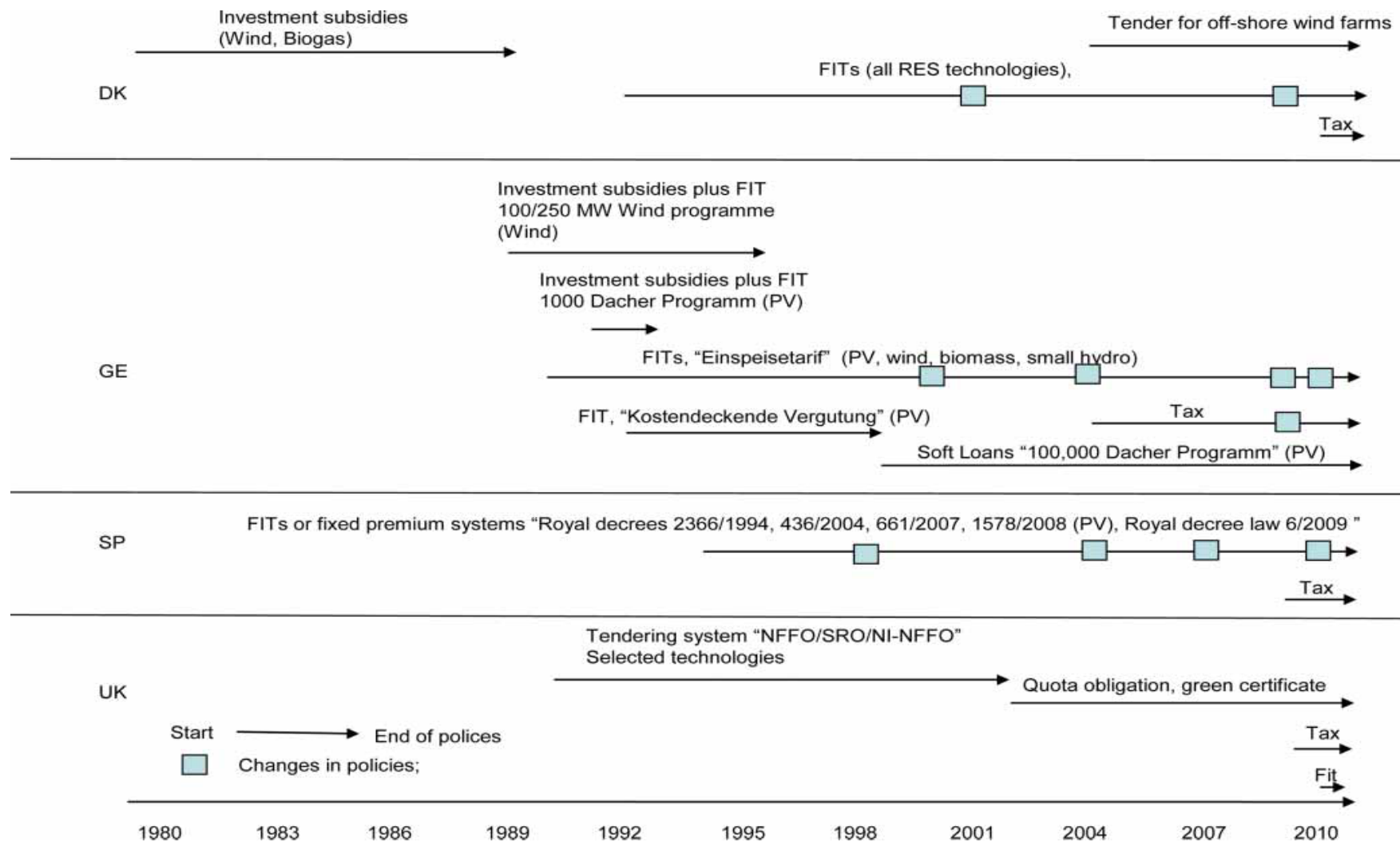
Despite the NFFO scheme attracting heavy criticism for being too bureaucratic, lacking in transparency (Gipe 1995) and unable to financially sustain small project developers (Stenzel & Frenzel 2008), the creation of national state-led strategic niche management opportunities within existing “socio-technical regimes” proved important to the North East offshore wind pathway (Hughes 1983; Scrase *et al* 2009; Essletzbichler 2012; Simmie 2012). Importantly for the North East growth path, Borderwind was the first project developer to secure a NFFO contract to construct and operate Blyth Harbour Wind Farm by cultivating political networks and client relations, particularly at a national level through leveraging the CEO of Borderwind’s reign as Chairman of the British Wind Energy Association (BWEA) to develop close professional relationships with Godfrey Bevan, Head of Renewable Energy at the DTI, and Frank Parish, Head of Marine Estates at the Crown Estates, who collectively:

“banged the drum in Whitehall for NFFO and European funding to go towards the first offshore wind farm demonstration site in Blyth” (CEO Borderwind, Author’s Interview 2011).

The example of Borderwind highlighted the significance of the dynamic relations between firms, regions and states in regulating, shaping and moulding patterns of investment (Dicken 1998; 2000; Mackinnon & Phelps 2001). The relative success of Blyth Harbour Wind Farm, and later Blyth Offshore Wind Farm, cemented the North East’s position as one of the UK’s leading locations for renewable energy technology (Head of Energy & Environment ONE, Author’s Interview 2011). At a national political scale, the election of the Labour Government in 1997 reaffirmed national politico-institutional commitment to liberalisation of the domestic energy market through the *Review of Energy Sources for Power Generation White Paper* (1997). Within the policy document, the incoming Government placed greater emphasis on environmental commitments through signatory to the 1997 UNFCCC Kyoto Protocol to reduce greenhouse gas emissions by 8% by 2012, when compared to 1990 levels, and implementation of the Fossil Fuel Levy as additional policy and regulatory layers to the

NFFO programme (Pearson & Watson 2011). Thus, despite wind energy contributing only 3% of the UK's total energy mix and lagging significantly behind international competitor markets, particularly in Europe, as the UK entered into the 21st century offshore wind energy had once again reappeared back on the political agenda.

Figure 4.7 National Renewable Energy Policies in UK, Denmark, Germany and Spain



Source: Essletzbichler 2012, p.803.

4.3.3 National State Science and Technology Policy: Flexible Electronics and Emerging Technologies

Between the late 1970s and early 1990s national political support for science, emerging technologies and niche sub-sectors was largely anonymous in favour of horizontal policies that supported broad areas of R&D, deregulation, market liberalisation and “hard” infrastructure programmes designed to support or shore up “traditional” UK industrial sectors which employed significant numbers of jobs (Morgan 2011). Despite emerging pockets of world-class science in polymer electronics, electrochemical materials and plastic substrates opening up within academic centres in Cambridge, Manchester, Swansea and Durham, national state institutional and political actors instead opted to pursue the creation of a domestic semiconductor-based microelectronics industry following rapid growth in the U.S. market (Professor of Physics Durham University, Author’s Interview 2011). In many respects, the nascent flexible electronics pathway in the North East and UK was reflective of a “path not taken” by national institutional actors, structures and networks (Schneiberg 2007). As a consequence, the Conservative Government continued to support the development of the UK semiconductor industry by directing supply-side science and technology policy through the Science & Engineering Research Council-Engineering and Physical Sciences Research Council (SERC-EPSC) to establish the DTI-led ALVEY microelectronics R&D programme (House of Commons 2009b). Nevertheless, despite macro-political support to stimulate a domestic industry:

“the UK has thus far failed to respond adequately to the changes which semiconductor technology has already brought about in a number of areas. As a result, we have been overtaken by competitors...In many of these fields we previously held a dominant position” (ACARD 1978, p.147).

By the end of the late 1980s, the ALVEY programme had been cancelled by national politico-institutional actors with the attempts of the state to generate a UK semiconductor industry and microelectronics market regarded as a case of “too little, too late” (Wilson 2002, p. 32).

By the 1990s national institutional actors and policy intervention to stimulate and support science and emerging technologies had moved away from supporting basic science to a

greater focus on technological R&D. The inability to establish a domestic semiconductor industry over the preceding two decades coupled with the growth of the global microelectronics market influenced state policy to re-explore novel electronic materials, components and technological applications emanating out of academia and industry (Emeritus Professor of Chemistry Durham University, Author's Interview 2011). Illustrating the role of state sponsored R&D programmes in supporting innovative firms with early-stage technological development, the DTI created the Link programme in the early to mid-1990s aimed at assisting small to medium sized enterprises (SMEs) to commercialise novel microelectronics technologies by providing access to funding and encouraging academic-industry linkages through collaborative R&D projects (Asheim *et al* 2007; Head of Electronics & Photonics BIS, Author's Interview 2012). However, funding support from the DTI Link programme and UK Research Council's provided little quantitative or qualitative impact on the regional flexible electronics pathway as fiscal stimulus disproportionately favoured universities and SMEs in the "Golden Triangle" territory of Oxford, Cambridge and London (Professor of Physics Durham University, Author's Interview 2011). Indeed, only Durham University and Epigem received fiscal support from national state R&D programmes during the temporal episode reaffirming the limited policy support the North East had received from government in advanced technology assistance over the two decades (Charles 2008). In the absence of a critical mass of regional academic excellence, industrial interest and state governance structures at the local and regional scale which remained preoccupied with attracting overseas semiconductor transplantation, national institutional actors, and particularly the state and national level policy decisions, had served to constrict the path creation of the flexible electronics industry in the North East (Emeritus Professor of Chemistry Durham University, Author's Interview 2012).

4.3.4 Summary: Divergent National Institutional Support for Path Creation

As with previous historical episodes that chronicled and illustrated the defining role national institutional and political actors, structures and settings on the industrial trajectories in the North East, the episode in the path creation of the flexible electronics and offshore wind industries re-emphasised the influence and impact of extra-regional actors and forces on peripheral regional economies such as the North East (Hudson 1997; Tomaney 2000). Prior to the 1990s, there had been no concerted political appetite by successive national political parties to generate electricity from renewable energy sources (Musgrove 2010). In a similar

vein to other forms of alternative energy, offshore wind had been discarded as a credible long-term technology option in favour of the incumbent, path dependent, carbon-based energy industry (Garud & Karnoe 2001). However, the rapid decline and “rupture” (Bathelt & Boggs 2003) in the traditional energy industries combined with increasing privatisation, competition and support for new alternative forms of energy opened up a niche window of opportunity for the offshore wind industry (Storper 1990). At a local and regional scale, national state supply-side (technology push) interventions had played a critical enabling role in providing a stimulant and catalyst for North East-based actors to initiate and sustain processes of path creation. Indeed, without the supportive national-level policy framework, niche market and connected fiscal stimulus at the early developmental stage of the regional pathway, Borderwind would not have possessed either the high upfront capital costs or guaranteed end-market required for Blyth Harbour Wind Farm and Blyth Offshore Wind Farm to be completed (CEO ClipperWind Power, Author’s Interview 2012; Howarth 2012; Simmie 2012).

Unlike the offshore wind industry which had demonstrated intermittent bouts of national political support to unlocking new local, regional and national industrial development pathways, national institutional and political support for science, technology and commercialisation of flexible electronics applications failed to provide an enabling environment for the emerging local and regional pathway. Rather, state-led policies at the national scale during the temporal episode failed to support institutional change, promote innovation or stimulate de-locking mechanisms from existing path dependent trajectories (Pike *et al* 2006; Boschma & Martin 2010). Instead, national political actors and policymakers opted to enter the increasingly saturated global micro-electronics market by initially pursuing, but ultimately failing to establish, an indigenous domestic silicon-based semiconductor industry. The unsuccessful attempt resulted in multi-scalar state actors reverting back to competing for footloose, semi-conductor inward investment (see Chapter 4.4). For the nascent regional flexible electronics pathway, national state innovation and industrial policy had re-enforced lock-in of existing North East agents and structures to the dominant silicon-based semi-conductor industry (Grabher 1993).

4.4. LOCAL AND REGIONAL INSTITUTIONAL ACTORS, FACTORS AND SETTINGS IN PATH CREATION

4.4.1 Introduction

As highlighted in Chapter 4.3, the mechanisms of the offshore wind and flexible electronics pathways in the North East had been enabled and constrained by national state strategies and extra-regional political economic relations (Coe 2011). Within this broader conceptual and empirical understanding of the influence of social and institutional agency at multi-scalar levels and contexts in mediating and stimulating the mechanisms of path creation at the local and regional scale, the following section addresses and analyses the role of sub-national institutional structures, state organisations, knowledge-based institutional actors and policy played in facilitating and “selecting” the emergent mechanisms in the offshore wind and flexible electronics pathways in the North East (Pike *et al* 2010). In so doing, the section illuminates the important role local and regional actors, strategies and policy performed in setting the appropriate environment for new growth paths to form, while simultaneously recognising the actions of key actors were conditioned by wider historical and place-based conditions and contexts (Coe 2011; Mackinnon 2012).

4.4.2 Local and Regional Institutions, Governance and Policy Intervention

Despite farsighted work undertaken by the Northern Region Strategy Team (NRST) in the late 1970s to understand the roots of the “regional problem” set contextually within changing national and international economies, the North East exhibited a fragmented system of local government organisations and sparse tier of regional state institutions (see, for example, Northern Economic Planning Council 1966; Smith 1970; Northern Region Strategy Team 1977; Town Planning Review 1978). To bring together the various disparate multi-scalar political institutions, the Strategic Plan for the Northern Region was constructed but later abandoned as a result of the election of the Conservative government in 1979 (NRST 1977; Buswell 1983). The remainder of the 1970s and early 1980s under the Thatcher regime witnessed reductions in central government expenditure to local and regional state institutions limiting the impact of regional policy in the North East.

Reflecting a shift of national state power and ideology from social democratic politics to neoliberal politics of competition and market liberalisation, local and regional economic development policies in the North East returned to the pursuit of FDI, primarily to address rising unemployment rates experienced as a result of job losses in the primary extractive industries, but also as a result of attempting to generate, but ultimately failing to instil, an endogenous enterprise culture within the North East (Tomaney & Mawson 2000). In the context of the emerging offshore wind and flexible electronics pathways in the North East, local and regional state institutions, including the newly established Northern Development Company (NDC), a quasi-autonomous non-governmental organisation (QUANGO) created to attract and secure FDI in the region, lacked an explicit mandate and institutional capacity in terms of resources, expertise and leadership to support the novel techno-industrial pathways (Albrechts 2004). Instead, local authorities and NDC continued to follow local and regional economic strategies based on attracting mobile, large-scale and low-wage forms of exogenous semiconductor, heavy engineering and manufacturing investments (Charles & Benneworth 1999; Head of Energy & Environment ONE, Author's Interview 2011).

Entering into the 1990s, local and regional state organisations of the North East continued to pursue economic strategies based on promoting the virtues of the region as a “space for profitable production” to overseas investors (Hudson 1997). For the evolving offshore wind pathway in the region, a clear disconnect existed between state policy at the national scale which had established a niche opening in the UK offshore wind industry in order to stimulate endogenous growth, and the function of local and regional state institutional actors and policy which remained fixed on creating employment from exogenous transplantation in order to absorb jobs discarded from changes to the international division of labour in the North East's declining traditional industries (Hudson 2005; CEO Borderwind, Author's Interview 2011). In the nascent flexible electronics pathway, the opportunity to build on indigenous assets, resources and competencies left from previous rounds of industrial activity in the North East by local and regional state institutions was lost in favour of pursuing and “embedding” (Grabher 1993) global semiconductor and microelectronics firms in the regional economy (see, for example, Robinson & Storey 1981; Storey 1982; Phelps & Waley 2004; Dawley 2005). Illustrating the effect of “ever-shifting market, competitive and regulatory environments” (Martin 2010, p. 22) on local and regional evolution, adaptation and “resilience” (Pike *et al* 2010), the global downturn in DRAM chips at the end of the century led to the closure of regional MNCs, including both Siemens Microelectronics and Fujitsu in

1998, with the total combined loss of 1,700 jobs (Dawley 2007). Importantly, the closure of Siemens Microelectronics and Fujitsu would later release resources and labour into the future regional flexible electronics pathway (Finance Director Atmel Corporation, Author's Interview 2012). In short, the reliance and failure of regional FDI policy in the North East during the period had re-opened the black box of (dis)investment decisions of exogenous investors, the long-term sustainability of attracting footloose exogenous inward investment to peripheral regional economies, and importantly, the spillover effect of pursuing transplantation mechanisms on the creation and emergence of novel local and regional technological pathways (Pike 1999; Dicken 2000; Dawley 2007).

Towards the end of the 1990s the collapse of the Conservative Government under John Major and revival of the Labour Party returned regional issues, including territorial industrial strategies and innovation ecosystem approaches, to the UK policy agenda (Jones 2001; Morgan and Nauwelaers 2003). Keynesian demand-side policies, particularly in relation to less economically developed regions such as the North East, had come to be regarded as helping to create a "branch plant economy", overly-dependent on external investment in manufacturing to exploit lower costs of production and without the endogenous capacity to generate growth (Phelps *et al* 2003). In the emergent regional offshore wind and flexible electronics pathways, state institutions at the local and regional scale and bottom-up policy had ultimately provided a constraining environment to support territorial innovation and stimulate institutional change (Pike *et al* 2006). In the absence of formal local and regional state structures, leadership and directive policy intervention to the offshore wind and flexible electronics industries, non-firm regional technology and innovation support actors, including the North East's universities, business support multipliers and technology-focussed organisations, were increasingly viewed as important drivers of technological and R&D support to both pathways (Head of Innovation, Industry & Science ONE, Author's Interview 2011). The following section picks up this thread by exploring the role and influence of universities and other knowledge-based local and regional institutional actors on facilitating the creation and development of the North East's offshore wind and flexible electronics pathways.

4.4.3 Regional Knowledge-based Institutions and Technological Development

In the absence of innovation strategies throughout the English regions, the 1980s and 1990s marked the increasing importance amongst state and regional policymakers of territorial innovation systems thinking, with universities and other knowledge-based institutional actors considered important regional resources in the context of “endogenous development strategies” (Saxenian 1994), but also as active participants in the construction of “regional competitive advantage” (Charles 2008). Following recommendations made by the NRST of the potential future relationship between the regional science base and industry, the five higher education institutions (HEI) in the North East established a number of mechanisms and initiatives to increase industry participation in the emerging offshore wind and flexible electronics industries, including the development of industrial consultancy programmes, research clubs and the establishment of the overarching Higher Education Support for Industry in the North (HESIN) collaborative initiative (Potts 1998; Tomaney 2006; Head of Innovation, Industry & Science ONE, Author’s Interview 2011). As with other comparable old industrial regions at the time, regional policymakers and institutional actors in the North East sought to emulate globally competitive “learning regions” that were characterised by a culture of collaborative intra-regional innovation networks of local public and private actors in order to raise the innovation and industrial capacity of the economy (Morgan 1997).

Despite the scientific discovery and advancements of core flexible electronics technology emanating out of Durham University, and increasing recognition amongst economic geographers and policymakers of universities as engines of growth in supporting processes of innovation, technology transfer and new industry creation, the North East’s universities during the temporal episode offered different forms of formal and informal “institutional change” towards the emerging offshore wind and flexible electronics pathways (Feller 1990; Hassink 2005). In the embryonic flexible electronics pathway, Durham University held a national lead position in the Electronics and Photonics Packaging and Interconnection (EPPIC) Faraday Partnership, whilst Newcastle University’s School of Electrical Engineering had developed R&D capabilities in service deposition technology which offered complementary technology relatedness to flexible electronics technology and potential industrial applications (Professor of Physics Durham University, Author’s Interview 2011). In this context, the region’s two foremost research-intensive academic institutions possessed knowledge and facilities that were difficult to replicate or transfer elsewhere, and over which,

academia and the indigenous business base had a time limited monopoly to exploit (Maskell & Malmberg 1999). Nevertheless, despite exhibiting early characteristics of competitive advantage amidst a declining global semiconductor industry and inability to revive the existing and maturing regional semiconductor manufacturing pathway, the region's universities resisted "institutional change, adaptation and diversification" into the emerging flexible electronics trajectory (Lundvall 1992; Nelson 1993). On the contrary, existing R&D structures, research practices and networks displayed by regional academia remained stable demonstrating a lack of adaptive capacity (Hodgson 2004), with both Durham University and Newcastle University exhibiting characteristics of "technological inertia and institutional hysteresis" within the confines of the dominant silicon-based semiconductor industry (Setterfield 1997; Kivimaa *et al* 2010).

In contrast to flexible electronics, local and regional institutional arrangements between academic institutions, innovation bodies and industry within the emerging regional offshore wind pathway remained more "open" and "fluid" between the 1980s and end of the century (Head of Energy & Environment ONE, Author's Interview 2011). Historically, Newcastle University and Durham University had possessed applied R&D expertise in mechanical engineering, electrical engineering and had previously provided geoscience expertise and labour to the coal, oil, gas and marine industries in support of national industries and former "traditional regional sectors" (Goddard *et al* 2011). However, unlike the non-existent relationship between firm and non-firm dynamics in the origins of the flexible electronics pathway, to facilitate and stimulate learning processes between local and regional actors in the offshore wind sector both universities began to exhibit "co-evolutionary patterns of technological development" with both institutions diversifying academic research portfolios and physical infrastructure capacity to include novel renewable energy technologies being developed by industry (Schienstock 1997; Head of Energy & Environment ONE, Author's Interview 2011). For instance, Newcastle University established the School of Marine Science and Engineering during the period to focus on design, offshore engineering, hydrodynamics and fluid dynamics to the offshore energy industries (Professor of Energy Newcastle University, Author's Interview 2011). In summary, the transfer of knowledge, learning and innovation in the offshore wind pathway between HEI and industry reflected an interactive process shaped by co-evolutionary institutional routines and patterns. In contrast, academic centres within the novel flexible electronics pathway exhibited institutional lock-in to past industrial trajectories which posed a significant barrier for North East-based actors

within the innovation and economic system to move onto the new and potentially more disruptive technology-based growth path (Hudson 1994; Lundvall 2000).

In addition to the prominent but limited role of local authorities, regional QUANGOs and HEI's in assisting and catalysing the offshore wind and flexible electronics pathways, the local and regional institutional vacuum was occupied, and partially filled during the episode, by a series of regionally-based business and innovation multipliers. For instance, in the context of the early potential demonstrated by Blyth Harbour Wind Farm, the North East Energy Cluster (NEEC) organisation, which, up until the early 1990s, had concentrated its innovation and business support focus upon growing the region's carbon-based energy footprint, included wind energy as a policy priority and business support focus from the mid-1990s onwards (Director of Business Development Shepherds Offshore Services, Author's Interview 2011). Simultaneously, the recently established Regional Technology Centre North (RTC North) secured EU and state funding to deliver tentative innovation and manufacturing advisory support programmes to firms in the advanced engineering and energy-based sectors (Head of Innovation, Industry & Science ONE, Author's Interview 2011). Consequently, both RTC North and NEEC became the first regional institutions to identify the potential economic benefits of the offshore wind industry to the North East and initiated a series of focus groups, workshops and light-touch business support programmes designed to map supply chain linkages and stimulate early firm diversification opportunities into the onshore and offshore wind industries (Director of Business Development Shepherds Offshore Services, Author's Interview 2011). In this regard, the actions of NEEC and RTC North highlighted the role non-firm actors and supportive innovation and business support organisations performed in mediating and shaping innovation, firms and new and emerging markets (Rao & Singh 2001; Boschma & Frenken 2006; 2008).

4.4.4 Summary: Deviation of Local Institutional Actors in Path Creation

This section shed light on the multiple roles social and institutional agency, and in particular, sub-national institutional structures, political governance, knowledge-based institutional actors and policy performed in mediating the creation and unfolding development of the flexible electronics and offshore wind pathways. With reference to Martin's (2010) alternative and broader conceptual model of path dependency, the emergence of the offshore wind and flexible electronics industries in the late 1970s to the end of the century had been

constrained by sub-national political actors and unrelated local and regional policy intervention (Mackinnon *et al* 2009). In the embryonic offshore wind pathway, local and regional political institutions and actors directed policy, economic strategies and intervention towards attracting and supporting low-skilled, low value-added exogenous investment rather than concentrating policy on supporting emerging technologies, the indigenous base and diversification of existing firms, drawn predominantly from the fabrication, engineering and energy-related sectors, to explore niche commercial opportunities in the renewable energy industry (Hudson 2005). Similarly, the flexible electronics pathway “failed to launch” (Professor of Physics Durham University, Author’s Interview 2011) in the region due, in part, to the rigidity and inflexibility of local and regional politico-institutional actors to deviate and adapt from existing path and place dependencies based on the incumbent semiconductor industry (Martin 2006). Reflecting characteristics of political lock-in to previous historical legacies and exhibiting an inappropriate institutional thickness to past successful regional economic trajectories, sub-national political institutions had formed a constraining barrier to transition to emerging niche economic opportunities within the North East.

In the context of the broader role of local and regional actors outside of the mindful deviation of entrepreneurs and firms in stimulating and providing an enabling environment to seed new path creation, the adaptive capacity of formal and informal knowledge-based institutional agents and arrangements to support, accelerate and transfer knowledge, innovation and learning to local and regional firm and non-firm actors varied. In the offshore wind pathway, regional knowledge-based institutions, including Newcastle University, Durham University, RTC North and NEEC, reconfigured existing institutional routines, norms and networks reflecting characteristics of “path plasticity” in facilitating and stimulating the offshore wind industry (Strambach 2008). Indeed, the regional offshore wind pathway exhibited initial patterns of co-evolutionary intra-regional institutional activity with knowledge-based actors demonstrating adaptive capacity within the innovation system to transfer innovation, resources and skills between academia, firms, markets and non-firm actors (Boschma & Frenken 2009). In contrast to the co-evolutionary arrangements demonstrated in the offshore wind pathway, knowledge-based institutional actors within the flexible electronics pathway failed to mobilise and adapt to the emerging industry. Although the pathway originated out of the scientific discovery and technological developments of the Emeritus Professor of Chemistry and Professor of Physics at Durham University, neither Durham nor Newcastle

University deviated from institutional lock-in to the incumbent silicon-based semiconductor industry (Grabher 1993).

4.5. CONCLUSION

This chapter investigated and analysed the path creation of the offshore wind and flexible electronics industries in the North East between 1978 and the end of the 20th century. By reviewing the evolutionary trajectories of both pathways within the context of the importance of multi-agent and multi-scalar conditions, factors and settings, the chapter has illustrated the key empirical elements and characteristics that have contributed to over 20 years of stimulating and constraining the mechanisms of path creation within the regional flexible electronics and offshore wind pathways. The chapter concludes by summarising the path creation episode and positions the empirical findings, beginning with the North East's offshore wind industry, within the context of the causal mechanisms, agents, factors and conditions that shaped the industrial trajectories of both pathways in the North East.

Offshore Wind Pathway: Mechanisms, Multi-scalar Actors and Policy in the North East Offshore Wind Industry

Exhibiting similar processes and characteristics to the origins of the Danish offshore wind industry and the subsequent forty years of path creation activity that followed it (see, for example, Garud & Karnoe 2012), the offshore wind pathway in the North East evolved out of a “mutation process” in which a small group of inquisitive individuals, entrepreneurs, scientists, technologists and R&D-intensive firms began to develop new knowledge, routines, technology, products and services that had not previously existed within the marketplace (Schumpeter 1942). As illustrated in Figure 4.8, despite external shocks to the energy system and an attempt by the state to cultivate interest of industry in wind energy opportunities, the offshore wind pathway remained a “cottage industry”, relevant only to a small group of environmentally conscious organisations and firms for much of the 1980s. However, the regional offshore wind pathway reached a turning point in the late 1980s catalysed by national level regulatory changes by the state which stimulated market opportunities creating state-led “strategic niche management openings” for firms and organisations in the North East (Schot & Geels 2008; Cumbers 2012). Recombining existing assets and exploiting natural geographical advantages, early-stage entrepreneurialism, exemplified by Borderwind,

combined with national political support stimulated the creation and diversification of SMEs and MNCs from technologically related industries to begin to develop products and/or supply services to the emerging offshore wind global production chain (Henderson *et al* 2002; Cooke 2012). By the end of the century, incremental innovations in offshore wind turbines, increasing experimentation and competition throughout the decade enabled by national institutional actors and fiscal policy levers had led to the installation of Blyth Harbour Wind Farm and deployment of Blyth Harbour Offshore Wind Farm leaving in place an iconic physical regional asset and demonstration site through to which to build a new regional industrial pathway.

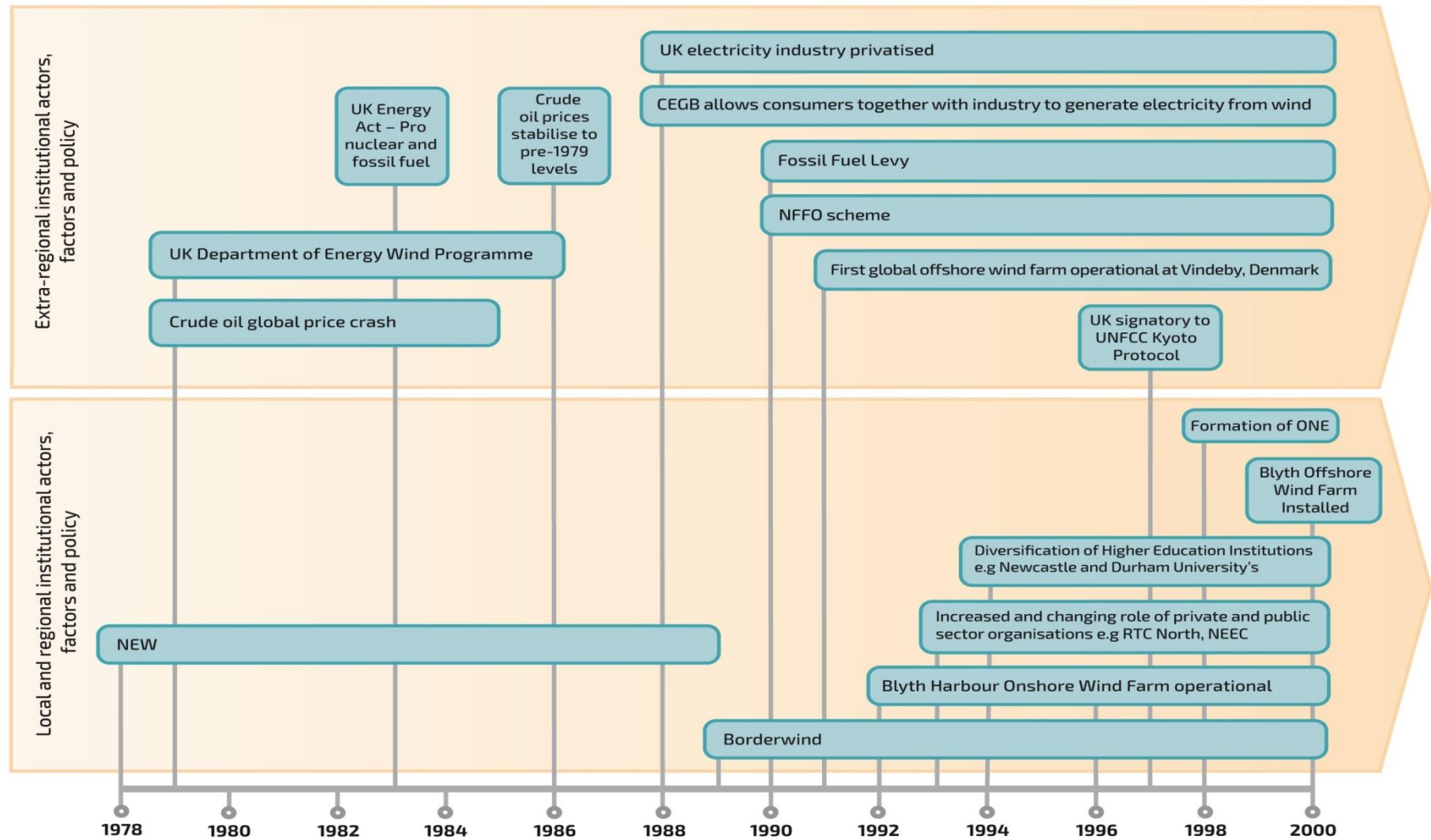
The timeline and supporting narrative detailing the offshore wind pathway in the North East highlighted a number of key elements that underpinned its path creation and evolutionary trajectory (see Table 4.2). First, connecting to consideration of the causal mechanisms of path creation in the regional offshore wind pathway, the temporal period illustrated the importance of indigenous creation in generating new local and regional path creation and the role played by the mechanism in connecting and stimulating follow-on mechanisms of related variety and branching (Martin & Sunley 2006). In particular, the analysis restated the importance of understanding the roles of “experienced entrepreneurs and diversifiers” (Boschma & Frenken 2009, p.11), in firm and non-firm entities, in identifying, harnessing and matching regional assets to new market opportunities (Garud & Karnoe 2003; Dawley 2013). Indeed, the example of the founder and CEO of Borderwind brought into light the unique positioning of entrepreneurs at “system borderlines” situated within multiple interlinked paths which offer entrepreneurs and firms the opportunity to switch to new openings when previous pathways become destabilised or locked-in (Kivimaa *et al* 2010).

Second, the path creation and evolutionary trajectory of the offshore wind pathway reiterated the importance and influence of social and institutional agency, and the role of institutional actors, networks and settings at multiple spatial scales play in creating, shaping, operating and mediating within processes and mechanisms of path creation. In particular, amidst existing institutional arrangements that remained locked-in and maintained path stability to the established fossil-fuel based energy system, national state institutions and the political economy played a critical role during the period in enabling and nurturing the embryonic regional offshore wind pathway through new forms of strategic niche management (Scrase *et al* 2009). Through the introduction of the NFFO programme, supportive climate change

policy and tax rises on the dominant energy pathway, purposive economic and political activities of state institutions at the national scale had transitioned the offshore wind pathway from an early period of tentative technology-push policies of the 1980s to a sustained period of state-led niche activities and mechanisms in the 1990s to support local and regional actors transfer to more sustainable forms of energy generation (Unruh 2000; Fuchs & Arentsen 2002; Kern & Howlett 2009).

Third, the formation and emergence of the offshore wind pathway in the North East restated the difficulty, particularly in peripheral regional economies that possess low adaptive capacity and often lack innovative agents, to transform novelty from the demonstration phase into contesting and de-locking from existing dominant industrial pathways and enforce “regime change” (Auerswald & Branscomb 2003). Notwithstanding a number of regional-based firms which had entered or diversified into the offshore wind industry during the period, the majority of firm and non-firm actors within the North East all held a “watching brief” over how the markets developed following state stimulation programmes (CEO Borderwind, Author’s Interview 2011; CEO SMD Hydrovision, Author’s Interview 2012). In other words, several path dependent barriers endured in the North East. The primary barrier to “selection” of the offshore wind pathway remained the inability to dislodge the prevailing industrial paradigm e.g. oil and gas industries, with offshore wind still offering weak market potential for firms, investors and consumers based on the technology remaining economically unviable, unreliable and offering an inflexible source of energy supply (Musgrove 2011; Simmie 2012). Indeed, the feeling towards the offshore wind industry was further intensified by the hostility of existing indigenous and overseas electricity generators who continued to hold long-term investments in fossil fuel-based generation technologies (Garud & Karnoe 2012). Nevertheless, despite persistent concerns over a long-term investment plan for offshore wind power amidst an increasing focus by the state on nuclear energy and competing niche renewable energy technologies, the offshore wind pathway in the North East displayed promising signs that the emergent pathway would transition from path creation phase into a path development trajectory (Martin 2010).

Figure 4.8 Path Creation of the North East Offshore Wind Industry: Timeline Analysis, 1978-2000



Source: Author 2014

Table 4.2 Key Elements of the Offshore Wind and Flexible Electronics Pathways

	Flexible Electronics	Offshore Wind
Nature of Pathway	Started in the late 1970s, scientific discovery but non-existent interaction between science base, corporate actors and policy until early 2000. Pathway remained dormant until early 21 st Century.	Started in the late 1970s, lack of continuity, but strong interactions between business base and national political actors for technology demonstration and seeding the market
Actors and Networks	Initial network comprising Durham University and several regionally-based MNCs. Later joined by government agencies. Universities remained the most active actors in the network.	First, local entrepreneurs, key marine engineering firms and a handful of academic staff from Newcastle University. Later, a broader network of regional actors including technologically related SMEs and MNCs from engineering and energy-related sectors, academia e.g. Durham University, energy-related business support organisation and government agencies. Local entrepreneurs and experiments remained the most active actors.
National Political Economy and Market Formation	National innovation policy limited and dispersed across multiple UK Government departments. Focus of policy on funding basic science in silicon-based semiconductor investment. 1990s state policy and focus redirected towards collaborative and applied R&D between academia and industry.	National industrial and R&D support began in 1979, focussing on technology-push interventions. Market formation supported later by introduction of NFFO scheme and national political commitment to global and domestic policy and tax e.g. Kyoto Protocol, Fossil Fuel Levy.

Sub-national Governance and Policy	Non-existent until early 2000s when regional government organisation (ONE) took interest.	Limited support from local and regional government organisations. Support concentrated on attracting technologically-related engineering and energy transplantation into the North East. Small business support diversification programmes.
Competing Niches	Silicon-based semiconductors	Nuclear, onshore wind, photovoltaics
Existing Dominant Techno-Industrial Pathways and Regime Influence	Microelectronics industry based on silicon semiconductors. Higher Education, Further Education, QUANGOs and business support organisations linked to existing/declining semiconductor regime.	Fossil fuel-based industries (Coal, oil and gas) and nuclear energy. Lack of interest in offshore wind industry by energy industry and associated supply chain before Kyoto Protocol, Fossil Fuel Levy and NFFO programme
Current Discourses and Advocacy Coalitions	Pro-silicon semiconductor advocacy coalitions e.g. NDC, DTI	Competing pro-renewable energy, anti-fossil-fuel, and pro/anti-nuclear energy advocacy coalitions e.g. North East Energy Cluster, DTI
Factor Conditions	High unemployment but skills unmatched to flexible electronics R&D	Offshore wind conditions recognised as locational competitive advantage. Availability of skilled and experienced workers, particularly related to heavy and advanced engineering, and oil and gas exploration and production.

Source: Author 2014, adapted from Lovio & Kivimaa 2012, p.782

Flexible Electronics Pathway: Mechanisms, Multi-scalar Actors and Policy in the North East Flexible Electronics Industry

Unlike the regional offshore wind pathway which had brought a community of actors together through shared interests and benefitting from complementary knowledge, skills and related technical competencies, the flexible electronics pathway throughout the temporal period remained latent within the incumbent semiconductor-based microelectronics industry. As illustrated in Figure 4.9, despite the scientific discovery of organic polymer and related “analytical knowledge base” at Durham University, the technology, industry nor market was sufficiently developed to translate promising technological potential into commercial applications (Asheim & Gertler 2005). Indeed, the temporal episode displayed elements or fragments of a “path not taken” (Schienberg 2007). Exhibiting tentative characteristics of “cross-path effects” (Schienstock 2007), local and regional actors from academia, industry and the state recombined elements from multiple co-existing institutional paths in the first part of the 21st century to reform the dormant flexible electronics pathway and establish the co-evolutionary beginnings of a new niche sector *in* and *for* the North East (Nelson 1994).

The key moments within the temporal episode of the evolutionary trajectory of the flexible electronics industry in the North East highlighted a number of key elements that explained the intermittent nature and character of the pathway (See Table 4.2). First, unlike the offshore wind pathway, the state, formal organisational structures and policy at multiple scalar levels had failed to transform novelty from the technology demonstration phase to an opening through which North East-based knowledge-intensive institutions, organisations and firms could exploit (Martin & Sunley 2006). In contrast to the expected role of the state in building and supporting new pathways, enabling markets and fostering new forms of strategic governance to initiate novel growth paths, national institutional actors and policymakers ignored the technical potential and long-term advantages of flexible electronics identified in the early 1980s (Spencer *et al* 2005). Instead, national politico-institutional actors opted to concentrate institutional support via national level innovation programmes to develop a domestic semiconductor market e.g. ALVEY, direct sub-regional state organisations to attract increasing volumes of exogenous silicon semiconductor and microelectronics investment, and encourage regional knowledge-intensive organisations, including regional academia, to become part of the package of incentives designed to embed overseas semiconductor branch plants in host economies (Dawley 2007). In the absence of state support and advocacy

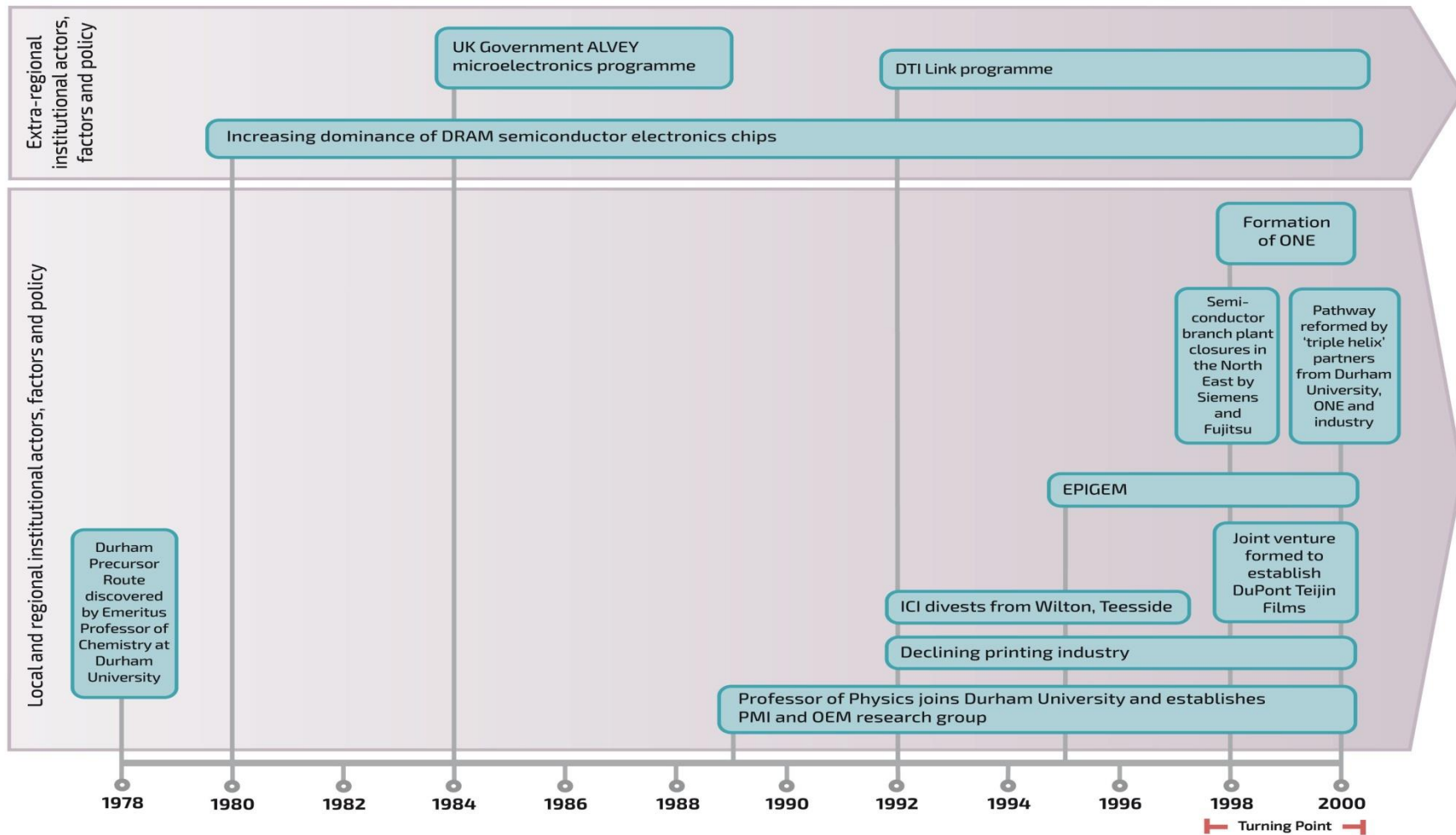
coalitions, such as that displayed by NEEC in the regional offshore wind pathway, multi-scalar state institutions and policy intervention had ultimately constrained the development of the flexible electronics pathway in the North East.

Second, without a supportive multi-scalar institutional environment to stimulate flexible electronics technology and protect from the competing and rapidly growing global silicon semiconductor industry, the flexible electronics pathway remained sheltered and nurtured by a small network of local and regional actors. Reasserting the notion that human agency remains distributed across a multiplicity of actors who are embedded in networks and shape, and are shaped by, emerging techno-industrial trajectories (Simmie 2012), the (re)emergence of the flexible electronics pathway at the end of the decade after over two decades of incubation highlighted the importance of social capital and relational assets in stimulating localised knowledge spillovers and supporting new path creation at the local and regional scale (Boschma 2006). In particular, the path creation episode highlighted the importance of dense social networks and geographical proximity within and between regional academia, industry and policymakers to facilitate tacit knowledge exchange and “enhance learning capacity” (Morgan & Nauwelaers 1999) in (re)creation of the flexible electronics pathway in the North East (Rallet & Torre 1999; Garud & Karnoe 2001; Boschma 2006).

Third, the stalled “lift-off” of the flexible electronics pathway in the North East more broadly highlighted the important connection between local and regional actors, assets and contexts and external factors, institutions and conditions in the creation of new local and regional growth paths (Grabher 2009). For instance, although discovered slightly before organic polymer in the 1960s, silicon semiconductor material had quickly diffused into the global market through established vertical production chains. Therefore, while flexible electronics remained a technology for the preserve largely of academia and a handful of MNCs, the growth of the global telecommunications industry, consumer electronics, and particularly the rise of personal computing, the DRAM-based semiconductor industry had increased in market value from \$33bn in 1987 to \$204bn by 2000 (SEMI 2011). In the context of the dominant industrial pathway, the critical moments in the timeline analysis depicted the North East in a state of unrest over de-locking from the incumbent semiconductor-based microelectronics industry. On the one hand, the North East had based successive (and successful) local and regional economic development policies on attracting, securing and positioning downstream manufacturing investment from semiconductor and microelectronics

firms within the global production chain (Henderson *et al* 2002). On the other hand, the (re)formation of the flexible electronics pathway in 2000 presented an opportunity for firm and non-firm actors, within and external to the North East, to build on existing related resources, assets and capabilities in stimulating and supporting a potentially new disruptive technology-based pathway. In so doing, both the flexible electronics and offshore wind pathways in the North East entered the 21st century with the potential beginnings of breaking and adapting from existing path and place-dependent industrial trajectories (Grabher 1999).

Figure 4.9 Path Creation of the North East Flexible Electronics Industry: Timeline Analysis, 1978-2000



Source: Author 2014

CHAPTER 5. PATH DEVELOPMENT OF THE OFFSHORE WIND AND PLASTIC ELECTRONICS INDUSTRIES IN THE NORTH EAST

5.1.0 Introduction

At the beginning of the 21st century the offshore wind and flexible electronics pathways in the North East had entered a “phase of path development” (Martin 2010). Purposive experimentation by local and regional actors enabled by supportive national institutional and political frameworks and place-based assets resulted in deployment of Blyth Offshore Wind Farm which had demonstrated the technical and commercial potential of the emerging offshore wind market to regional industry and multi-scalar policymakers. Similarly, in what became a universal change in terminology from “flexible” to “plastic” electronics reflecting the rapid adoption and diversity of polymer substrates utilised by industry to print electronic materials, the emerging regional plastic electronics pathway witnessed local and regional firm and non-firm actors collaborating in intra-regional networks of cooperation, recombining past technological structures and existing knowledge to establish a new growth path in the North East (Cooke & Morgan 1998).

Following the path creation phase, the purpose of this chapter is to analyse the conceptual path development phase in the evolutionary trajectories of the offshore wind and plastic electronics pathways in the North East (Martin 2010). Connecting to the previous path creation episode, the chapter picks up the chronological thread from 2000 to 2010 representative of a rapid and sustained period of state-derived and driven market stimulus, contextual enabling conditions and policy support to the expanding offshore wind and plastic electronics industries. In contrast to Chapter 4 which addressed the prominent role the mechanisms of path creation performed in shaping both pathways *ex-ante* of sustained multi-scalar institutional and political intervention, the order is reversed in Chapter 5 reflecting the importance, during the path episode, of the role and significance of national and regional institutional actors, conditions, settings and policy in stimulating the mechanisms of path development. Accordingly, the chapter begins in Chapter 5.1 by identifying and assessing the catalysing role national institutional structures, state actors and policy intervention performed in setting the conditions and enabling environment for the mechanisms in both pathways to accelerate. In addition to the prominent role of extra-regional actors during the temporal

episode, Chapter 5.2 examines the key role, type, influence and causal links between regional institutional actors, assets and strategic policy intervention in establishing an enabling territorial innovation environment in support of the developing pathways (Cooke 2002). Situated within the broader and supportive economic, political and social-institutional conditions, Chapter 5.3 identifies the key candidate mechanisms of path creation and development during the period which were shaped, and they themselves manipulated by, wider economic, political, social and institutional forces and factors. The penultimate Chapter 5.4 provides a brief synopsis of the resultant outcomes and impact from over thirty years of path creation and development activities in the North East's offshore wind and plastic electronics pathways. Chapter 5.5 draws the empirical assessment of the path development phase to a close by placing the analytical findings in the context of the causal mechanisms, multi-scalar actors and policy interventions that had stimulated the industrial trajectories of both pathways during the episode.

5.1. NATIONAL INSTITUTIONAL ACTORS, CONDITIONS AND SETTINGS IN PATH DEVELOPMENT

5.1.1 Enabling State Horizontal and Vertical Policy Activism in the Path Development of the Offshore Wind Industry

Connecting to the previous episode in the regional offshore wind pathway which had been characterised and influenced by tentative bouts of national state horizontal and vertical policy, the NFFO programme of the 1990s and the investiture of the Labour Government in 1997 had been important in laying the foundations for the UK offshore wind industry as it entered a period of path development at the beginning of 2000 (Peck & Theodore 2007). Reflecting the importance of multi-scalar strategic agency in underpinning new path creation at the local and regional scale, national state institutions exhibited a “paradigm shift” (Gibbs 2000) in backing the offshore wind industry, supported by marine data which pointed to the consistency of offshore wind speeds as a national competitive advantage in comparison to competing European nations (Boettcher *et al* 2008; Markard 2009; Howarth 2012). Encouraged by the successful installation of Blyth Offshore Wind Farm, and subsequently witnessing further deployment of offshore wind farms in Denmark, Holland and Sweden during the intervening period, the UK Crown Estates initiated a formal Round 1 Offshore Wind Programme for allocating future offshore wind farm sites in UK waters (BWEA 2005).

Illustrating an example of state-led, purposive planning by policymakers to create and enable new industrial pathways, interested offshore wind farm developers were invited to apply for a 22-year lease period with each developer limited to one site comprising of a maximum 30 offshore wind turbines (Sydow *et al* 2009). In April 2001, 18 lease applications at 13 sites were approved, predominantly between 5 and 10km from the coastline, with North Hoyle off the coast of North Wales becoming the first to become operational in November 2003 (Musgrove 2010; CEO ClipperWind Power, Author's Interview 2011). In the context of connecting supportive national regulatory conditions to stimulating and building momentum to the developing offshore wind pathway in the North East, EDF Energy Renewables was awarded a licence in Round 1 by the UK Crown Estates to own and operate Teesside Offshore Wind Farm and began the process of requesting planning permission from Middlesbrough Borough Council to install 27, 2.7MW class Siemens offshore wind turbines 1.5km off the coast of Redcar, Teesside (Professor of Energy Newcastle University, Author's Interview 2011; EDF Energy Renewables 2013).

Following the publication of the Energy White Paper in 2003 which had set an aspirational target of achieving 20% of UK electricity supply from renewable energy sources by 2020, the UK Crown Estates called for expressions of interest in the Round 2 offshore wind programme in December 2003 (DTI 2003; Greenpeace 2004). Unlike the previous offshore round which awarded licenses across multiple, small-scale geographical sites, Round 2 leases were confined to three geographical areas: the Thames Estuary (South East England); Greater Wash (East of England); and the North West (Liverpool Bay) (see Figure 5.1). The decision by the UK Crown Estates not to lease seabed in North East waters represented a minor blow to the North East offshore wind pathway after initial momentum was generated by Blyth Offshore Wind Farm and Teesside Offshore Wind Farm (CEO ClipperWind Power, Author's Interview 2011). Nevertheless, reflecting renewed interest by industry and investors in the evolving offshore wind pathway, oversubscription to Round 2 was demonstrated in 17 of 41 submitted projects to be granted approval contributing to a proposed total capacity expected to exceed 7.2GW of electricity by 2015 (UK Crown Estates 2011).

Figure 5.1 UK Crown Estates Round 1 and 2 Offshore Wind Farm Site Locations

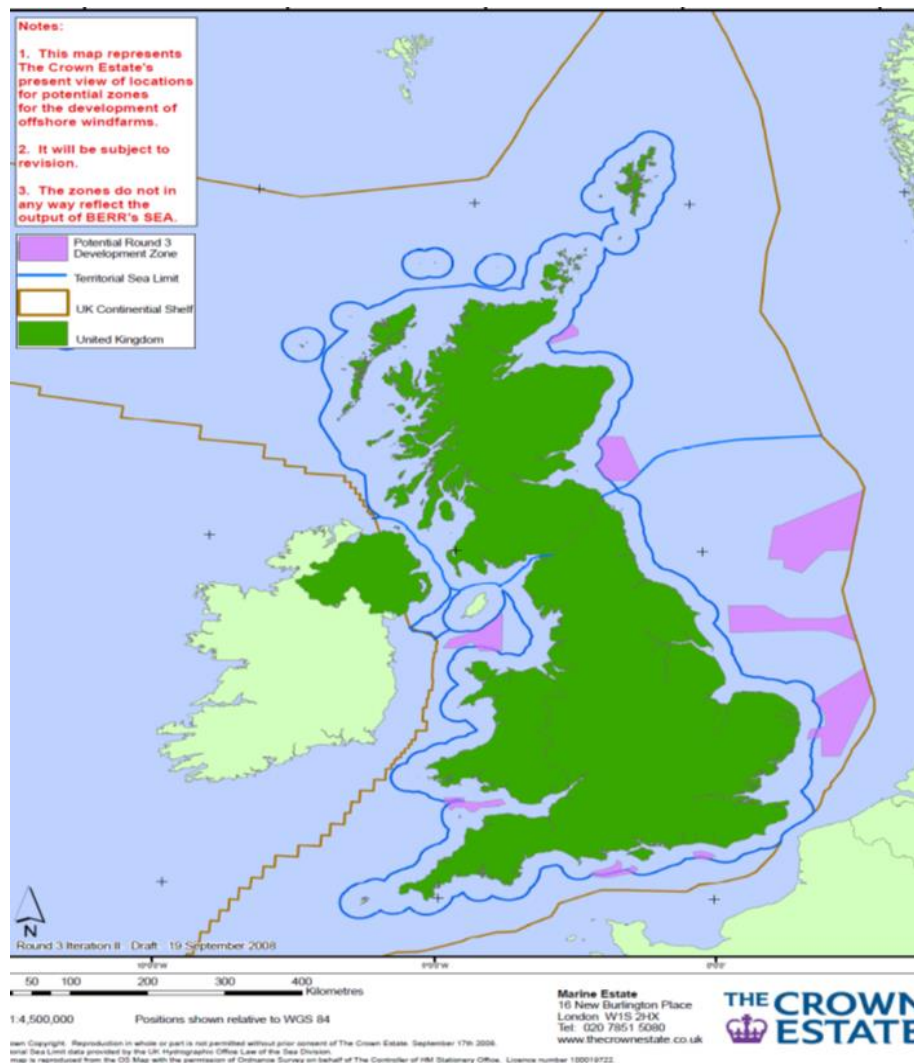


Source: UK Crown Estates 2011

National political support for the burgeoning offshore wind industry was further accelerated in December 2007 when the UK Government initiated a further spatial strategic environmental assessment (SEA) of the UK's offshore wind resource. The SEA identified the potential for the UK to add an additional 32GWs of offshore wind capacity by 2020, identifying a significant portion of Europe's overall offshore wind capacity was situated in UK waters (BWEA 2005; GWEC 2008). Indeed, Ernst and Young's *Long-Term Wind Index* (2008) ranked the UK as offering the best global market for generating electricity from offshore wind. Despite objections from environmentalists and on-going tensions between local residents and central government in contrast to local community ownership structures in Denmark (see, for example, Garud & Karnoe 2012), the UK Crown Estates initiated a third round of bidding in May 2008 with nine offshore zones identified as potential sites suitable for multiple multi-megawatt offshore wind farms (Munksgaard & Morthorst 2008; Cooke

2010; Simmie 2012). As Figure 5.2 highlights, five of the nine sites were located off the Eastern (3) and Southern (2) coastline with the remaining sites off the coast of Scotland, Wales and West of England. For the North East offshore wind pathway, geographical proximity to Dogger Bank, the largest site in the Round 3 programme, along with an indicative 75% of commercial value designated in other offshore sites in the North Sea (Dawley *et al* 2015), the Round 3 offshore wind programme represented a significant commercial opportunity for North East-based engineering, fabrication and O&M firms to supply products and services to the expanding UK offshore wind market (Director of Business Development Shepherds Offshore Services, Author’s Interview 2011).

Figure 5.2 UK Crown Estates Round 3 Zones for Development



Source: UK Crown Estates 2011

In January 2010, the regional and national offshore wind trajectory gathered further economic momentum following the announcement by the UK Crown Estates of the successful bidders for the 32GW Round 3 offshore wind programme. In total, the Round 3 offshore wind programme was valued at \$75bn with anticipated supply chain requirements equating to approximately 6,000 turbines (based on a typical 5MW class turbine), 5,000 foundations, additional supply chain components and O&M requirements (Carbon Trust 2008). Reflecting the scale of the state-conditioned market opportunity and status of the burgeoning offshore wind industry in the UK, lease site contracts were awarded to individual and/or consortiums of project developers comprised predominantly of multinational, vertically integrated utility and energy providers (see Table 5.1). To further stimulate the market in an example of direct policy intervention by national political actors, the UK Crown Estates acted as a co-investor on several occasions with developers in Round 3 projects in order to facilitate the development of the offshore wind market (RedPoint 2012). For the North East offshore wind pathway, the opportunity presented by the Round 3 offshore wind programme after a decade of sustained national state strategic decisions and intentional policy intervention through the UK Crown Estates programme had “marked a major tipping point for the future of offshore renewables” in the North East (NaREC 2010).

Table 5.1 UK Crown Estates Round 3 Successful Bidders

Wind farm	Region	MW Capacity	Project Developer (owner)
Bristol Channel	South West	1500	RWE Npower Renewables
Dogger Bank	North Sea	9000	Forewind Consortia (SSE Renewables, RWE Npower Renewables, Statoil and Statkraft)
Firth of Forth	Scotland	3500	SeaGreen Wind energy Ltd (SSE Renewables, Fluor)
Hastings	South	600	E.On Climate and Renewables
Hornsea	North Sea	4000	Mainstream Renewable Power, Siemens Project Ventures
Irish Sea	Irish Sea	4200	Centrica

Moray Firth	Scotland	1300	EDP Renovaveis, Seaenergy Renewables
Norfolk Bank	Southern North Sea	7200	East Anglia Offshore Wind Ltd (Scottish Power Renewables and Vattenfall)
West of Isle of Wight	South	900	Eneco New Energy
TOTAL		32200	

Source: Renewables UK 2012

As an outcome and product of the conditions and policy stimulus that underpinned the path creation in the regional offshore wind pathway, the North East's contribution to the UK's overall electricity generated from offshore wind technology rose from just 1GWh in 2000 to 3,045GWh by 2010 (see Table 5.2). Despite a comparatively slow start in the earlier path creation phase, by 2008 the UK had overtaken Denmark to become the world's leading market for offshore wind energy (GWEC 2008). As with the onshore wind power sector before it, the scale of the UK market opportunity had signalled increased investment and ownership of offshore wind farm sites by prominent multinational energy conglomerates intent on diversifying their company portfolios (Markard & Peterson 2009). Consequently, a further eleven offshore wind farms had become operational off the UK coastline by the end of the decade, including the completion of Thanet offshore wind farm in 2010, at that time, the world's largest offshore wind farm with 300MW of installed capacity (GWEC 2010; Renewables UK 2012) (see Table 5.3) (DECC 2011b). For the expanding offshore wind pathway in the North East, the indigenous, technologically-related industrial base and geographical proximity to the largest zones off the East coast of England at Dogger Bank, Hornsea and Norfolk, together with expanding offshore wind markets in Denmark and Sweden, catalysed the regional offshore wind industry into a period and trajectory of rapid path development growth (CEO ClipperWind Power, Author's Interview 2011; Simmie 2012).

Table 5.2 UK Offshore Wind Generation, 2007-2010

Generation (GWh)	2007	2008	2009	2010
Offshore Wind	782.6	1,305.1	1,740.2	3,045.5
Total Renewable Energy	19,6000	21,565	25,182	25,734
% of UK renewable energy from offshore wind	4.0%	6.1%	6.9%	11.8%

Source: DECC 2011b

Table 5.3 UK Operational Offshore Wind Farms, 2000 - 2010

Wind farm	Location	Region	Operational	Turbines	Power	MW	Developer
Blyth Offshore	1km Blyth Harbour	North East	2000/01	2	2	4	E.ON UK Renewables
North Hoyle	7.5km Prestatyn & Rhyl	North Wales	2003	30	2	60	RWE Npower Renewables
Scroby Sands	3km NE Great Yarmouth	East of England	2004	30	2	60	E.ON UK Renewables
Kentish Flats	8.5 km offshore from Whitstable	South East	2005	30	3	90	Vattenfall
Barrow	7km Walney Island	North West	2006	30	3	90	Warwick Energy
Burbo Bank	5.2km Crosby	North West	2007	25	3.6	90	DONG Energy
Beatrice	Beatrice Oilfield, Moray Firth	Scotland	2007	2	5	10	Scottish & Southern
Lynn & Inner Dowsing	5km Skegness	East Midlands	2009	54	3.6	194.4	Centrica Renewable Energy Ltd
Rhyl Flats	8km Abergele	North Wales	2009	25	3.6	90	RWE Npower Renewables

Thanet Offshore	11km off Kent coast	South East	2010	100	3	300	Vattenfall
Robin Rigg	12.5km off Solway Firth	Scotland	2010	60	3	180	E.ON
Gunfleet Sands1 &2	7km Clacton-on-Sea	South East	2010	48	3.6	172.8	DONG Energy

Source: Renewables UK 2012

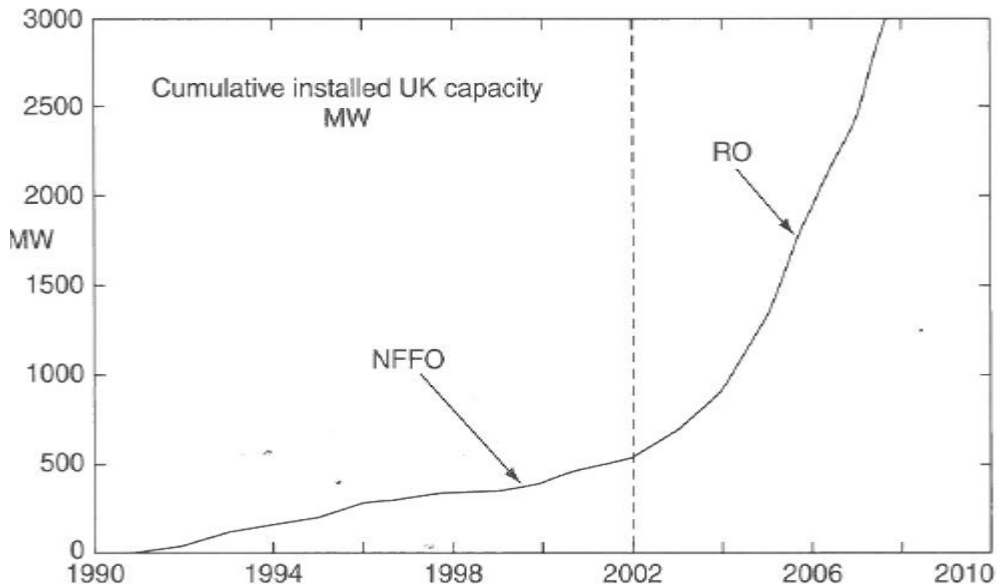
5.1.2 Offshore Wind and Role of the Nation State in Delivering Horizontal Policy Stimulus

In support of the path development of the UK offshore wind industry, state institutional actors and macro policy at the national scale provided a series of supportive “layers” during the episode by adding new “rules”, “procedures” and “structures” to provide an enabling and long-term sustainable environment for local and regional actors to enter the pathway (Simmie 2012). In the context of the publication of the *Stern Review* (2006) of climate change policy, the UK Government’s process of layering began with a domestic commitment to produce 32% of electricity by 2020 from renewable energy sources, with wind power intended to supply two-thirds (BIS 2009a; Musgrove 2010). The pledge was later followed by the UK Climate Change Act (2008) which was enshrined into Parliament and set a domestic target to reduce emissions of greenhouse gases by at least 80% by 2050 from 1990 baseline levels (Renewable UK 2010). At a macro-scale, the UK entered into the EU Renewable Energy Directive in 2009 which represented a legally-binding target of meeting 15% of the UK’s energy consumption from renewable sources by 2020 (DECC 2011a).

In the context of introducing procedures to support the construction of the market by the state, the perceived failure of the NFFO scheme of the previous path creation episode led to the introduction of renewable obligation certificates (ROC) in 2002 (Musgrove 2010) (see Figure 5.3). Following Denmark’s example, under the Renewable Obligation (RO) policy ROC’s were awarded to all generators of renewable energy based on the volume of energy produced which was passed on to electricity suppliers at the point of sale (Musgrove 2010). The increasing emphasis on later stage “demand-pull” mechanisms by the UK Government reflected a changing approach towards the introduction of new niche renewable energy technologies in stimulating transition to new low carbon pathways (Howarth 2012) (see Figure 5.4). However, in the absence of setting a fixed electricity price from renewable energy sources national political regulatory conditions instilled limited market confidence in facilitating a competitive domestic economy for offshore wind technology (Johnstone *et al* 2010; Howarth 2012). Moreover, although the tendering system and RO was useful in obtaining low support prices (Haas *et al* 2011), the introduction of ROC’s at the same price band led to an oversubscription of mature, cost effective and more reliable renewable energy technologies by energy and utility firms with less proven technologies, such as offshore wind,

under-subscribed and undermined due to high technology and capital costs (CEO ClipperWind Power, Author's Interview 2011).

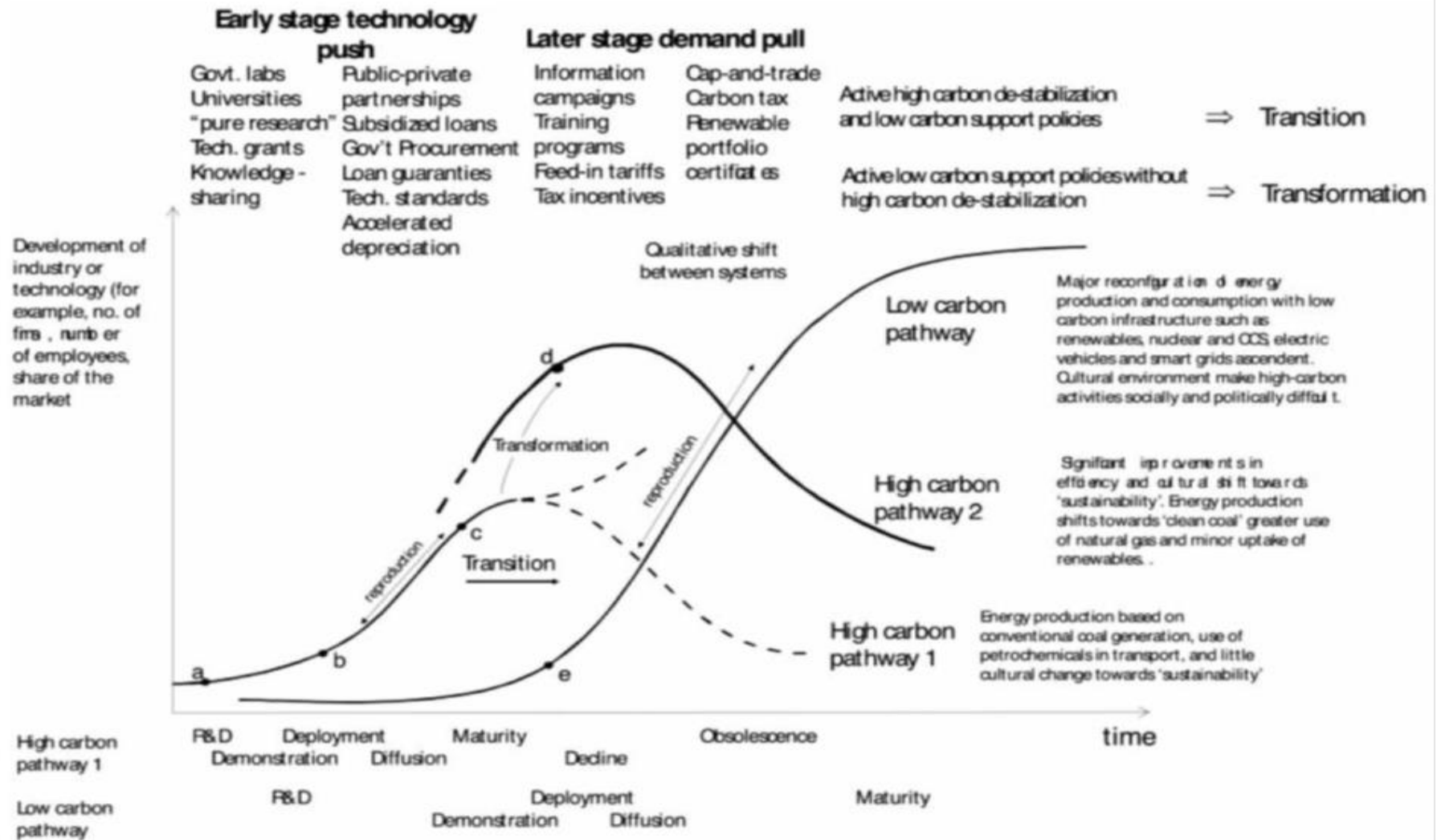
Figure 5.3 NFFO and ROCs



Source: Musgrove 2010, p.188.

In tandem with a systematic review of the RO proposed in the UK Government published *New Industry, New Jobs* (NINJ 2009) and *UK Low Carbon Industrial Strategy* (2009), additional procedural layering occurred throughout the decade to stimulate offshore wind activities at a local and regional scale, including the introduction of a Feed-in-Tariff (FIT) system in 2010. Enshrined in the 2008 Energy Act, FITs intended to provide a payment for electricity produced by renewable technologies up to 5MWs. On a global scale, FITs linked to stimulating domestic offshore wind markets had operated in Germany, Denmark and Spain since the early 1990s offering a more credible and long-term return on investment (ROI) for investors (IPPR 2009) (see Figure 4.7). For firms in the North East generating electricity from offshore wind, the FIT scheme signified another state fiscal policy mechanism which had provided further business and investor confidence to entering the UK offshore wind market (CEO ClipperWind Power, Author's Interview 2011; Simmie 2012).

Figure 5.4 Technology Push and Market Pull in Low Carbon Pathways



Source: Howarth 2012, p.877.

Finally, the offshore wind pathway in the North East was further strengthened throughout the path development episode by national politico-institutional actors strengthening key state structures by providing additional tiers of governance and regulation in support of the developing industry. For instance, the UK Crown Estates was granted statutory authority in 2004 to manage the development of all offshore wind farm schemes in the Renewable Energy Zone i.e. the UK continental shelf out to 200 nautical miles, in order to speed up regulations, deployment and installations of offshore wind farms (RedPoint 2012). Having experienced significant challenges and bottlenecks in similar fashion to other European nations developing domestic offshore wind markets, not least often lengthy delays in obtaining central planning consent, national institutional state structures were further re-enforced during the temporal period by the creation of the UK Government Department of Energy and Climate Change (DECC). Importantly, DECC was established to intertwine industrial policy delivered by the UK Department for Business, Innovation and Skills (BIS) (formerly DTI) with responsibility for energy infrastructure, security and climate change policy (Professor of Energy Newcastle University, Author's Interview 2011). Together, BIS and DECC produced a series of national renewable energy and climate change vertical policy strategies at the end of decade, including the *UK Low Carbon Industrial Strategy (2009)*, *Low Carbon Transition Plan (2009)* and *Renewable Energy Strategy (2009)*, which committed the UK Government to further strategic and direct policy intervention in local and regional economies. Consequently, for existing place-based innovation assets in the North East, commitment to accelerating the offshore wind industry by the national political economy of the UK state resulted in a further £12m investment in demonstration and capital testing assets at the newly formed New and Renewable Energy Centre (NaREC) in Blyth, Northumberland, injecting added impetus to the ongoing path development of the offshore wind industry in the North East (Business Development Manager International Paint, Author's Interview 2011) (see Chapter 5.2).

5.1.3 National Innovation Policy: Facilitating Niche Path Development of the Plastic Electronics Industry

Unlike the offshore wind sector which had been referenced in national policy discourse since the early 1980s and supported by national state policy initiatives throughout the first decade of the 21st century, national state institutional support to the plastic electronics industry remained concentrated on horizontal science, technology and innovation (STI) policy

targeted at basic and applied research within academia and industry. Reflecting strong academic research, particularly at the Universities of Cambridge, Oxford, Southampton, Manchester and Durham, “technology-push” national STI policy and direct investment committed to connecting basic polymer electronic science, engineering and innovation to industry continued to be channelled through the EPSRC and DTI Link programmes that jointly committed over £30m per annum from 2004 onwards towards plastic electronics research (CST 2007). Moreover, having witnessed early prototype applications produced by firms including CDT and Plastic Logic, the DTI began exploring the potential of establishing a national plastic electronics technology centre in 2003 (Head of Electronics & Photonics BIS, Author’s Interview 2012). Nevertheless, reflecting the importance of connecting national innovation policy to place-based assets, resources and multi-disciplinary networks at the local and regional level, the UK Government established a series of knowledge transfer networks (KTNs) to facilitate R&D between industry and academia (Lambert Review 2003). In particular, the creation of Flexynet, a national industry body comprised of UK-based flexible electronics firms, HEI’s and related organisations was critical in stimulating interactive learning, knowledge exchange, co-evolutionary innovation and strengthening the “cognitive proximity of agency” within the industry (PHS Consulting 2008; Balland *et al* 2013). Alongside attendees from Kodak, CDT, Plastic Logic, Logystx, Micro Device Science, Dow Corning and DSTL in the network, the presence of DuPont Teijin Films, and particularly through the inaugural chairmanship of the Chief Scientific Officer of DuPont Teijin Films, whom had been instrumental in the earlier path creation phase, was important in connecting social and institutional agency at the macro-scale with the mechanisms of path development at the local and regional level (Boschma 2004; Ponds *et al* 2007; Chief Scientific Officer DuPont Teijin Films, Author’s Interview 2012).

Following the purposive intervention of national institutional actors and policy to the developing plastic electronics pathway, the temporal period between 2004 and 2010 illustrated further attempts by national state actors and policy to create and incubate niche management settings to stimulate the path mechanisms. For instance, recognising the important function public agencies play in funding basic research, an additional £48m in research, training and knowledge transfer was administered by the EPSRC, DTI and Technology Strategy Board (TSB), the state government’s newly created national innovation agency, to accelerate technology and collaborative research activities between academia and industry (House of Commons 2009b). For the developing plastic electronics pathway in the

North East, research groups in Durham University's physics and chemistry departments, together with companies including Epigem, continued to secure competitive research funding from European and national state sources to support collaborative research programmes (TSB 2009; Professor of Physics Durham University, Author's Interview 2011). To stimulate collaborative knowledge exchange and spillovers, the UK Displays and Lighting KTN (DLKTN), a replacement for the Flexynet group, remained central to the early development of the regional pathway with a strong contingent of North East-based organisations, including Thorn Lighting, Newcastle University, High Force Research, Epigem, Durham University and the Centre for Process Innovation (CPI) featuring prominently on the national network of 640 members (UK DLKTN 2010).

By the end of the decade intentional national institutional and political activities of key state government departments had placed plastic electronics as one of five key pillars of the TSB's UK Strategy for Electronics, Photonics and Electrical Systems (TSB 2014). The positioning and strategic value of plastic electronics to the UK economy was illustrated by the UK Government Council for Science and Technology (CST) advisory body that stated "as a disruptive technology, plastic electronics may create entire new industries" (CST 2007, p. 29). As one of a handful of emerging and potentially revolutionary technology-based industries identified in NINJ (2009), UK Government support for plastic electronics became wrapped up as part of the state's industrial policy activism agenda, with BIS earmarking a further £12m towards the expansion of the Plastic Electronics Technology Centre (PETEC) in Sedgefield, County Durham (see Chapter 5.2). Thus:

"the [Plastic Electronics] sector has already benefited from significant government support which has been well earned and well spent, and is completely justified by the stunning global opportunities for the UK in plastic electronics.... We propose an important role for government in supporting pilot projects [in the future]" (House of Commons 2009b, p. 234).

National politico-institutional support for plastic electronics culminated in the production of the UK's first plastic electronics strategy: *Plastic Electronics: A UK Strategy for Success* (2009). The strategy committed multi-scalar state actors to continue predominantly supply-side policy interventions through further investment in early stage R&D, enterprise activity through start-up and related firm diversification business support programmes, inward

investment, training and skills development programmes, and further multi-scalar networking and knowledge exchange activities (BERR 2009).

5.1.4 Summary: National Institutions Catalysing Path Development

This chapter examined and addressed the role social and institutional agents, and particularly the role of the national state and policy, played in animating and facilitating the ongoing development of the offshore wind and plastic electronic pathways in the North East. The path development of the offshore wind and plastic electronics industries during the temporal period highlighted and re-iterated the multi-faceted role socio-institutional agency and the national political economy performed in conditioning and catalysing new local and regional industrial trajectories as “producer, animateur, regulator and purchaser” at the macro-level (Morgan 2011). As a consequence, the regional offshore wind and plastic electronics trajectories were subject and underpinned by a decade of strategic “policy on” (Dawley 2013) interventions by national institutional and political actors which established, built upon and mediated niche management platforms from the previous temporal episode to stimulate and accelerate both industrial pathways during the first decade of the 21st century (Cooke 2012).

In a similar pattern to state-led industrial policy support to the oil and gas industry of the 1970s, the regional offshore wind pathway was recipient to prolonged national institutional and political industrial activism policy from 2000 (CEO ClipperWind Power, Author’s Interview 2011). Mirroring attempts by the U.S. government to establish an onshore wind turbine industry in the 1980s (see, for example, Garud & Karnoe 2001), the Labour Government’s approach was reminiscent of a “breakthrough” approach to developing a competitive domestic market structure through long-term planning and strategic industrial policy driven forward by the DTI (and later government departmental versions) and the UK Crown Estate’s Offshore Wind programme (Meyer & Schubert 2007). As a principal driver and market for the adoption of new renewable energy technologies, the UK Government fashioned the “rules of the game” (Gertler 2010) under which all other institutions operate, including initiating a series of supply and demand-side layers through the implementation of new rules, structures and procedures, such as the creation of legally-binding carbon emission targets, establishment of national institutional offshore wind actors, ROCs and tax benefits (Haar & Theyel 2006; Kern *et al* 2014). The development of the offshore wind pathway in the North East during the period restated the critical role investment subsidies, ROCs and tax

exemptions of renewable energy generators from the climate change levy performed as macro-scale enabling drivers for growth of the domestic offshore wind market during the decade (Markard & Peterson 2009). Coupled with national vertical industrial activism policy, the example of the UK Government demonstrated the critical role the state performed during the path development episode in nurturing transformative innovation by building pathways, enabling new markets and inspiring business confidence to firms entering and/or diversifying into the expanding regional offshore wind pathway (Haar & Theyel 2006; Scrase *et al* 2009).

In contrast to the offshore wind industry, the nascent condition of the plastic electronics industry witnessed state STI horizontal, supply-side policy embark upon a more advanced version of a “bricolage” strategy through the animation of loose couplings between multi-scalar institutions, actors and networks, underpinned by sustained UK Government fiscal stimulus in support of new knowledge, R&D and innovation (Garud & Karnoe 2003; Meyer & Schubert 2007). Illustrating an example of the “softer” (Storper & Walker 1989) role state institutions and policy can play in encouraging and building capacity of local and regional economic agents in emerging technology and industrial opportunities, the establishment of the national collaborative network Flexynet highlighted the inherent social processes and embeddedness of multi-scalar socio-institutional and political interrelations between actors to interact, exchange and produce knowledge, and foster new organisational and territorial partnerships (Argote *et al* 2000; Boschma 2004; Scrase *et al* 2009). To further accelerate the translation of applied science to industry, the temporal episode exhibited further strategic niche settings to incubate and stimulate the mechanisms within the North East’s plastic electronics pathway, including expanded financial support to collaborative R&D programmes between industry and academia, and strategic policy investment in the PETEC facility in order to build innovation capacity in the North East’s innovation ecosystem.

5.2. LOCAL AND REGIONAL INSTITUTIONAL ACTORS, FACTORS AND SETTINGS IN PATH DEVELOPMENT

5.2.1 Introduction

The 1980s and 1990s had marked a period in the North East’s history which exhibited an institutional and political vacuum at the sub-national scale in support of emerging industrial pathways, with local and regional institutional actors and policy largely constricting the

conditions and mechanisms of path creation in the evolving regional plastic electronics and offshore wind pathways. In contrast, the expansive period of national state-led market stimulus, enabling institutional frameworks and policy intervention to both pathways was reflected at a regional scale as devolutionary governance arrangements, powers and policy were passed down to the regional scale following the election of the Labour Government in 1997 (Tomaney 2006). As a result, ONE was created in 1998 ushering in a new period of purposive and “contextual policy support” (Asheim *et al* 2011) to the regional plastic electronics and offshore wind pathways through the establishment and delivery of the regional Strategy for Success (SfS) innovation programme (Hudson 2005; 2011). Reflecting a much altered role from the previous path creation phase of the importance of the role, type, influence and causal linkages between regional institutional actors, assets and strategic policy intervention in establishing an enabling territorial innovation environment in support of the developing pathways, the chapter analyses the contribution of ONE, local and regional institutional innovation assets and purposive policy intervention in fundamentally “changing the industrial structure of the region, through support for the strategic sectors” of offshore wind and plastic electronics (Technopolis 2008, p. 2).

5.2.2 Regional Institutions, Governance and Policy: One NorthEast’s Strategy for Success Programme

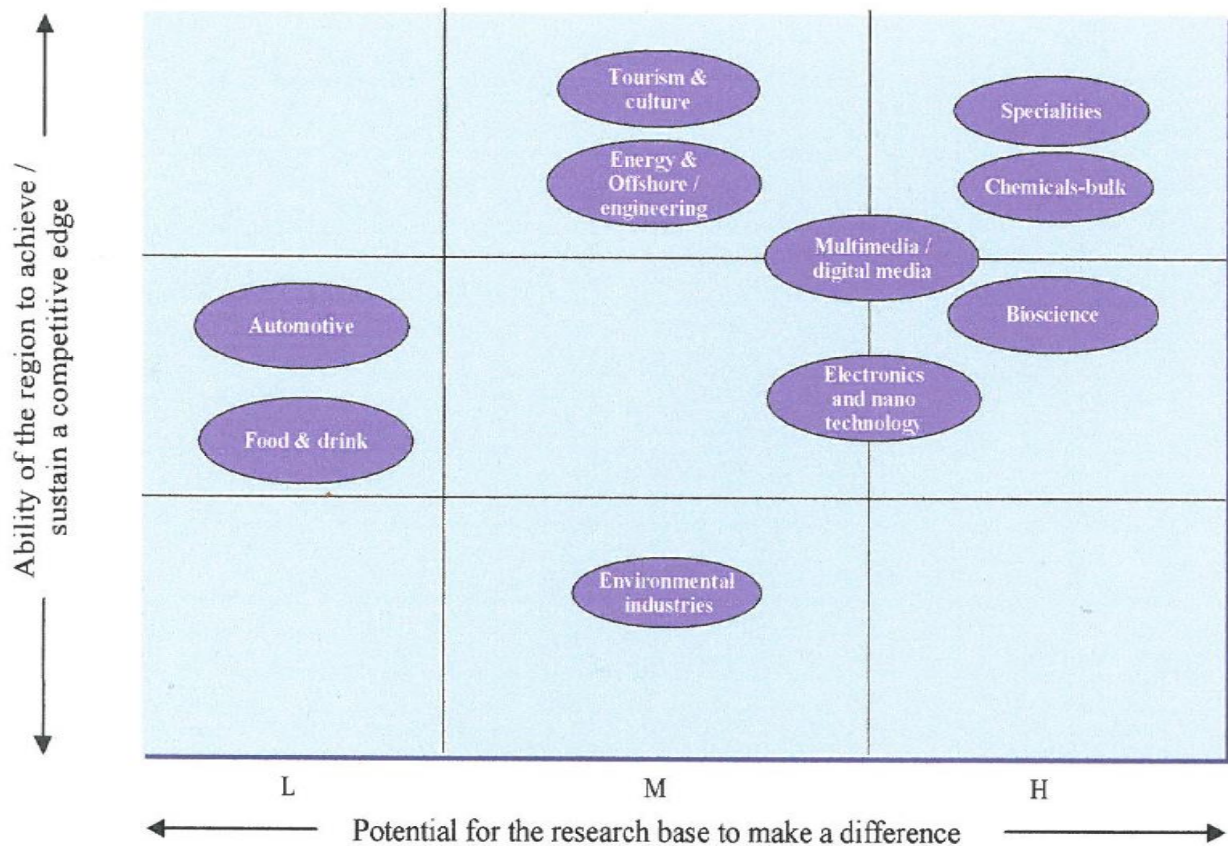
The introduction of ONE and integration of the SfS innovation programme into the politico-institutional fabric and innovation ecosystem of the regional economy coincided with a period in the history of the North East in which very little private sector R&D activity was left in the region, with companies including British Gas, NEI, ICI and Corus restructuring, fragmenting and/or divesting (Pike & Tomaney 1997; Tomaney 2006). Only small elements of the former ICI research centre at Wilton on Teesside and the Proctor & Gamble (P&G) technical facility in Newcastle were regarded as significant regional corporate R&D assets (ADL 2001). The level of private sector R&D activity remained the lowest in the country, whilst general levels of entrepreneurship and new enterprise formation, a clear legacy from a culture of “wage earner life-mode” (Illeris 1986) activity based on exogenous transplantation mechanisms, were particularly poor (Tomaney & Mawson 2000). In addition, the North East, at the beginning of the 21st century, possessed no major government or public sector technological and innovation assets, with only the Universities of Newcastle and Durham ranked in the “premier league” in research excellence terms (Hudson 2011).

To begin to address systemic socio-institutional and economic weaknesses in the regional economy, ONE commissioned consultancy firm Arthur D Little (ADL) to undertake a review of the North East's economy in relation to emerging technologies and industrial markets in 2001 (Hudson 2011). Reminiscent of evolutionary-inspired policy principles based on a “contextual approach” (Boschma 2013) and influenced by national government rhetoric on cluster theory and a recognisable shift towards territorial innovation policy at the local and regional scale, the ADL report (2001, p.6) sought to “identify current and future needs and trajectories of key industrial clusters” based on historical regional assets in transition to a new knowledge-based economy (Amsden 2001). For the developing offshore wind pathway in the region, offshore wind and high value engineering/energy was identified as a prospective driver of future regional economic growth based on recognisable academic research strengths at Newcastle University, an established and technologically related cluster of offshore fabrication and high-value engineering firms, and the successful demonstration of Blyth Harbour Wind Farm (see Figure 5.5). As the report stated:

“energy and engineering is particularly important to the North East because of the region's manufacturing heritage and, more recently, its prominent role in the North Sea offshore industry. Developments in marine systems and in highly reliable and robust engineering, brought about by the offshore industry over many years, can be applied to renewable sources such as offshore wind” (ADL 2001, p. 65).

Described as “visionary” (Head of Energy & Environment ONE, Author's Interview 2011), the ADL report was an important milestone in the formulation of regional policy in support of the developing offshore wind pathway as the findings connected evolutionary principles of diversification and related variety with past historical competencies, place-based assets and the “absorption of human capital” (Frenken *et al* 2008) left by heavy engineering and energy production industries to be recombined in pursuit of the new local and regional growth path (Director of Technology and R&D NaREC, Author's Interview 2012).

Figure 5.5 Early Sector Prioritisation in the North East



Source: ADL 2001, p.38.

In parallel to evolutionary-derived policy prescriptions in the offshore wind pathway, the ADL report (2001) identified nanotechnology, electronics and photonics (NEP), of which plastic electronics was one of several promising technology platforms championed by the Professor of Physics at Durham University, the Chief Scientific Officer of DuPont Teijin Films and the Head of Innovation, Industry and Science at ONE as a prospective niche technology opportunity for the North East (Chief Financial Officer CPI, Author’s Interview 2011). In similar ilk to the foundations supporting offshore wind pathway as a policy priority, the rationale was based principally on existent world-class research in materials, chemicals and polymers at Durham and Newcastle University’s, a technologically-related industrial base of chemical, electronics and printing firms, and historical technical assets left behind by ICI following the firm’s divestment in the previous temporal episode (ADL 2001).

Following on from the ADL report, and based largely on the evolutionary-derived policy recommendations, ONE initiated the start of a sustained period of purposive, experimental

and strategic regional policy activism by submitting the SfS innovation programme to the DTI for endorsement and approval in September 2001. At the time, the SfS programme was symptomatic of regional policymakers, particularly in peripheral regional economies, that began to develop strategies in order to build innovation systems for the purposes of economic resurgence. This was particularly true of the North East in light of a series of laboratory closures of former public and private sector knowledge-intensive corporations including British Gas (ADL 2001). Consequently, the published aim of the SfS was:

“to develop, based on existing strengths, leading expertise within the North East of England in emerging technologies for growing markets, and in the exploitation of those technologies” (Technopolis 2008, p.4).

Illustrative of evolutionary policy principles that recognise industrial change remains shaped by past and existing place-based actors, resources and assets, the SfS programme adopted an explicit regional innovation system (RIS) approach (Cooke *et al* 1997; 2002) by focusing on the endogenous development and support of five key industrial “pillars”, inclusive of offshore wind and plastic electronics (ONE 2001). In the context of the formation of socio-technical regimes within complex adaptive systems, the approach adopted by ONE demonstrated a “portfolio approach” (Boschma & Lambooy 2000) to niche path development in order to ensure “path flexibility” (Alhemade *et al* 2009) and refrain from having to “select winners” (Boschma 2004; Essletzbichler 2012).

Highlighting the purposive and innovative role and nature of regional institutional actors and policy during the temporal period in creating a science and innovation-based enabling environment and system for learning and innovation, the SfS programme created five centres of excellence (CoE) designed to link the university research base to industry and nurture those industries through a combination of sector-based development programmes (see section 5.2.3). At this juncture:

“the North East was in the midst of a dramatic shift in the regional policy framework [moving] away from traditional instruments and approaches towards recognition of the importance of innovation” (Charles 2008, p. 8).

Having obtained political approval from central government and regional stakeholders, ONE invested £103m as part of the initial R&D “capacity-building phase” of the SfS programme between 2002 and 2005 (Head of Energy & Environment ONE, Author’s Interview 2011). In the context of the developing offshore wind and plastic electronics pathways in the North East, £23.5m was expedited to the energy and environment pillar to support the creation and scale-up of NaREC and £23.9m was injected into CPI and the Centre of Excellence for Nanotechnology and Micro Photonic Systems (CENAMPS) to stimulate and support the regional printable electronics pathway (ONE 2006a; ONE 2011b) (see section 5.2.3). As a result, targeted regional policy intervention by ONE had:

“played an important role in providing significant investment and taking a large degree of risk in pump priming new industries and regional economic opportunities...the private sector wouldn’t take the risk and without it there was no basis for stimulating change’ (Area Regeneration Manager Northumberland County Council, Author’s Interview 2011).

The remainder of ONE’s period of targeted and directed policy of R&D and innovation capacity building witnessed continued investment in revenue-based R&D programmes, investment of capital into “strategic innovation hubs” (Head of Innovation, Industry & Science ONE, Author’s Interview) and business support to established clusters across the North East (Hudson 2011). In the growing regional printable electronics pathway, the SfS programme continued to enhance early-stage innovation capacity in NEP technologies. In particular, ONE directed policy and interventions through the scale-up of CPI and CENAMPS, and financially-backed university-based R&D facilities and research programmes, including injecting £4.6m into the DTI-backed University Innovation Centre (UIC) in Nanotechnology at Newcastle University (ONE 2011b).

Similarly, to build upon “regional competitive advantage” (Pike *et al* 2006) in the burgeoning UK offshore wind industry, contextual regional policy intervention continued to focus on supply-side interventions in R&D facilities, including investment in a series of “strategic regional energy centres” at Durham University Energy Institute for turbine reliability and condition monitoring, £1.16m to The Welding Institute for turbine aerodynamics and materials research, and the ongoing build of large-scale capital assets at NaREC (ONE 2011b; Director of Business Development Shepherds Offshore Services, Author’s Interview

2011). Moreover, in support of the wider renewable energy ecosystem, ONE built additional capacity in the “regional learning network” by building on the initial momentum created by the NEEC in the previous path creation episode to form the North East Energy Leadership Council (NEELC) and expand the role and remit of NOF Energy to support engineering and manufacturing firms, typically supplying the oil, gas and nuclear industries, to stimulate mechanisms of diversification and branching into the North East offshore wind pathway (Lewis & Wiser 2005).

In parallel to ONE’s R&D approach, the rationalisation of the Sfs programme in 2005 as a result of external evaluation and recommendation to migrate from capacity-building to project delivery phase coincided with the development of a territorial industrial strategy for plastic electronics and offshore wind which concentrated on the mechanisms of variety, branching and transplantation (Head of Energy & Environment ONE, Author’s Interview 2011; Dawley 2013). In the context of the North East offshore wind pathway, the change of approach by ONE was partly prompted by national political actors who reaffirmed the state’s commitment to producing one-third of the UK’s electricity from renewables by 2020 by imposing a series of regional targets for renewable energy deployment in local and regional communities (Essletzbichler 2012). Following the announcement of the UK Crown Estates Round 3 offshore wind programme and recognising the scale of the opportunity for the North East which could “feasibly capture 50% of the total job creation implied by the growth in UK offshore wind power, or 35,000 to 40,000 jobs by 2020” (Greenpeace 2004, p.18), ONE created a dedicated offshore wind team in an example of institutional conversion (Martin 2010) in order to support the mechanisms of transplantation by capturing one of the dominant European offshore wind turbine manufacturers (Business Development Manager Siemens Wind Power, Author’s Interview 2012). As a result, ONE’s offshore wind team embarked upon a series of business networking events in tandem with NOF Energy and NaREC to stimulate mechanisms of transplantation, variety and related variety by targeting companies with related technologies and/or services that possessed the potential to branch into the growing offshore wind industry. Led by Ray Thompson, the offshore wind team’s previous industry experience was critical in providing institutional leadership and strategic focus as “knowledgeable agents” (Simmie 2012) in recombining expertise from past and current sectors in facilitating and supporting firm diversification and branching activities (Business Development Manager Siemens Wind Power, Author’s Interview 2012; Dawley 2013).

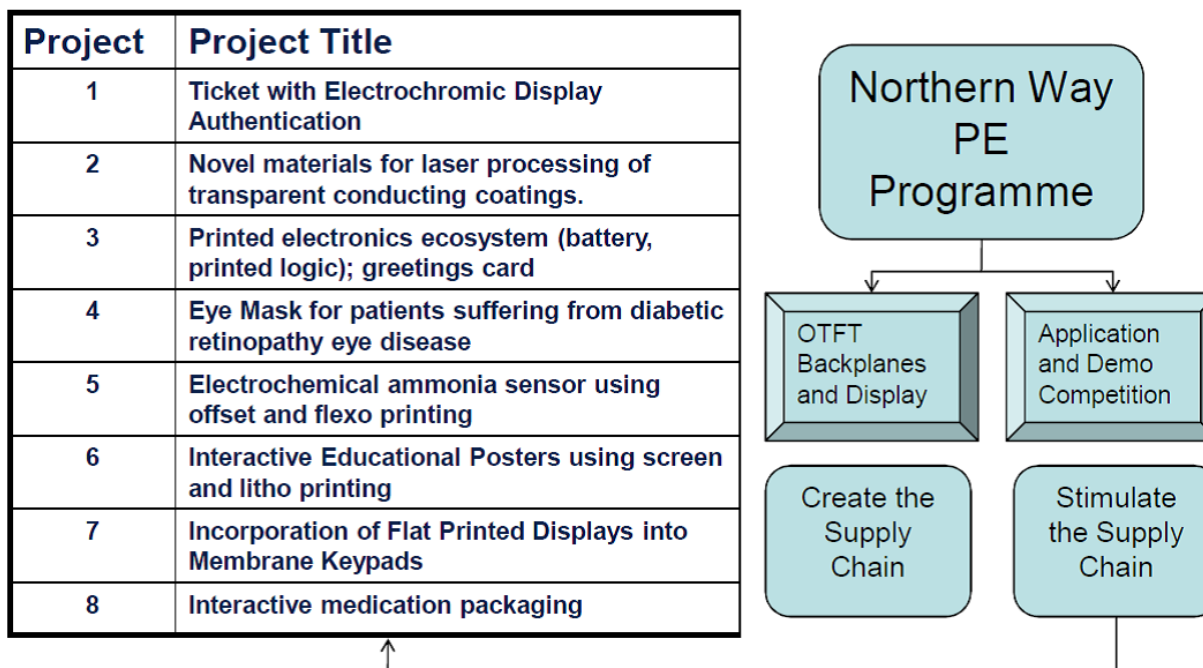
Analogous to the Sfs' "technology push" R&D and innovation-based policies which had provided a supportive and enabling institutional environment within the plastic electronics pathway in the North East, ONE, in tandem with the Northern Way, a pan-Northern RDA initiative with the objective to support innovation and economic development across the three Northern regions, entered a period of purposive pan-regional industrial policy intervention through the creation and implementation of the Northern Way Innovation Programme (NWIP) plastic electronics initiative (Goodchild & Hickman 2006). Highlighting the role of practitioners and policy intervention in shaping and stimulating path creation and development mechanisms, the purpose of the NWIP plastic electronics programme was the deliberate attempt by strategic agency to create an embryonic supply chain across the three Northern regions by supporting mechanisms of diversification and branching of firms from the process industries, printing and electronics sectors to develop new or reconfigure existing practices to develop novel materials, substrates and prototype devices (PHS Consulting 2008; Senior Specialist Advisor Northern Way, Author's Interview 2012) (see Figure 5.6). Indeed, the NWIP plastic electronics programme restated the importance of geographical proximity between firm and non-firm actors in establishing interdisciplinary research and commercial collaborations (Singh 2005). In total, £5.7m was allocated to five firms in the North of England, with DuPont Teijin Films, High Force Research and James Robinson in the North East recipient of R&D funding to stimulate new process development, chemical synthesis, and the scale-up of organic semiconductor materials (Senior Specialist Advisor Northern Way, Author's Interview 2012). In the example of High Force Research, regional institutional agents and targeted policy intervention had been significant in enabling the firm to branch into the emerging plastic electronics pathway. As such:

"we have been a speciality chemical firm based in Durham for over 20 years and our focus has always been to provide contract research services mainly to the pharmaceutical industry. What the Northern Way did for us was get us into a new area that we didn't know anything about but it's the same core skills that we use for doing pharmaceutical process and product development...so it opened us up to a new business area and one that we were confident in which the market was going to grow" (CEO High Force Research, Author's Interview 2011).

To ensure "market pull" was in parallel with technology push policy, the NWIP plastic electronics programme leveraged MNC's in the North East, including GlaxoSmithKline and

P&G, to act as technology development partners and provide end-purchaser insight into R&D projects (Senior Specialist Advisor Northern Way, Author’s Interview 2012). As a consequence, intra and inter-regional collaborations, orchestrated by ONE and the Northern Way, between academia, industry and the CoE, had “galvanised interest in plastic electronics” (Technopolis 2009b, p.3) across the North East, leading to approximately 40 businesses entering and diversifying into the regional plastic electronics pathway by the end of the decade (SQW Consulting 2011).

Figure 5.6 Northern Way Pan-Regional Printable Electronics Policy and Delivery Programme



Source: SQW Consulting 2011, p. 87.

5.2.3 Regional Centres of Excellence, R&D and Innovation

To remedy the “regional innovation paradox” (Oughton *et al* 2002) in the North East, exhibited by a strong academic research base (the “supply side”) poorly matched to regional industrial needs (the “demand side”), NaREC, CPI and CENAMPS were originally established as key components of ONE’s Sfs R&D programme and important “external intermediaries” in supporting the mechanisms of path development within the offshore wind and plastic electronics pathways in the North East (Goddard *et al* 2012). Adopting a mixture of capital and network-based business models, the CoE reflected distinct characteristics of the

technologies and sectors that they were intended to support (Hudson 2011). Each centre was established as not a not-for-profit enterprise receiving co-investment from European Regional Development Funding (ERDF) matched by ONE Single Programme funding under the strategic direction of the newly formed North East Science and Industry Council (SIC). To strike a balance between corporate autonomy and delivery of “public good” on behalf of the region, each CoE appointed a high-profile senior management team drawn largely from industry and established an independent board with ONE retaining legal step-in rights for security of public investment (Innovation Manager ONE, Author’s Interview 2011).

Offshore Wind Pathway: NaREC

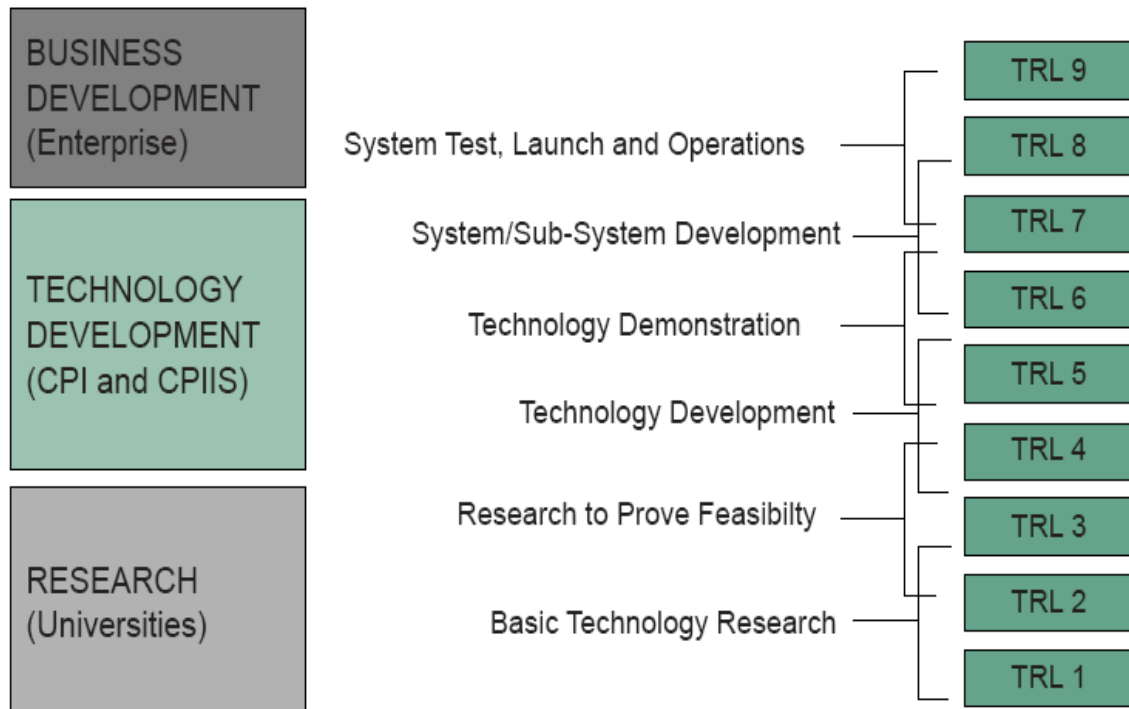
In the context of the path development of the regional offshore wind pathway, the original concept and mission of NaREC was predicated on the provision of physical innovation assets, including the construction of blade and gearbox testing facilities and services to the offshore wind and wider renewable energy industry. Connecting pre-existing variety to market-based selection mechanisms, the role of ONE was important in mediating the interaction as:

“we [ONE] researched similar global facilities and all of them operated capital equipment and large testing assets...[but] recognising the capital-intensive nature of the renewable energy industry it was considered that regional, national and overseas firms would gain benefit from access to pre-commercial facilities in order to take the technology to the next level and there was no existing UK facilities doing that” (Head of Energy & Environment ONE, Author’s Interview 2011).

In the centre’s infancy, NaREC’s business model proposed close linkages with the upstream innovation chain of Newcastle University’s School of Marine Sciences and Technology, Engineering Design Centre, Resource Centre for Innovation & Design, and Durham University Energy Institute (Head of Energy & Environment ONE, Author’s Interview 2011). Indeed, both universities lobbied extensively within regional state institutions for NaREC to be subsumed into the region’s HEI architecture reflecting the notion at the time that academia would be a major user of equipment and facilities (Director of Business Development Shepherds Offshore Services, Author’s Interview 2011). Nevertheless, NaREC was established as a stand-alone company limited by guarantee with the overriding aim of acting as a bridge between scientific research and commercialisation, and becoming a central node

in stimulating and supporting mechanisms of firm diversification, indigenous firm growth and transplantation (RES 2003; Head of Energy & Environment ONE, Author’s Interview 2011; Hudson 2011) (see Figure 5.7).

Figure 5.7 'Bridging the Gap' between Research and Commercialisation



Source: House of Commons 2009c, p.33.

ONE identified the coastal town of Blyth in Northumberland as the geographical location to situate NaREC, heavily influenced by the entrepreneurial endeavours, identity and profile of David Still, Borderwind and Blyth Offshore Wind Farm which linked:

“the demonstration effect of the early path creation phase with the ensuing period of policy activism” (Dawley 2013, p.103).

The rationale for locating NaREC at Blyth was influenced, contingent and benefited from a distinctive set of inherited local institutional, economic and physical assets left behind from the previous path creation episode and earlier rounds of industrial activity, including existing electrical cabling to the National Grid network and the availability of land with the potential for expansion (Simmonds & Stroyan 2008; Head of Innovation, Industry & Science ONE, Author’s Interview 2011; Plummer *et al* 2013). Despite NaREC positioning itself as a

technology and innovation testing facility for the full gambit of renewable energy technologies, NaREC's location was particularly conducive to developing and deploying offshore wind turbine systems based on a combination of place-based assets and geographical advantages, including access to a coastal wind turbine test site, a historical legacy from the early path creation phase of onshore turbine deployment at Blyth, a former offshore research centre operated by EEST, existing deep sea water port infrastructure at the Port of Blyth, and geographical proximity to the North Sea for the purposes of offshore wind turbine deployment (Charles 2008; CEO ClipperWind Power, Author's Interview 2011; Head of Energy & Environment ONE, Author's Interview 2011).

Plastic Electronics Pathway: CENAMPS, CPI and PETEC

The second CoE to be formed by ONE to enable and boost the embryonic plastic electronics pathway was the creation of CENAMPS. Connecting to the earlier path creation phase and the "systemic failure" (Laranja *et al* 2008) in the regional plastic electronics innovation system observed and highlighted by institutional actors within the North East, the aim of CENAMPS was to stimulate academic research and de-risk commercial R&D, primarily in plastics and electrically conductive materials, by sponsoring applied research and building new small-scale test and pilot-scale manufacturing facilities in partnership with regional academia and the private sector (Former CEO CENAMPS, Author's Interview 2011). Comprising a small team of staff, including the former Finance Director of Atmel Corporation, who had transferred occupations to become interim CEO of CENAMPS and thereby demonstrated the significance of "key entrepreneurs and industry figures in making use of new and/or existing resources to seize emergent niche market opportunities" (Isaksen 2011, p. 295). The mandate of CENAMPS to stimulate NEP technologies was radically different to the economic development approach and chequered history the North East had encountered with the semiconductor industry representing a conscious decision by strategic agency to:

"move away from attracting conventional silicon-based semiconductor investments and overseas electronics firms which the likes of Siemens had come into region, taken lots of time and money from government authorities to set-up, quit and then moved out of the region leaving empty manufacturing sites and hundreds unemployed "

(Chief Financial Officer CPI, Author's Interview 2012).

In the context of the North East's plastic electronics pathway, the new *modus operandi* placed Durham and Newcastle University's at the crux of a new regional science and innovation-based approach to new industrial path creation and development by building institutional capacity with HEI's in existing research capabilities and developing closer and deeper collaborative research linkages with North East-based firms. For example, CENAMPS directed investment into diversifying the research and physical asset base of the School of Electrical, Electronic and Computer Engineering at Newcastle University and building technical capacity in the Chemistry department at Durham University in order to expand and influence the research direction, facilities and profile of the PMI under the continued stewardship of the Professor of Physics (Former CEO CENAMPS, Author's Interview 2011). The approach adopted by ONE was in stark contrast to past models of the 1990s in which local and regional state institutions mobilised indigenous resources around external FDI (Charles & Benneworth 1999, Dawley 2001; Dawley & Pike 2001). Consequently, CENAMPS was tasked with stimulating the internal knowledge base, generating and supporting University spin-out enterprises, and supporting existing technology-related businesses with access and technology transfer of new knowledge, technology and innovation (Professor of Physics Durham University, Author's Interview 2011).

The third CoE formed by ONE during the Sfs programme, and second in relation to connecting the predominantly upstream research activities of CENAMPS with the downstream innovation and commercialisation by industry within the regional plastic electronics pathway, was the establishment of CPI. Following a similar capital-based business model to NaREC, CPI was formed with the initial objective to create technology platforms in industrial biotechnology, advanced processing and sustainable energy from which knowledge, skills and expertise of industry and academia could come together in collaborative projects (Goddard *et al* 2012). In a further example of "re-bundling" of past and local physical assets, the former UK headquarters of ICI's plastics and advanced materials division in Wilton, Teesside was acquired by ONE to form the hub for the new centre (Bathelt & Boggs 2003). Along with "restructuring" (Bathelt *et al* 2011) existing R&D facilities left by ICI at the Wilton Centre towards new materials technology and new chemical processing techniques, CPI appointed former ICI employees to senior management positions within the company ensuring that knowledge, skills and "relational capital" (Capello & Faggian 2005) was transferred from ICI to CPI in order to develop and exploit the

Centre's long-term technology roadmap for plastic electronics (Business Development Manager PETEC, Author's Interview 2011).

Following the initial creation of the CoE in 2002, the ensuing period witnessed continued institutional and infrastructural capacity building in the CoE and, to a lesser extent, the regional academic base by ONE. From an operational perspective, the CoE were encouraged to establish extra-regional linkages with the wider national and international offshore wind and plastic electronics industries in order to generate consultancy revenue and contract R&D testing as part of the long-term objective to become self-sustainable (Hudson 2011; Head of Innovation, Industry & Science ONE, Author's Interview 2011). With NaREC and CPI carrying an increasingly extra-regional remit, the centres, along with CENAMPS, were joined by a fourth centre in 2006: PETEC. Ultimately established as a product of transplantation elaborated on further in Chapter 5.3, several prominent North East-based "champions of industry", including the Chief Scientific Officer of DuPont Teijin Films and the Research Team Lead at Thorn Lighting, lobbied within regional and national state institutions for the North East to establish an R&D facility illustrating the multi-scalar distributed nature of networks in fostering and driving economic development at the local and regional level (Chief Scientific Officer DuPont Teijin Films, Author's Interview 2012). Underlining the multidisciplinary nature of plastic electronics innovation or so-called "mode two science" (Gibbons *et al* 1994), with the often requirement for new organisational and institutional forms unencumbered by traditional disciplinary boundaries in the creation and development of new disruptive technologies, the ambition for PETEC was to bring together academia and industry to create:

"a regional centre and flagship national asset providing world-class facilities, services and expertise at the centre of a UK-wide network in plastic electronics, on a cost-effective and open-access basis" (ONE 2006b, p.1).

Having secured investment of £12m from state actors and European sources, including £3m from Durham County Council, the PETEC facility was officially opened in March 2009 at the North East Technology Park (NETPark) in Sedgefield, County Durham (ONE 2006a). Operated by CPI, the new centre's mandate was to stimulate and support the mechanisms of variety and branching amongst the process industries, electronics and printing industries of the North East through a series of targeted business intervention programmes and

engagement events (Director of PETEC, Author's Interview 2011). In the context of the emergent plastic electronics pathway in the North East, by the end of the decade the origins of PETEC had ultimately transferred from an intended strategic asset in the attraction of exogenous manufacturing investment to become a significant regional innovation node in supporting the territorially specific processes of innovation, variety and branching at the local and regional scale.

The culmination of ten years of purposive policy and injection of approximately £140m in direct intervention in the North East's innovation ecosystem by ONE had created two regional innovation centres enabling the plastic electronics and offshore wind pathways to develop and grow (Perry 2007; Technopolis 2008). With respect to stimulating and supporting the development of both pathways, the CoE performed a number of roles and contributions to the positive developmental trajectory of both pathways. Importantly, the CoE were physical innovation assets and infrastructure rooted in the North East possessing the capability to build collective action and reduce uncertainty in the contextual, territorially-specific processes of innovation (Storper 1997; Cooke & Morgan 1998). In short:

“the RDA certainly got its act together by developing NaREC, as it did a few years ago. It was absolutely crucial for, and far-sighted of, the Agency [ONE] to support that, underpinned by the science, industry and innovation strategy in the region” (House of Commons 2009c, p. 38).

The decision to establish CENAMPS, CPI, NaREC and PETEC was vital in supporting knowledge, innovation and learning at the local and regional level ensuring a sense of “local buzz” (Bathelt *et al* 2004) and “stickiness” emerged within and between multiple firm and non-firm actors within the regional plastic electronics and offshore pathways (Patel & Pavitt 1991). The decision to establish PETEC in the North East was particularly important to the regional plastic electronics pathway given the polarisation of opinion by extra-regional actors from the state, industry and academia in locating the CoE in the region. Indeed, the strength of feelings on the subject subsequently surfaced in a UK Government Science & Innovation Select Committee Review which noted that:

“PETEC's location is a function of the fact that it was established as a regional initiative. It is an open question whether PETeC would have been sited elsewhere had

it been founded as a national resource, something that it undeniably is. However, we do not see further discussion on this issue as constructive or worthwhile, and wish to see a line drawn under the debate” (House of Commons 2009a, p. 4).

Even within the North East the destination to locate PETEC at NETPark came under scrutiny with the decision to build a new purpose built facility rather than acquire and reconfigure the former Filtronic semiconductor fabrication facility at Newton Aycliffe considered a missed opportunity to recombine an inherited regional asset into generating new rounds of investment (Research Team Lead Thorn Lighting, Author’s Interview 2011). Nevertheless, by the end of the decade both NaREC and CPI were recognised as significant R&D assets in a review of major innovation assets in the North of England’s sub-national innovation system (SQW Consulting 2008; OECD 2008). As such, strategic and purposive policy intervention by ONE had built institutional and innovation capacity in the pathways through processes of recombination and institutional layering providing the region with first mover advantage within those emerging and developing global industrial pathways (Goddard *et al* 2012).

5.2.4 Summary: Local and Regional Institutions Enabling Path Development

Following the devolution of national state powers to regions under an increasing neo-liberalist political framework, the introduction of RDAs marked a radical shift towards building sub-national institutional capacity in comparison to the previous path creation phase. As a consequence, the beginning of 2000 marked the start of a sustained period of regional policy activism to the endogenous development of local and regional economies in the English regions (Hudson 2005). Based on the evolutionary-inspired strategic and policy recommendations of the ADL report which had championed for the North East to base any future regional economic development strategy on the importance of knowledge creation and innovation, ONE instigated a decade-long period of regional contextual, experimental and inventive policy support to the offshore wind and plastic electronic industries based largely on recombining past historical assets and place-based capabilities into new industrial growth paths (Goddard *et al* 2012). Set within a supportive national institutional and “political framework” (Benneworth 2001), and influenced by dominant RIS approaches to create an enabling environment for new technology and industry creation, ONE initiated the SfS programme as the principal delivery vehicle to transition the North East towards a “knowledge-based economy” (ONE 2006a). As the largest regional innovation initiative

amongst the RDAs, the SfS programme concentrated regional policy intervention on a blend of risky but calculated technology-push R&D and industrial policy through direct investment of over £130m in building institutional and innovation capacity in the offshore wind and plastic electronic pathways. In so doing, the SfS programme built physical innovation assets, upgraded R&D capabilities of existing non-firm knowledge-intensive institutional agents and enhanced local and regional collaborative networks in order to stimulate and support the mechanisms of transplantation, variety, indigenous creation and branching (Amin 1999; Puffert 2001; Goodchild & Hickman 2006). In short, the period had highlighted the importance of regional institutional actors, and particularly the state and purposive policy intervention based on platform policies and technology-push innovation, to stimulate and provide the contextual conditions for firm and non-firm actors within the offshore wind and plastic electronics pathways to explore niche window of opportunities within the expanding markets (Scott 1988; Storper & Walker 1989; Boschma & van der Knaap 1997).

As primary catalysts to address the “system failure” (Boschma 2009) and support the “phoenix industries” (Todtling & Trippel 2004) of offshore wind and plastic electronics in the North East, CENAMPS, PETEC, NaREC and CPI represented a bold move by ONE to construct a series of “regional innovation assets” (Coe *et al* 2004) situated in the North East based on the recombination of latent assets and creation of new organisational forms (Bathelt & Boggs 2003; Bathelt & Spiegel 2010). In both pathways, the role played by individuals and “novel agents” (Morgan 2012) embedded in multi-scalar social and institutional networks and settings to stimulate, attract and support additional technological and innovation capacity for the North East was important (Gluckler 2007). For the regional offshore wind pathway, multi-scalar state intervention in NaREC had been a “proactive investment seeking to create a new industrial path in the region” (Goddard *et al* 2012, p. 23) by stimulating the candidate mechanisms of transplantation and diversification to reposition the North East within the evolving global offshore wind innovation and industry supply chain (Henderson *et al* 2002). Similarly, state actors at the local and regional scale and intentional policy intervention to support the embryonic plastic electronics pathway had “re-bundled” and constructed a series of regional technical innovation centres within the territorial innovation ecosystem in enhancement of the ongoing paths development (Bathelt & Boggs 2003). By the end of a decade of intentional activity by strategic agency and direct policy action, NaREC, CPI and PETEC were considered UK success stories, forming a central axis in the rapidly evolving

regional pathways and shaping future national innovation and industrial policy (Technopolis 2008; Hauser 2009).

5.3. PATH DEVELOPMENT MECHANISMS

5.3.1 Introduction

Unlike the previous path creation episode, the mechanisms stimulating the rapid growth in the offshore wind and plastic electronics trajectories in the North East had been enabled by a sustained period of multi-scalar policy activism. Illustrating the role and impact of the state, quasi-state, external intermediaries and local and regional policy intervention in mediating the unfolding and expansion of the pathways, this section analyses the contribution those multi-actors at multi-scalar levels played in accelerating the mechanisms which underpinned the conceptual path development phase in the regional plastic electronics and offshore wind pathways (Martin 2010). In addition, the section also provides further analytical clarity of the operation of the mechanisms, and importantly, sheds light on the interconnectivity between mechanisms across the path creation and current path development phase in collectively building economic momentum of both growth paths in the North East.

5.3.2 Indigenous Creation

Unlike the previous temporal period which exhibited and highlighted purposeful entrepreneurial deviation in processes of path creation, local and regional entrepreneurial activity amongst firm actors in the regional offshore wind pathway throughout the ensuing decade remained limited. Despite the creation of NaREC to address the regional innovation paradox and act as a connective node and stimulant between academia and the local and regional industrial base, the temporal episode highlighted ongoing challenges faced by the CoE in support of the offshore wind industry because of limited absorptive capacity and initial high fixed capital costs for new enterprises with aspirations to provide core offshore wind components to the sector (Head of Energy & Environment ONE, Author's Interview 2011). Consequently, indigenous firms formed during the period were predominantly concentrated at the early technical planning, consent and R&D phase or at the end installation, O&M stage of the supply chain continuum. For instance, Evolving Generation Ltd was spun-out of Durham University to commercialise a novel direct drive train for

offshore wind turbines (Head of Business Development Durham University, Author's Interview 2013). The spatial concentration of R&D intensive firms in geographical proximity to public innovation assets was similarly mirrored by Wind Power Ltd which co-located the start-up company at NaREC headquarters in order to access technical personnel, test facilities and leverage the CoE to secure ONE R&D grant funding to design, develop and prototype an offshore vertical axis turbine (NaREC 2013). Several dedicated technical consent and planning consultancies to the offshore wind industry were also established during the period including Blade Offshore Services Ltd and Paul Wurth UK Ltd (TVLEP 2013). At the other end of the supply chain, the North East became host to several new O&M start-up firms, including Sts Resources and Technology and Aag Swepeco, which disproportionately concentrated business activity in and around regional portside sites in order to be in close proximity to existing facilities, labour and offshore wind farm sites in the North Sea (Technopolis 2008).

Unlike the offshore wind industry, entrepreneurial and indigenous firm dynamics in the plastic electronics pathway in the North East was solely predicated on geographical proximity to regional innovation actors in order to access key people, technology assets and benefit from “untraded interdependencies” (Storper 1995). Indeed, the rationale for the creation of CENAMPS, CPI and PETEC was on the basis that the CoE's were originally tasked with generating and supporting the mechanism of indigenous firm creation, reflecting the notion that regionally rooted and embedded technology and innovation assets was critical for creating local positive externalities and intra-regional spillovers (NESTA 2008; Neffke *et al* 2009; Head of Energy & Environment ONE, Author's Interview 2011). Thus, in the example of CENAMPS:

“the focus was very much on trying to support start-ups and spin-outs, particularly emanating out of Durham University and Newcastle University...the characteristics of the [plastic electronics] industry in those early days was very entrepreneurial with new companies starting-up or spinning-out of the major academic centres and recognised technology clusters in the UK...Durham and Newcastle [University's] had some real strength in this emerging space and CENAMPS' role was to capitalise on it” (Former CEO CENAMPS, Author's Interview 2012).

As a consequence of the role and influence of the centre's on indigenous firm dynamics, start-up organic light emitting diode (OLED) lighting company Polyphotonix was formed at PETEC in 2008 following equity investment from CPI and two innovation grants from the TSB (CEO Polyphotonix, Author's Interview 2012). The decision to co-locate the business at NETPark provided the company with direct access to specialist facilities and human resources for the company's organic lighting technology (CEO Polyphotonix, Author's Interview 2012). The importance of spatial proximity for building up "trust and tacit knowledge sharing" (Morgan 1997) was important to Polyphotonix and also evident in the decision by start-up electronic packaging company Mixicap to establish the company in the North East in 2009 to take advantage of skilled and experienced staff, equipment and cleanroom facilities at PETEC (CEO Mixicap, Author's Interview 2012). Nevertheless, despite the creation of several promising technology-based indigenous businesses, Polyphotonix and Mixicap remained the only two core plastic electronics firms that were created in the North East during the time period.

5.3.3 Technology Relatedness and Related Variety

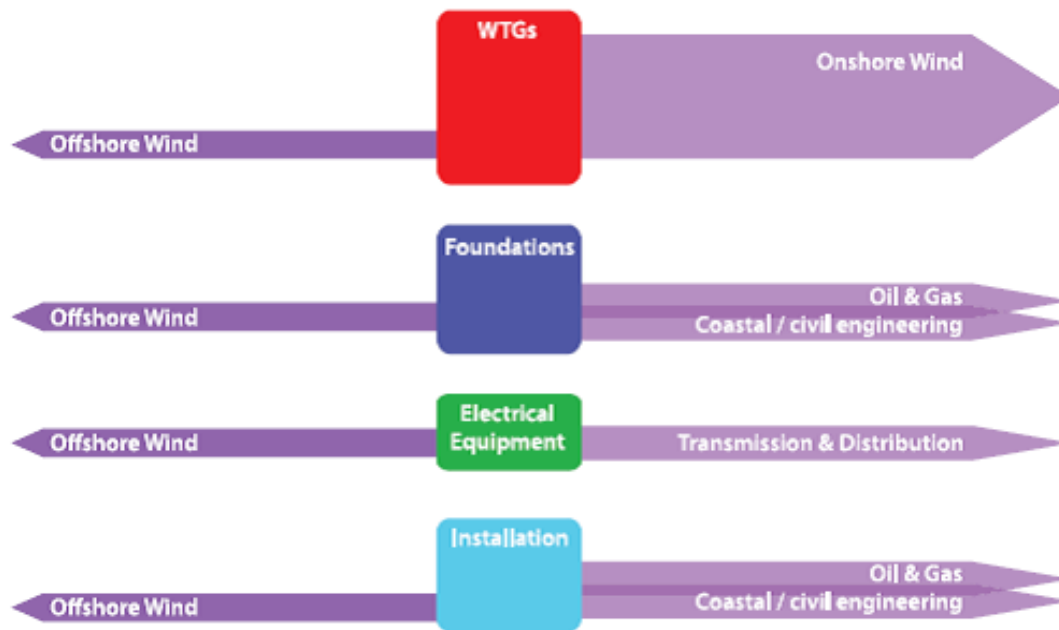
The early period in the regional offshore wind and plastic electronics pathways followed a similar pattern and characteristics to the previous path creation episode. The volume of companies diversifying from multiple local and regional industries into the offshore wind pathway remained low and those that did so possessed a related knowledge base and technological competencies (Jay & Jeffrey 2010). For instance, AMEC possessed strong competitive advantage through expertise in North Sea oil and gas drilling and through the acquisition of Borderwind in 2002 allowed AMEC to begin the branching process as:

“one of the first oil and gas providers to expand into wind energy and to respond positively to the government's recently announced commitment to developing wind energy projects” (AMEC 2000).

During the same timeframe, sharp spikes in global oil and gas commodity prices illustrated in Chapter 5.1 acted as an exogenous catalyst for local and regional firms, predominantly from related industries, to diversify into the offshore wind market and temporally de-lock from existing path dependencies (David 1988; Arthur 1994). As a consequence, the external shock to the oil and gas market accelerated and stimulated local and regional positive “cross-path

effects” between the oil, gas, engineering and advanced manufacturing sectors into the North East offshore wind pathway (Scheinberg 2007) (see Figure 5.8). In many respects, the transition to alternative path trajectories reflected the notion and practices of “adaptation” and “resilience” within local and regional industrial evolution (Pike *et al* 2010).

Figure 5.8 Technology Relatedness and Path Interdependencies between Offshore Wind and other Industrial Sectors



Source: BWEA 2009, p.5.

As previously indicated in sub-sections 5.2.1 and 5.2.2, to accelerate adaptation, diversification and branching amongst the local and regional industrial base ONE’s creation of NaREC resulted in the acquisition of a series of dock and shipbuilding infrastructures, beginning with the conversion of a marine test site previously owned by the nationalised gas industry into an offshore energy testing facility (see Figure 5.9) (Director of Business Development Shepherds Offshore Services, Author’s Interview 2011). Further physical reconfigurations of several disinvested technology facilities by NaREC followed, including the construction of a 70m offshore wind blade test facility in a former shipyard fabrication shed (NaREC 2013). Similarly, the reconversion of the Euroseas centre, which had previously hosted EEST and housed a number of business support service firms to the offshore energy industry, into NaREC headquarters was particularly important in connecting the expanding regional offshore wind pathway with the mechanisms of variety and branching

(Boschma & Frenken 2009). As such, current occupant CAPCIS, an advanced materials consultancy and testing company to the oil and gas industry which had been previously overseen by the Head of Innovation, Industry and Science at ONE and whom became responsible for setting the regional strategic direction of ONE's renewable energy programme, began to explore technology branching opportunities into the regional offshore wind pathway (Boschma & Frenken 2008; Head of Innovation, Industry & Science ONE, Author's Interview 2011). The example illustrated the importance of key local actors in both firm and non-firm settings in recombining knowledge and experience to stimulate and diversify into new but related economic pathways (Garud *et al* 2010).

Figure 5.9 Recombination and Diversification of Physical Assets into Related Rounds of Industrial Activity



Source: NaREC 2012

In parallel to the Sfs' R&D programme, ONE's offshore wind team instigated regional policy interventions based on the principles of diversification and related variety through the initiation of a regional business support programme, primarily targeted at oil, gas and offshore fabrication sectors, but also as diverse as insurance, finance and legal firms, to raise market awareness of commercial opportunities available to industry through the Round 3 offshore wind programme (Business Development Manager Siemens Wind Power, Author's Interview 2011; Dawley 2013). Recognising the important ways policy practitioners can bridge the gap between firm and market selection mechanisms by supporting knowledge transfer between related sectors, Ray Thompson played a particularly prominent role in

stimulating some of the largest diversification projects in the North East. For instance, Tees Alliance Group Energy Solutions (TAG ES) diversified away from constructing oil and gas drilling rigs and opted instead to invest in a tubular production facility in Billingham, Teesside for the construction of steel foundations for turbine manufacturers as a direct result of regional state intervention (Boschma & Frenken 2009; Garud *et al* 2010; Asheim *et al* 2011; CEO TAG ES, Author's Interview 2011). Having been encouraged of the market potential and demand for 8 million tonnes of steel foundations required for Round 3 by ONE's offshore wind team, TAG ES secured £17m in venture capital backing alongside £3m in public sector grant funding to convert and recombine a derelict shipyard previously owned by shipbuilding firm Swan Hunter into a 100,000te steel foundation production facility on the banks of the River Tees (Garud *et al* 2010; CEO TAG ES, Author's Interview 2011). In this regard, experienced entrepreneurs, such as the CEO of TAG ES, played an important function as cross-sector "mutation agents" in transferring skills, assets and networks from the oil and gas sector to the evolving regional offshore wind pathway (Cooke 2010).

With global carbon-based energy markets continuing to plummet and the mobilisation of state actors and active regional industrial and R&D policy to enable the path development of the offshore wind industry, the regional pathway began to climb an upward trajectory demonstrated by increasing regional "inter-sectoral linkages" and spillover effects with firms branching into the sector from the energy, engineering, manufacturing, subsea and logistics industries (Boschma & Iammarino 2009) (see Table 5.4). For instance, McNulty Offshore Construction Ltd, an engineering, pipe and structural fabrication contractor of substations to the oil and gas sector since 1988 diversified into the offshore wind pathway having secured contracts with OEM firms and offshore wind farm developers in the UK Crown Estate's Round 1 and 2 offshore wind programmes (Head of Commercial Development McNulty Offshore Construction, Author's Interview 2011). The same picture was similarly reflected by North East-based firms including CTC Marine, whom secured a contract to provide trenching and installation services to BARD Offshore Wind Farm, and JDR Cables which captured a contract with the London Array Wind Farm developer consortium to supply 200km of inter-array cabling (Business Development Manager CTC Marine, Author's Interview 2011). Moreover, the upward trajectory of the temporal episode also illustrated examples of "path interdependency" (Martin & Sunley 2006) with SMD Hydrovision entering into a long-term commercial agreement with Modus Seabed Intervention to supply offshore trenching equipment to the firm following Modus securing commercial contracts

with offshore wind farm developers for trenching and survey services, including Teesside Offshore Windfarm (CEO SMD Hydrovision, Author’s Interview 2012). In the case of the offshore wind pathway in the region, Porter’s (1990) claim that technical interdependencies between sectors form strongest in the early life-cycle of industries held some credible theoretical weight during the temporal episode.

Table 5.4 Offshore Wind Technologically-Related Firm Branching, 2000-2010

Name of Company	Year of Company Formation	Origins of Business	Year of Entry into Pathway	Offshore Wind Supply Chain	Current Supplier/Service to Offshore Wind Industry
Jordan Engineering	1981	Machining to multiple industries	2000	Machining (Mechanical Engineering)	Bolt manufacturer and precision engineering to tier 2 wind turbine component manufacturers
JDR Cables	1993	Subsea umbilical cords and power cables to oil and gas	2003	Cable Supply (Towers & Foundations)	Inter-array power cables to the offshore wind industry
CTC Marine	1993	Trenching & cable installation	2001	Cable Supply (Towers & Foundations)	Cable installation, ploughing and trenching to offshore wind farm developers
McNulty Offshore Construction Ltd	1988	Oil & gas fabricator	2002	Offshore Substation (Towers & Foundations)	Offshore engineering and fabrication to OEM/offshore wind farm developers
MKW (Gazelle Wind Turbines)	1998	Precision engineering to multiple industries	2003	Machining and control panels (Mechanical and Electrical)	Onshore wind turbine manufacturer, electrical control panels to offshore wind turbines

				Engineering	
TAG ES (formally Seadragon)	1996	Substructure and foundations to oil & gas industry	2009	Tower suppliers, substructure and foundations	Monopile foundations for offshore wind turbines

Source: Author's Interviews 2011-2012

With strong market conditions forecasted, the offshore wind pathway in the North East entered a period of rapid private sector-led investment at the latter end of the decade with increasing volumes of experienced, technologically-related firms from across the production and supply chain beginning to branch into the pathway (Boschma & Frenken 2009; CEO TAG ES, Author's Interview 2011). For instance, in an example of the recombination of infrastructure connecting history to catalyse related rounds of industrial activity, the banks of the River Tyne and River Tees were subject to aggressive regeneration by landowners and local authorities under the coordination and financial stimulus of ONE to regenerate and market former heavy engineering and manufacturing shipyards (Business Development Manager Siemens Wind Power, Author's Interview 2011; Fornahl *et al* 2012). The most notable redevelopment site was Shepherd Offshore Services acquisition of the former 60 acre Neptune shipyard to sit adjacent to the company's existing Walker Riverside manufacturing site (see Fig 5.10). Investing over £50m of public-private expenditure to redevelop the site as a "clean" operational quay and regenerate former dry docks, the rebranded Neptune Energy Park integrated core offshore wind companies, including providing ClipperWind Power, a U.S wind turbine OEM under the leadership of the former founder and CEO of Borderwind, with a purpose built portside facility in geographical proximity to existing engineering, manufacturing and sub-sea firms on the banks of the River Tyne (CEO ClipperWind Power, Author's Interview 2011). In the case of Shepherds Offshore Services, the diversification into the offshore wind market was the latest episode in the "rebirth of the River Tyne" (Mullaney 2012) and signified over 30 years of commercial activity in which the company had acquired redundant shipyards and reconverted them to suit the market demand of the oil, gas, offshore fabrication, subsea, and most recently, offshore wind industry (Director of Business Development Shepherds Offshore Services, Author's Interview 2011).

Figure 5.10 River Tyne Riverside Sites



Map 1 – River Tyne

Source: ONE 2011b, p. 23.

Unlike the offshore wind sector, the region’s plastic electronics industry had still yet to develop any initial industrial momentum. Despite the consolidation of the region’s semiconductor industry resulting in the “shake-out” of uncompetitive overseas and domestic firms e.g. the closure of Atmel in 2007, the remaining firms demonstrated little interest or evidence of diversifying into the plastic electronics industry (Klepper 2001; 2003; Dawley 2007). However, connecting to the early path creation period, two notable exceptions during the early part of the decade were Epigem and DuPont Teijin Films. In the case of Epigem, the company marked seven years of R&D investment since its management buy-out (MBO) from ICI to begin production and sales of the company’s first polymer microfluidic component (Epigem 2013). Indeed, in a further example of state institutions stimulating the candidate mechanisms of diversification and related variety during the path development episode, Epigem secured Single Programme funding from ONE to establish the Centre for Microfluidics and Polymer Electronics as part of the UK Micro and NanoTechnology KTN

programme (Boschma & Frenken 2009; Epigem 2013). For DuPont Teijin Films, the company's earlier merger and acquisition (M&A) followed by a prolonged period of R&D identified a major diversification opportunity in 2003 to utilise the firm's existing experience in conjugated polymers and roll-to-roll processing to manufacture flexible substrates (Chief Scientific Officer DuPont Teijin Films, Author's Interview 2011). The resultant output of the decision by DuPont Teijin Films to develop new materials for the plastic electronics industry was to secure contracts with CDT, Plastic Logic, Philips and Polymer Vision to supply plastic substrates. By 2006, DuPont Teijin Films had exploited its niche position in the regional and global marketplace to become the world's leading supplier of substrate materials to the industry (Technopolis 2008; Chief Scientific Officer DuPont Teijin Films, Author's Interview 2011).

As a result of technological advancements in materials technology leading to the introduction of new consumer plastic electronic applications in the marketplace, the period between the mid-2000s to 2010 exhibited increasing numbers of regional firms from related sectors diversifying into the pathway (Martin & Sunley 2006). Stimulated by multi-scalar institutional actors and policy, particularly at a regional and pan-regional scale through the activities of the Northern Way, ONE and the CoE, local and regional companies across the embryonic supply chain, such as Thorn Lighting, began diversifying the firm's existing lighting portfolio by introducing OLED and P-LED technology into the company's corporate R&D pipeline (Research Team Lead Thorn Lighting, Author's Interview 2011). Indeed, illustrating the role of the CoE in stimulating effective couplings between local and regional firm and other non-firm institutional actors to enhance learning processes, acquire new knowledge and transition away from internal knowledge generation to "interdisciplinary research collaborations" (Singh 2005) and "open innovation" practices (Metcalf 1994; Chesbrough 2003), CENAMPS and Durham University collaborated with Thorn Lighting to develop OLED materials and efficient device structures for large area lighting applications as part of the £3.3m DTI-funded Thin Organic Polymer Light Emitting Solid Surfaces (TOPLESS) project (Durham University 2007). The pattern of firm branching was also evident in the diversification of Onyx Scientific, High Force Research, Nanojet Ink, Thomas Swan and Lucite International into the regional plastic electronics pathway (see Table 5.5). In several instances, both PETEC and CPI took on an increasingly important role in catalysing firm diversification and related variety activities. In the case of PETEC:

“what we are trying to do is stimulate a new industry by playing to existing industrial strengths. The thought is that unless you’ve got incredibly deep pockets you can’t create a new industry from scratch. So what we’ve tried to do is leverage what we’ve got...our first theme was to latch onto existing industries where we can add a product. The second theme was can we get adjacent industries, such as the printing industry, to enter this field. Can we use or create supply chains based on the region’s industrial base. Now our thinking is around can we go to existing supply chains and adding functionality to existing companies and products” (Director of PETEC, Author’s Interview 2011).

As a consequence of the dynamic role of the centre’s in stimulating the mechanisms of variety and related variety, PETEC provided technical support to North Shields-based Mapp Systems in order to redesign and configure the firm’s existing membrane switches for keypads, labels and fascia by utilising new flexible electronic embossing and texturing techniques (Director of PETEC, Author’s Interview 2012). Moreover, PETEC began purchasing electrically-conductive base materials from DuPont Teijin Films and High Force Research which led to inter-organisational labour mobility and tacit knowledge exchange between PETEC and local and regional industry (Chief Financial Officer CPI, Author’s Interview 2011; CEO High Force Research, Author’s Interview 2011). By the end of the decade, the North East had an estimated 472 core and related companies from the chemicals, printing, electronics, advanced processing, machinery industries and potential end users which had branched or had the potential to diversify into the regional flexible electronics pathway (PHS Consulting 2008).

Table 5.5 Plastic Electronics Core Technologically-Related Firms, 2000-2010

Name of Company	Origins of Business	Technology Value Chain	Product/Service Offering to Plastic Electronics Industry
Thomas Swan	Chemical manufacturer	Materials & Inks	Manufacturer of carbon nano-tubes
High Force Research	Speciality chemicals to pharmaceutical industry	Materials & Inks	Chemical synthesis and R&D

Edwards Analytical	Chemical materials analysis to multiple industries	Components and/or services	Materials evaluation for polymer processes and packaging
Flex-Ability	Printed circuit boards (PCBs)	Technology and Design/Components and/or services	Design and manufacturer of flexible printed circuits
NanojetInk	Speciality chemicals to multiple industries	Materials and Inks/Process scale-up and/or Prototype Design	Novel chemical materials and printing technologies
Onyx Scientific	Specialty chemicals to multiple industries	Materials & Inks	Compound material synthesis

Source: Author's Interviews 2011-2012

5.3.4 Transplantation

In contrast to the previous path creation episode in which transplantation mechanisms had offered limited potential to the region's offshore wind pathway, the prevailing path development phase witnessed a quantitative and qualitative shift in the importance of the mechanism to the pathway. Illustrating the role and presence of regional institutional structures in stimulating transplantation mechanisms, NaREC took on an increasingly important role as regional asset, national profile and international "hook" intended to attract overseas investors and forge "strategic couplings" between the North East and leading global firms (Coe *et al* 2008). Although not considered "unique individual innovation assets" (Technopolis 2008), the geographical proximate grouping of multiple open-access offshore wind testing facilities at NaREC was considered a competitive inward investment offering to offshore wind supply chain firms in a global context (Head of Energy & Environment ONE, Author's Interview 2011; Professor of Energy Newcastle University, Author's Interview 2011). Confirming the North East's competitive advantage, U.S. OEM turbine manufacturer ClipperWind Power announced the design and prototype build of a 7.5MW offshore wind

blade at NaREC's blade test facility in 2007 as part of the company's strategic corporate decision to locate the firm's European Centre of Excellence in Blyth (NaREC 2007). Prior to ClipperWind Power, the North East had received a number of offshore wind FDI enquiries from GE Wind (2003), LM Blades (2004) and SIAG (2005), with overseas investments continuing to concentrate on the oil and gas sector with the promise of short-term, lucrative contracts in the North Sea (Business Development Manager International Paint, Author's Interview 2011). Nevertheless, ClipperWind Power's decision to invest in the North East also revealed a broader set of social and institutional processes behind the decision. Along with geographical proximity to NaREC's blade test facilities, ClipperWind Power's rationale for locating in the region reflected the "locational inertia" of entrepreneurs (Boschma 2009) with the CEO of ClipperWind Power establishing the business in Blyth because:

"I was very familiar with the local knowledge and asset base. We made a decision to be here because of close proximity to the market, a strong labour force with heritage of engineering, and proactive political and financial support from ONE" (CEO ClipperWind Power, Author's Interview 2011).

Amidst intense competition for the investment from the South East England, Yorkshire and Humber, Scotland and Ireland, ClipperWind Power represented the only exogenous wind turbine OEM in the UK at the time reflecting the strength and experience, particularly of regional state institutional actors and policy support, to attract and embed the company in the North East (CEO ClipperWind Power, Author's Interview 2011; Dawley 2013).

Having established ClipperWind Power's centre of excellence in Blyth, the company announced the intention to open a prototype turbine blade fabrication facility at Shepherd Offshore Services Offshore Technology Park in Walker, Newcastle-Upon-Tyne in February 2010 (CEO ClipperWind Power, Author's Interview 2011). Located at the Neptune Energy Park on the south bank of the River Tyne, ClipperWind Power anticipated manufacturing approximately 100, 10MW Britannia turbines per annum on the site, leading to the direct creation of 500 jobs and up to 3,000 indirectly in the supply chain (Jupp 2009; Johnson 2010). More broadly, ClipperWind Power's investment programme in the North East reflected over five years of investment promotion activities by central and regional government, including leveraging £5m of regional capital funding from ONE and indirect support through the provision of £4.4m from DECC in a new drive train facility at NaREC

(CEO ClipperWind Power, Author's Interview 2011). Indeed, further illustrating the role of the state in transforming local and regional industrial pathways into national trajectories, the UK Crown Estates agreed to purchase two turbines from ClipperWind Power at a cost of £1.6m (Schienstock 2007). According to a UK Crown Estates official:

“[The UK Crown Estates] had an important role in stimulating the offshore wind turbine market in the UK, resulting in the development of next generation offshore wind turbines” (Tighe 2011, p.3)

Importantly, the investment by ClipperWind Power raised the profile of the North East's offshore wind industry amongst local and regional businesses, supported NaREC to leverage an estimated £200m in additional investment and becoming a specialist advisor to the UK Crown Estates in 2010, and later recognised as a national innovation asset in UK Government industrial policy (NINJ 2009; Director of Technology and R&D NaREC, Author's Interview 2011). Furthermore, the episode further illustrated the dynamic relations and inter-play between local and regional firms and multi-scalar institutional actors in attracting, manipulating and embedding inward investment in host economies (Dicken 2000; 2003; Mackinnon & Phelps 2001; Head of Energy & Environment ONE, Author's Interview 2011).

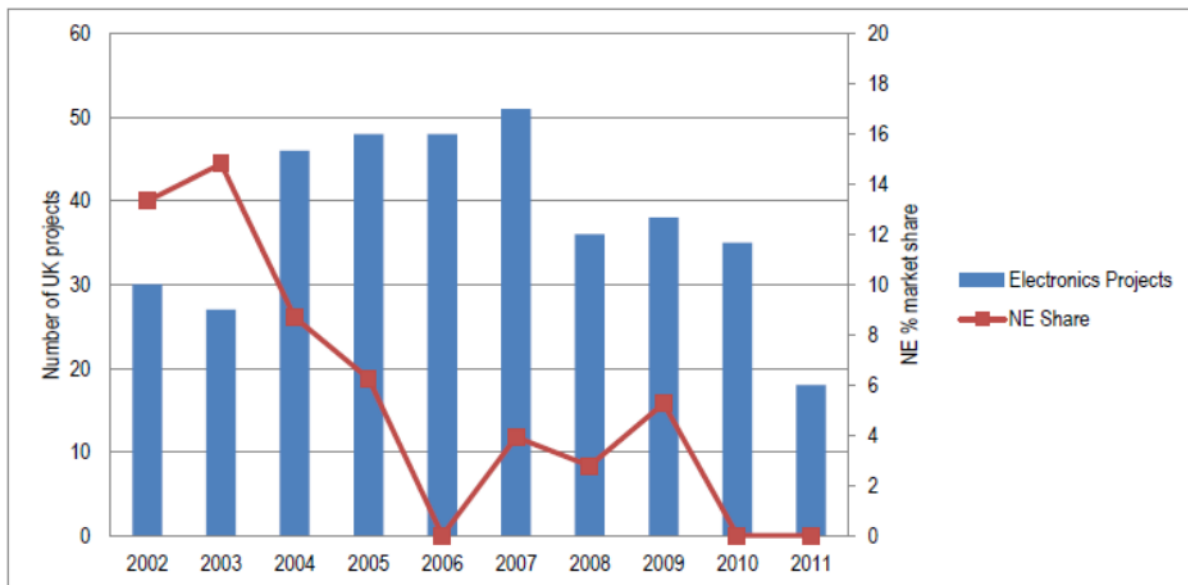
Mirroring the previous path creation episode, the entry of exogenous investors into the regional plastic electronics pathway failed to occur due to the nascent state of the market and slow uptake of firms commercialising applications (Director of PETEC, Author's Interview 2012). At that moment in the path development episode, a disconnect continued to exist between the emergence and development of a new local and regional pathway on the one hand, and extra-regional dynamics typified by the existing and established semiconductor GPN on the other hand (Mackinnon *et al* 2009). Nevertheless, unlike CPI, NaREC and CENAMPS which had been conceived as regional assets designed to strengthen the territorial innovation system, the opportunity to create PETEC was a direct response by local and regional policy actors to attract Cambridge-based Plastic Logic to the North East (Senior Specialist Advisor Emerging Technologies ONE, Author's Interview 2011). The exponential growth of Plastic Logic following an injection of \$150m in venture capital (VC) backing had led Scotland, Wales and the English regions vying to attract the company's displays manufacturing business (House of Commons 2009b). On the basis that the North East possessed complementary resources, characteristics and a track-record of attracting and

embedding large-scale manufacturing plants in the regional economy by successive local and regional development agencies, ONE and CENAMPS drew up plans to establish the Direct Write Technology Centre (DWTC) which combined specialised fabrication equipment with Plastic Logic's proprietary technology to establish a manufacturing line for plastic displays (Tribal Consulting 2006). However, despite assurances given to Plastic Logic by ONE over the timeframe for constructing the DWTC, alongside an enhanced package of inward investment support functions and financial incentives given the prospective importance of the company to the regional plastic electronics pathway, Plastic Logic opted instead to invest in Dresden, Germany based on superior capital-based grant support offered by the State of Saxony and a commitment by the Lander to build a bespoke manufacturing facility which was duly completed less than 15 months later (Dicken 2003; Fuller & Phelps 2004; House of Commons 2009a; Head of Innovation, Industry & Science ONE, Author's Interview 2011).

Despite the apparent setback and stark reminder of the broader extra-regional contexts, factors and power relations at play in the pursuit of transplantation mechanisms of path creation and development on, but not exclusive to peripheral regional economies, the decision by Plastic Logic not to invest in the North East positively altered the developmental trajectory of the plastic electronics pathway in the region (Coe 2011; Mackinnon 2012). In parallel to repurposing the DWTC in favour of creating the PETEC facility amidst declining volumes of semiconductor FDI towards the end of the decade, the North East attracted the joint venture (JV) between U.S. firm DuPont and Japan's Teijin to form DuPont Teijin Films at Wilton, Teesside to create the world's largest speciality producer of polyester films (see Figure 5.11) (DuPont Teijin Films 2013). Re-iterating the important function local and regional external intermediaries perform in attracting and supporting mechanisms of transplantation at the micro and meso-scale, both CPI and PETEC played particularly prominent roles in the regional inward investment process as DuPont Teijin Films established the £4m open-access Flexible Electronics Substrate Facility at CPI, which was capable of supplying thin film products to downstream companies and would serve as potential future customers for PETEC's prototyping and pre-commercial scale facility (BIS 2009b; Director of PETEC, Author's Interview 2011). Indeed, the re-investment by Zumtobel, the parent company of Thorn Lighting, in the firm's OLED and P-LED R&D programme and manufacturing plant at Spennymoor, County Durham was a direct consequence of the investment by ONE in PETEC (HM Government 2009). Thus, by the end of the decade policy practitioners and inward investment agencies led by ONE within the North East had begun to utilise and leverage CPI

and PETEC’s increasingly international remit to proactively market the region to overseas investors, with East Asian OEM’s including Samsung Electronics and Lucky Goldstar (LG) undertaking exploratory fact-finding visits to the North East between 2009 and 2010 (ONE 2011a).

Figure 5.11 North East Micro-Electronics Foreign Direct Investments, 2002-2011



Source: UK Trade & Investment North East 2012, p.23.

5.3.5 Summary: Related Variety, Transplantation and Path Development

The cumulative effect of multi-scalar social and institutional intervention highlighted in Chapter’s 5.1 and 5.2 catalysed and accelerated the path development mechanisms in the plastic electronics and offshore wind pathways in the North East between 2000 and 2010. Unlike the majority of broader path creation studies which underlined the role of indigenous firm activity in creating new development pathways, both trajectories during the path development episode were characterised by firms from related firms sectors diversifying, branching and recombining existing firm routines, assets and capabilities into the developing pathways (Boschma & Wenting 2007; Frenken *et al* 2008). In the case of the offshore wind industry, the earlier path creation phase which had been initiated through the “mindful deviation” (Garud & Karnoe 2001) of local entrepreneurs had been connected and built on by a period of related variety and branching activity in the path development phase (Boschma & Frenken 2009). Primarily, the “diffusion agents” during the period were companies that had

diversified out of the related industries of oil, gas and advanced engineering (Simmie 2012). Spurred on by technological innovations and positive market dynamics, the offshore wind pathway in the North East was characterised by increasing diversification of related firms that had been stimulated by diversification policies of local and regional firm and non-firm knowledgeable agents (Simmie 2012). In particular, NaREC took an increasingly important function to the path's ongoing progression by stimulating related variety and path branching mechanisms illustrating the importance of connecting strategic agency and the co-evolution of local and regional institutional actors to market and territorial contexts (Martin 2000; Tomaney & Mawson 2002; Pike *et al* 2010; Director of Technology and R&D NaREC, Author's Interview 2011). In so doing, NaREC, private sector infrastructure providers and other local and regional actors recombined expertise from existing sectors, networks and supported the translation of knowledge across sectoral boundaries to realise market opportunities and sustain momentum in the expanding offshore wind industry.

In addition to technology relatedness and branching activity, the temporal period also highlighted the role of transplantation in the path development phase demonstrating the importance of the mechanism in forging strategic couplings between the North East and GPNs in enabling the development of new local and regional economic activity (Mackinnon *et al* 2009). This was reflected in the inward investments of ClipperWind Power and DuPont Teijin Film in the North East which displayed, and was influenced by, a broader set of social, institutional and political forces which combined to provide an enabling environment for new exogenous investment to take place (Dawley 2013). For instance, both the CEO of ClipperWind Power and Chief Scientific Officer of DuPont Tiejin Films lobbied within their respective corporate hierarchies for investment in the region based on deep-rooted personal associations, place-based resources and existing capabilities specific to the North East. Moreover, the temporal period also illustrated the importance of the state at a local and regional level and the role of regional external intermediaries and strategic innovation assets performed in acting as a hook and determinant in stimulating processes of transplantation amongst exogenous firms. Consequently, the spillover effect of the Centre's and exogenous "invasion" of focal firms in the North East acted as a connective node between the mechanisms of transplantation and attraction of further external firms, indigenous activity and additional related diversification of firms into the pathway (Castaldi & Dosi 2004). In summary, the nature and characteristics of the offshore wind and plastic electronics pathways during the path development period had highlighted the importance of understanding and

interpreting the evolutionary candidate mechanisms as overlapping constructs and interlinked processes, rather than solitary change agents, whilst illustrating the composite effect of each scenario in unravelling the causal explanations for the path development in the North East.

5.4. PATH DEVELOPMENT SUMMARY

5.4.1 Introduction

Within the context of the local and regional mechanisms which had shaped, and been accelerated by, their positioning within broader and supportive multi-scalar social and institutional agents, factors and conditions, the offshore wind and plastic electronics pathways in the North East had transitioned from a path creation phase into a sustained period of path development. This penultimate section in the path development episode provides a brief synopsis of the resultant outcomes and impact from over thirty years of path creation and development activity in the regional offshore wind and plastic electronics industries.

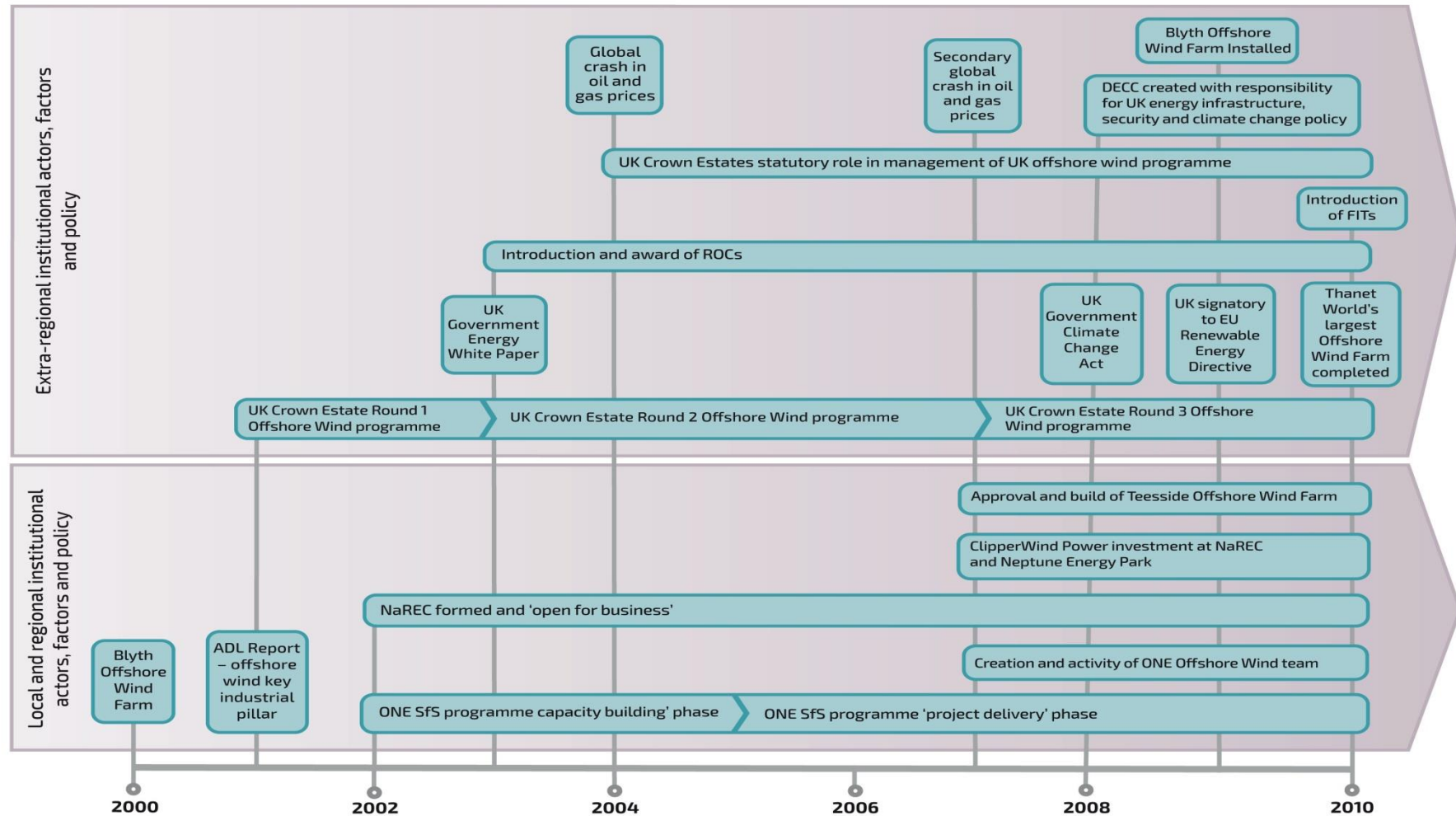
5.4.2 Path Development of North East Offshore Wind Industry

The underlying period between 2000 and 2010 in the regional offshore wind industry was characterised as an episode in which the emergent pathway entered a conceptual and actual phase of path development, endogenous change and dynamism (Brenner & Fornahl 2008; Martin 2010). However, the early part of the decade reflected a similar pattern to the previous temporal episode with only a small number of local and regional actors entering or diversifying into the industry. Despite the onset of state multi-scalar institutional support and enabling policy intervention, the regional offshore wind pathway remained constricted by a number of existing path and place dependencies. First, the cost of producing electricity from offshore wind remained prohibitively high in comparison to cheaper carbon-based energy sources (Douglas-Westwood 2005). Indeed, for many regional enterprises the onshore wind industry remained a more attractive and profitable sub-sector (CEO ClipperWind Power, Author's Interview 2011). Second, despite incremental advances in wind turbine technology, offshore wind remained an expensive and unproven technology (Carbon Trust 2008). Third, a number of approved projects in the UK Crown Estates Round 1 and 2 programmes had suffered significant delays in planning and development highlighting the lack of community

participation in the ownership and development of the offshore wind industry (Cumbers 2012). Fourth, the drive to incorporate renewable energy technologies into the overall UK energy mix within developing macro energy and climate change policy witnessed intervention to seed a range of competing niche renewable energy technologies including wave energy and photovoltaics in an example of the state “unwilling to pick winners” (Professor of Energy Newcastle University, Author’s Interview 2011). Fifth, the domestic offshore wind supply chain and associated skills provision to support the industry continued to exhibit gaps with the failure of the North East, and UK, to attract a major offshore turbine OEM a significant hindrance to the development of the supply chain and UK market opportunity (Douglas-Westwood 2006; Carbon Trust 2008).

Within the context of existing path and place industrial dependencies, a combination of de-locking and adaptation mechanisms or “moments in time”, throughout, but particularly during 2007, altered and accelerated the developmental trajectory of the offshore wind pathway in the North East (Dawley 2007). As highlighted in Figure 5.12, a number of external crises and internal evolutionary processes proved the turning point in catalysing the North East offshore wind pathway (Bassanini & Dosi 2001; Jovanovic 2009). Declining global oil and gas prices coupled with the composite effects of layering and recombination, principally through state policy and intervention, the decade-long construction of regional institutional and innovation capacity, firm branching and the symbolic “focal firm” (Coe *et al* 2004) of ClipperWind Power into the North East economy catapulted the North East’s offshore wind pathway into a period of rapid public and private sector growth (Boas 2007; Head of Energy & Environment ONE, Author’s Interview 2011). After over twenty five years of “learning by doing”, local and regional actors within the offshore wind pathway had begun to solve many of the technological, environmental and societal issues that had dogged the industry (Arrow 1962; Jovanovic & Lach 1989; Potter & Watts 2011). For example, following four years of local public opposition, consent was granted to EDF Energy Renewables by the DTI in 2007 to begin installation of Teesside Offshore Windfarm (Professor of Energy Newcastle University, Author’s Interview 2011; EDF Energy Renewables 2013). The cumulative effect on the regional supply chain witnessed tier 1 and tier 2 companies in the North East driving up the quality of existing products, investing in R&D and innovation to meet the demands of the supply chain and beginning to benefit from early tentative patterns of local and regional increasing returns and network externalities (Arthur 1989).

Figure 5.12 Path Development of the North East Offshore Wind Industry: Timeline Analysis, 2000-2010



Source: Author 2014

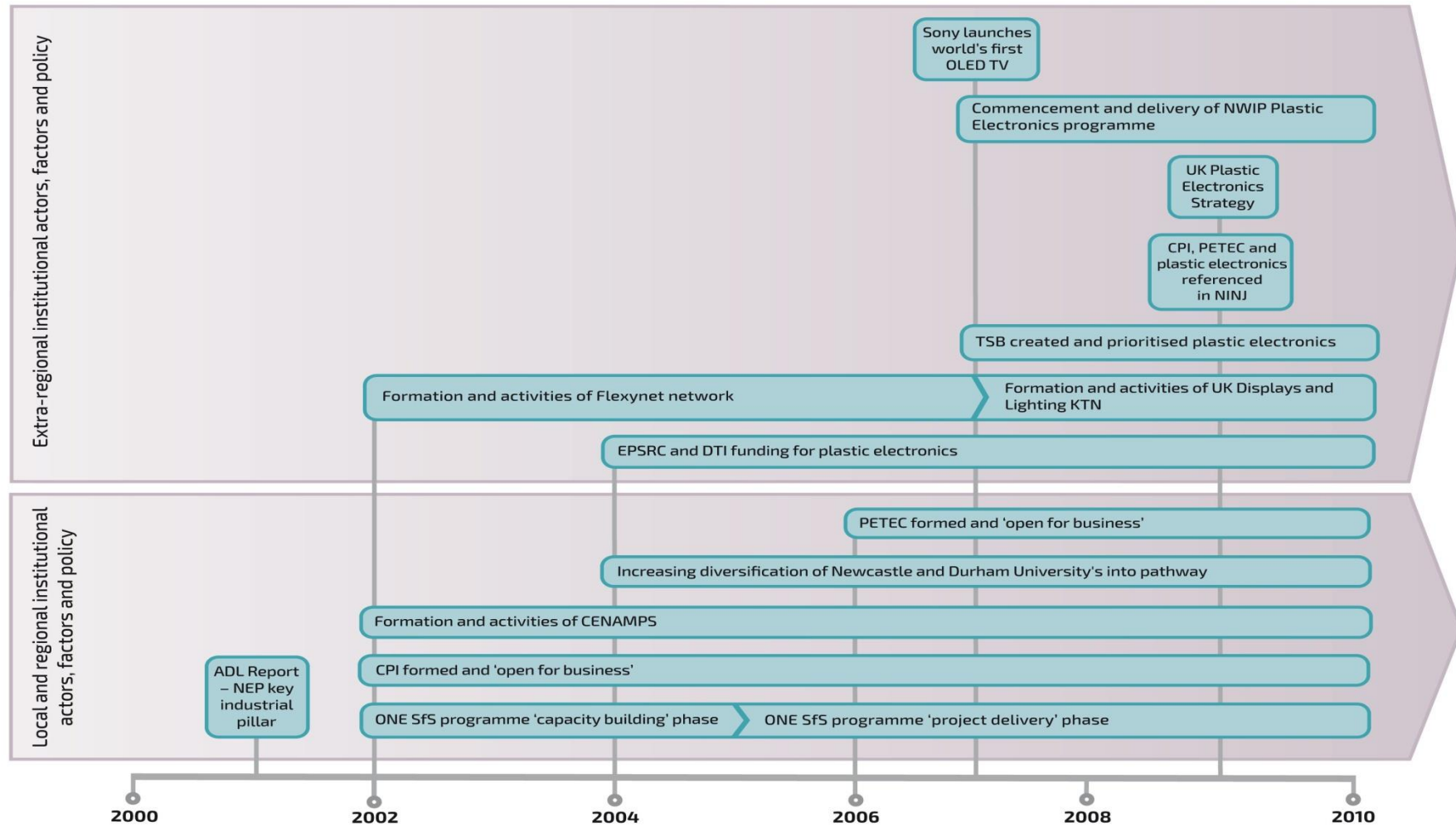
Highlighting the uneven geography of path creation and development, the regional offshore wind industry began to demonstrate spatial concentrations of firm and industrial activity within geographical pockets of the North East. Unlike the previous path creation episode which had displayed entrepreneurial activity spatially de-concentrated throughout the North East region, the majority of core offshore wind firms that had entered or branched into the pathway were geographically located on the banks of the River Tees and River Tyne illustrating the link between geography and the recombination of inherited place-based knowledge and resources from previous episodes of heavy industrial activity in building new industrial environments (Maskell & Malmberg 2006). Previously, existing agglomerations in Tyne & Wear and Teesside had experienced prolonged periods of decline instigated by a combination of demand, supply and policy factors including exogenous shocks, market overcapacity and intensive price competition. However, existing companies possessing related variety, together with several new firm entries and a continued low rate of firm exits from the emerging agglomerations, provided for a period of renewal and adaptation in and around the Port of Tyne and Tees (Dunne *et al* 1988; Klepper & Miller 1995). Indeed, based on the disproportionate number of firms at the beginning and end of the offshore wind supply chain, “related specialisation” (Pike *et al* 2010) of firms led to the renewal and build-up of local, specialised labour, local supplier linkages and knowledge spillovers via inter-firm ‘technological learning effects’ (Uyterlinde *et al* 2007). The sub-region which capitalised most during the path development period was Teesside which, because of high concentrations of equipment manufacturers and advanced engineering firms required in the early phase of project development by contractors and offshore wind farm developers, resulted in the emergence of a subsea engineering and manufacturing “growth agglomeration” in Darlington that led to positive spillover effects, jobs and economic development for the Tees Valley sub-region (Pyke *et al* 1990; Porter 1990; Saxenian 1994; CEO SMD Hydrovision, Author’s Interview 2011).

5.4.3 Path Development of North East Plastic Electronics Pathway Industry

Connecting to the earlier path creation episode, the initial period in the evolutionary trajectory of the plastic electronics industry in the North East exhibited slow but persistent growth of firm and non-firm actors exploring R&D and commercial opportunities. Aside from a number of technologically-related companies at the beginning of the industrial supply chain that pursued small-scale internal research and pre-commercial prototype development programmes, the plastic electronics industry failed to generate traction because of difficulties in converting past and inherited knowledge, skills and resources into new competencies (Maskell & Malmberg 2006; Director of PETEC, Author's Interview 2011). Those actors that was able to conduct R&D drew-up upon place-specific factors and conditions restating the notion of innovation as a fundamentally localised activity (Audretsch & Feldman 1996; Audretsch & Stephan 1996). In addition to issues of institutional adaptive capacity, the progress of the regional plastic electronics pathway was also hampered by a number of internal and external barriers, including a lack of awareness amongst the regional business base of the potential of the technology, a vertically disjointed and fragmented supply chain, without the presence of OEMs required for economies of scale to mass manufacture, and the perception of high investment costs for new infrastructure and product qualification (BERR 2009; Director of PETEC, Author's Interview 2011). However, the most significant barrier to the uptake of plastic electronics remained the existing GPN connecting semiconductor material on rigid substrates to the global microelectronics industry. Despite claims by prominent businesses that had entered the plastic electronics sector during the episode, including Sony, Samsung Displays, Kodak, Polymer Vision, Plastic Logic and CDT over utilising new printing techniques on different substrates, simpler fabrication processes and low-cost production of low and medium volume devices to create new conformable, disruptive technologies, the incumbent micro-electronics industry and long-established supply chain based on semi-conducting materials remained the dominant pathway (Dawley 2007; PHS Consulting 2008). With the semi-conductor market worth over a trillion dollars and thereby driving investment into the incumbent technology, regional firms unwilling and unable to meet the high cost of innovation in plastic electronics without sufficient market demand, and the region continuing to attract new semi-conductor manufacturing branch plants with the promise of high volume but low skilled jobs, the North East continued to exhibit signs of "path contingency" with overreliance on national and international firms and markets (Xu 2000).

However, after seven years of relative stasis in the plastic electronics pathway, the North East experienced a series of internal and external “trigger” events that broke with existing path and place dependencies and started to lead to realization of the technology and industrial potential (Brenner & Fornahl 2008; Hassink *et al* 2012). In parallel to timings in the offshore wind pathway, the external trigger moment came during 2007 when Sony, as part of the firm’s global product differentiation strategy, launched the first commercial OLED TV featuring an 11 inch display (see Figure 5.13). The first mover advantage displayed by Sony to create radical new product innovations and “niche differentiation” in the market quickly catalysed competitors with Samsung Displays Inc and Kodak quickly entering the nascent market a year later with the introductions of OLED technology for mobile phone and camera displays (Utterback & Abernathy 1975; Audretsch & Feldman 1996). With respect to the North East pathway, the external shock of Sony’s breakthrough innovation encouraged sub-national state institutional actors, led by ONE and the Northern Way, to stimulate the endogenous business and build on the North East’s industrial legacy in chemicals, printing and microelectronics by instigating a decade-long period of policy intervention based on indigenous creation, diversification and branching that was designed to stimulate local and regional-based actors and networks to explore new market opportunities and build innovation capacity within the RIS (Cooke 2002; PHS Consulting 2008). Consequently, the established process industries sector were the first to branch into the pathway and began developing substrate products including thin film, paper, glass and/or metal composites e.g. DuPont Teijin Films, and supplying electro-chemical materials and inks for different parts of the electronic circuit e.g. High Force Research (CEO High Force Research, Author’s Interview 2011; Chief Scientific Officer DuPont Teijin Films, Author’s Interview 2011).

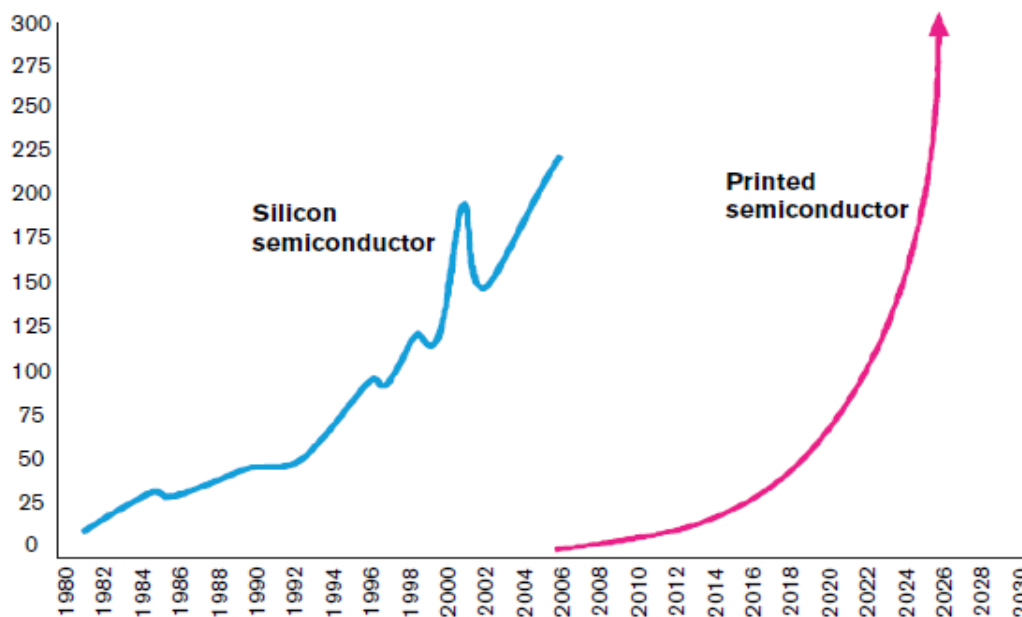
Figure 5.13 Path Development of the North East Plastic Electronics Industry: Timeline Analysis, 2000-2010



Source: Author 2014

Based on a combination of external factors and enabling sub-national institutional actors and directed policy intervention, the remaining period between 2007 and 2010 displayed increasing experimentation, competition and adaptation to shifting market environments amongst local and regional agents in the pathway (Martin 2010) (see Figure 5.14). For instance, to compete with UK-based MNCs, including Merck which had established a materials technical centre in Chilworth, Philips Research which increased its applied research activity in OLED for roll-to-roll printing in Cambridge and expansion of Kodak’s European Research Centre focussed on optoelectronic displays and materials, Thorn Lighting in County Durham implemented an applied R&D programme for printed LED and solid state lighting applications (Technopolis 2009b; Research Team Lead Thorn Lighting, Author’s Interview 2011). Similar to the offshore wind industry in the North East, the pathway became increasingly stimulated by processes and the candidate mechanisms of related variety and branching with regional firm and non-firm actors building on capabilities and assets from the previous path creation episode to cultivate an internationally-leading niche position in applied conductive polymer research, early-stage chemical materials and component supply, and niche manufacture of plastic electronics products (Boschma & Frenken 2009; Chief Scientific Officer DuPont Teijin Films, Author’s Interview 2011).

Figure 5.14 Current and Projected Market Growth (\$Billion) of Global Printed Electronics Industry



Source: Bit Bang 2009, p.66.

By the end of the decade, the North East mirrored patterns of firm and industrial growth exhibited across the UK which had experienced gradual increases in the number of core plastic electronics firms engaged predominantly at the beginning of the vertical innovation and supply chain through the production and supply of materials, process development and device prototyping (Tribal Consulting 2006). With increased levels of private and public sector R&D, access to world-leading intellectual capital and technology, and a supportive policy environment at the regional and national level, the market potential of the UK became progressively more appealing to investors and firms. As a consequence, companies such as Japan-based MNC Sumitomo Corporation entered the UK through the aggressive acquisition of CDT for \$285m (PHS Consulting 2008). With further advancements expected in digital and telecommunication technologies brought about by changing consumer habits, the global plastic electronics market was projected to be worth \$55.1bn by 2020 (IDTechEx 2010). As stated by the former UK Government Chief Scientific Advisor:

“In Britain we have a world-leading position in a technology that could wipe out silicon chip technology and could convert photovoltaics into easily accessible materials at a much cheaper price, and I am talking about plastic electronics” (Council of Science & Technology 2007, p. 65).

Entering into the next decade, the “North East remained well placed to capitalise on the economic potential of the growing plastic electronics industry” (House of Commons 2009b, p.97) by taking advantage of a strong academic base, sustained investment from industry creating niche R&D and manufacturing areas of expertise, and sustained policy support and intervention by the state (BIS 2009b; Professor of Physics Durham University, Author’s Interview 2011).

5.4.4 Summary: Incubation and Acceleration towards Path Development

In summary, the offshore wind pathway in the North East failed to escalate until 2007 when multi-scalar state-led market opportunities, combined with technological developments and an emerging supply chain, led to increased commissioning of large-scale offshore wind farms off the UK coastline and significant commercial opportunities for North East-based companies supplying predominantly balance of plant components to the industry (Carbon Trust 2008). In many respects, the path development period of the sector had been

synonymous with incremental steps in the innovation chain by “doing, using and interacting” (DUI) over time which had reduced the cost and risk of producing energy from offshore wind sources (Neij 1997). Exhibiting similar characteristics, the regional plastic electronics pathway also took off during a similar timeframe but relied more heavily on a mixed combination of multi-scalar state innovation programmes, disruptive technological developments and external stimuli of Sony’s commercialisation of OLED TV’s. The resultant outcome led to the diffusion of a handful of plastic electronic products onto the marketplace signalling an opportunity for North East-based firms, beginning with the embattled chemicals sector, to conduct further R&D and begin to manufacture and sell products and/or services within the rapidly expanding plastic electronics industry (IdTechEx 2010)

5.5. CONCLUSION

The positive developmental trajectory of the North East’s offshore wind and plastic electronics industries between 2000 and 2010 illustrated and offered an empirical assessment of the conceptual transition from path creation to a path development phase characterised by ongoing adaptation and path progression. In many respects, the escalating offshore wind and plastic electronic pathways were symbolic developments *in* and *of* the region during the episode (Morgan & Sayer 1988). Within this context, the final section draws the temporal period to a close by placing the empirical findings, beginning with the North East’s offshore wind industry which by the end of the decade had “created a new industrial chapter for the North East”, within the context of the causal mechanisms, multi-scalar actors and policy interventions that stimulated the industrial trajectories of both pathways during the path development episode (McAteer 2011, p.21).

Path Development: Mechanisms, Multi-scalar Actors and Policy in the North East Offshore Wind Pathway

In contrast to the path creation episode, the original mechanisms of indigenous creation which had previously catalysed the North East’s offshore wind pathway was enhanced during the path development phase by a rapid period of firm diversification, branching and transplantation into the burgeoning offshore wind industry. The episode and narrative demonstrated two important points with respect to the mechanisms, multi-scalar agents and policy actors during the period. First, the progressive path creation and development phases

in the local and regional industrial trajectory illustrated the interconnected processes of the causal candidate mechanisms in building up sufficient economic momentum to transition the regional pathway from a period of experimentation and competition amongst local and regional agents to displaying processes of recombination, layering and path stabilisation (Martin 2010). Thus, after over thirty years of path creation and development activity, the offshore wind pathway in the North East, as heralded in 2010 by the then Prime Minister, Gordon Brown (cited in Jupp 2010), was indicative of:

“...an area which had a shipbuilding industry which was renowned throughout the world. Now again we have the opportunity to lead the world from the North East.....Offshore wind is a new industry where Britain can be number one in the world...and the North East is at the forefront in providing the skills, expertise, and enterprise to capitalise on this rapidly expanding market...(and)...thousands of green jobs”.

Second, offering a deeper understanding of the linkages between the multifaceted nature of social and institutional agents and the mechanisms, the temporal episode in the regional offshore wind industry also restated the importance and broader incorporation of wider multi-scalar social and institutional agents, factors and contexts in shaping the mechanisms of path creation and development (Dawley 2013). Specifically, the period highlighted the significant role multi-scalar actors and knowledgeable agents, within both firm and non-firm contexts, performed in setting and administering contextual policy interventions to stimulate the mechanisms of related variety, branching and transplantation. In particular, the episode highlighted the importance of national institutions and horizontal and vertical policy in setting the broader technological and market conditions to enable the path to develop at a local and regional scale. In parallel but reflecting a shifting scalar focus, the path development episode also reiterated the importance of strategic agency at a local and regional scale and the role played by ONE's Sfs programme and policy practitioners in firm and non-firm organisations in delivering regionally embedded interventions which reflected the institutional and industrial history and make-up of the North East (Neffke *et al* 2011; Boschma *et al* 2012)

*Path Development: Mechanisms, Multi-scalar Actors and Policy in the North East
Plastic Electronics Pathway*

Unlike the offshore wind industry which had progressed gradually over the course of four decades, the episode in the path development of the regional plastic electronics pathway was one synonymous with rapid scientific advancement and industrial adoption. Transitioning from a period of local entrepreneurial activity by a handful of firm and non-firm actors, the North East plastic electronics pathway entered a period of growth catalysed by a combination of firm and non-firm policy actors and interventions across multiple spatial scales (Essletzbichler 2012). The episode in the path's ongoing development highlighted two important points to a deeper understanding of the causal processes and mechanisms at play in local and regional path creation. First, in similar ilk to the North East offshore wind pathway, the indigenous-orientated mechanisms displayed in the earlier path creation phase offered a level of overlap and complementarity with increasing volumes of firms diversifying, branching and inward investing. Moreover, the temporal period also illustrated the orchestral role of local and regional state actors, knowledge-based agents and strategic local and regional innovation assets that displayed "organisational adaptation" (Garnsey & Heffernan 2007) in stimulating processes of indigenous creation, heterogeneity, related variety and transplantation (Boschma & Frenken 2009).

Second, with respect to the relationship between the mechanisms and deliberative social agency, the path development episode restated the importance of multi-scalar institutional and political forces in mediating and enabling forms of "niche management" offered by state organisations and regional knowledge actors in support of new and emerging industrial growth paths (Cooke 2012). At a macro scale, national politico-institutional bodies and policy adopted an advanced form of a bricolage strategy through fiscal support for basic research, loose couplings between academic-firm networks and concentrated industrial and innovation investment in places, including the North East, which possessed historical, place-based assets and technologically-related competencies (Simmonds & Stroyan 2008). At a local and regional scale, ONE and the Northern Way's evolutionary-inspired innovation policy interventions had performed important roles as "intermediary regime organisations" (Cooke 2010) and "brokers" in stimulating local and regional knowledge interaction, innovation and purposeful exploitation of state-derived market opportunities for incumbent and related firms in the North East (Boschma & Lambooy 2001).

In conclusion, the North East's offshore wind and plastic electronics pathways had entered a "tipping point" in their developmental gestation period symbolised by the expansion and reproduction of both industries that underpinned the putative paths (Simmie 2012; Dawley *et al* 2015). For the regional plastic electronics industry, multi-scalar institutional actors and purposive policy intervention had proved decisive in accelerating the mechanisms during the period translating promising R&D into the creation, diversification and transplantation of firm and non-firm actors. In contrast, the North East offshore wind industry had traced out a development trajectory over forty years of slow industrial change and adaptation through which broader social and institutional agents and policy provided stable enabling conditions for the mechanisms to advance during the period rendering the North East offshore wind industry both path dependent *and* path evolving as the pathway entered 2010 (Martin 2010).

CHAPTER 6. PATH DEPENDENCY OF THE OFFSHORE WIND INDUSTRY AND PATH REGRESSION OF THE PRINTABLE ELECTRONICS INDUSTRY IN THE NORTH EAST

6.1.0 Introduction

By 2010, the role, influence and actions of dynamic couplings between state institutions, purposive policy intervention and local and regional actors had assisted in establishing the UK as the world's largest offshore wind market (GWEC 2010). In parallel, the Labour Government had embarked upon a sustained period of multi-scalar state institutional support and enabling policy by stimulating strategic niche opportunities amongst the academic and industry community towards nurturing "printable electronics" technology, as it was referred to by industry at this point in time, from "blue sky research" to commercialisation (Geels 2004; Garud *et al* 2010; Simmie 2010). In short, the offshore wind and printable electronics pathways had demonstrated the importance of connecting path creation and development processes to wider politico-institutional economic conditions and structural contexts to accelerate both pathways (Mackinnon *et al* 2009; Mackinnon 2012).

Following the path development phase, the purpose of this chapter is to chart and analyse the evolutionary trajectories of the offshore wind and printable electronics industries in the North East as both pathways entered the conceptual phase of "path dependency" (Martin 2010). Connecting to the previous path development episode, the chapter picks up the chronological thread from 2010 to 2012 which, after a decade of strategic and "contextual" policy support, the ousting of the Labour Government in May 2010 by the Conservative-Liberal Democrat coalition government marked the beginning of a radical rescaling and re-scoping of state institutions and policy intervention to both pathways (Asheim *et al* 2011). Consequently, illustrating the role and importance of national institutional actors, frameworks and conditions in stimulating path creation at the local and regional scale, Chapter 6.1 examines the impact on the North East's offshore wind and printable electronics pathway's positive growth trajectory of a clear rupture, and turning point, in the national politico-institutional context and enabling environment previously active in supporting the mechanisms of path creation and development. Within the context of the UK's shifting political, institutional and economic landscape, Chapter 6.2 addresses and examines the changing role, influence and

causal links between local and regional institutional actors, strategic assets and policy intervention, and particularly the transition from regional to sub-regional governance structures and policy, in sustaining and accelerating the previously supportive enabling environment in the earlier episodes of the paths evolution. Situated within the broader but erosive multi-scalar socio-institutional and political structures, conditions and frameworks, Chapter 6.3 investigates the key candidate mechanisms during the episode which were shaped, and they themselves shaped by, wider multi-scalar social, institutional, political and economic actors, forces and factors (Mackinnon *et al* 2009). In the case of the North East offshore wind industry, the constrained conditions and setting served to have little impact upon the mechanisms catalysing the pathway towards path dependency and ongoing adaptation. In contrast, the disruption to the broader multi-scalar and multi-actor institutional environment stalled the mechanisms stimulating the printable electronics pathway in the North East, leading to regression of the pathway back to its less developed state comparable with the previous path creation episode. To conclude, Chapter 6.4 draws the empirical assessment of the episode in the North East's offshore wind and printable electronics pathways to a close by placing the analytical findings in the context of the causal mechanisms, multi-scalar actors and policy interventions that shaped the industrial trajectories of both pathways during the episode.

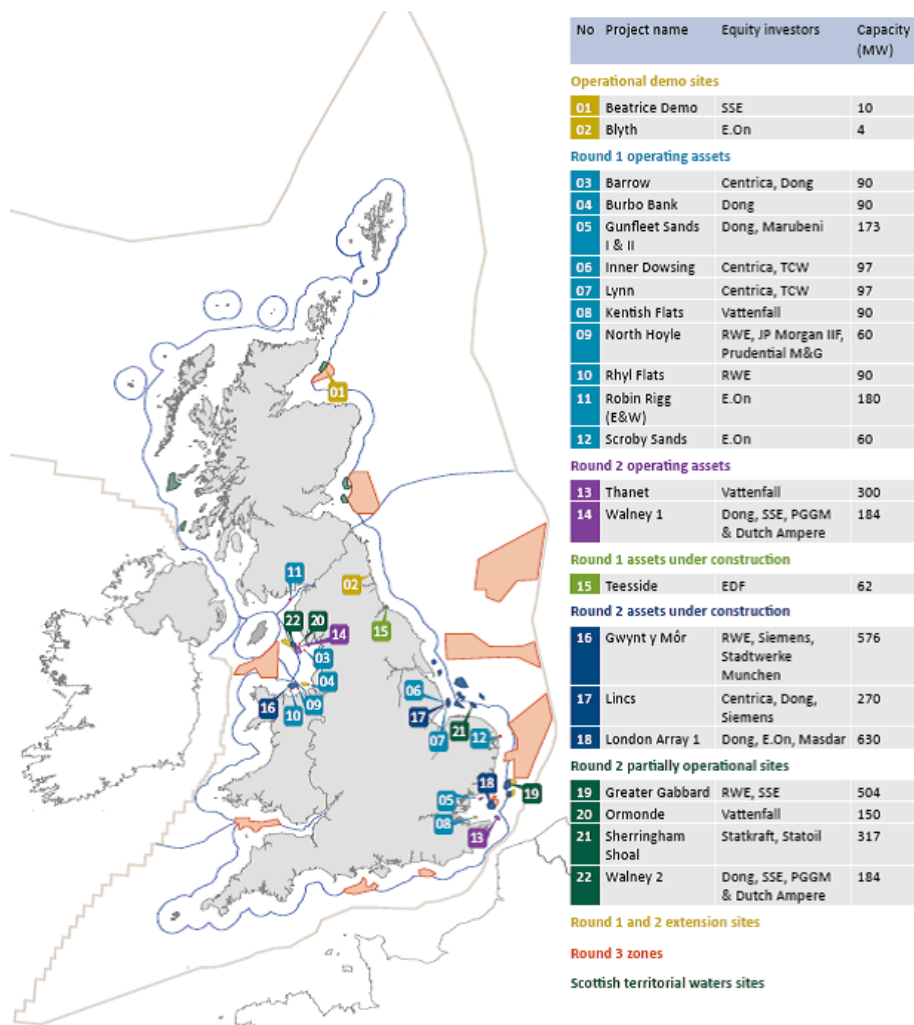
6.1. NATIONAL INSTITUTIONAL ACTORS, CONTEXTS AND SETTINGS

6.1.1 The Altered Role of the State in Path Dependency of the Offshore Wind Pathway

Upon entering power, as part of an immediate assessment and wider long-term approach to deficit reduction, monetary stimulus and supply-side reform of the UK economy, the Coalition Government embarked upon a systematic review of national state-led governance structures, agents, regulations and policy layers which had been implemented to catalyse the previous developmental phase of the offshore wind industry (Simmie 2012). Indeed, whilst recognising the propensity for incoming national political parties to “make change for changes sake” (Pugalis & Fisher 2011), the appraisal of energy and industrial policy reflected neo-liberal political ideology, particularly favoured by the Conservative Government, in support of market forces, competition and supply-side intervention in comparison to the previous Labour Government's supply-side policy framework based on correcting market

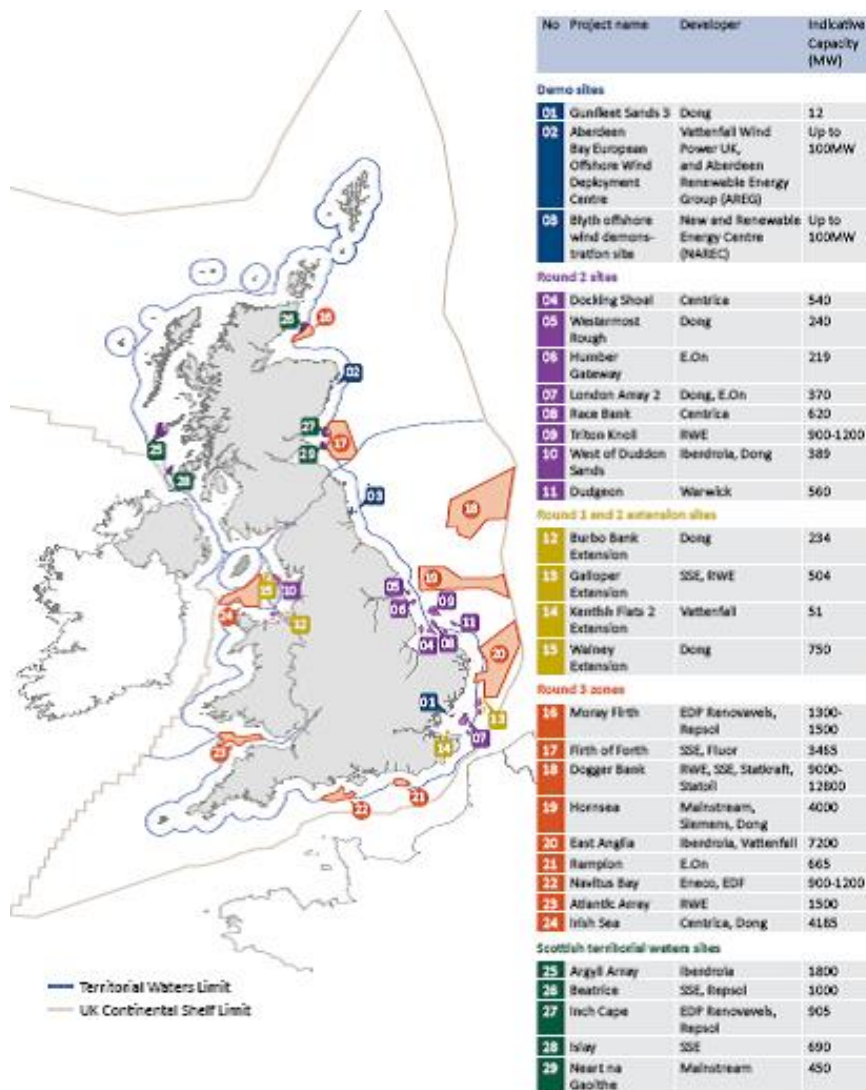
failings (Director of PETEC, Author’s Interview 2011). As a consequence, the Coalition Government initiated their own brand of “industrial activism” by identifying eleven industrial sectors, including offshore wind, in a revised national industrial policy for the UK designed to rebalance the economy by supporting a manufacturing revival (Chang *et al* 2013; HM Government 2013). Nevertheless, despite the explicit identification of offshore wind in national industrial policy and recognition that the offshore wind industry had reached a point of path dependent development in which offshore wind developers had registered an intention to deploy 46GW of offshore wind capacity, of which 10GW had been already progressed to consent, construction and operational stage, the ensuing period to 2012 witnessed constricted support by national state institutional and political actors to the developing regional and national offshore wind pathway (see Figures 6.1 & 6.2) (Howarth 2012; UK Crown Estates 2012)

Figure 6.1 UK Offshore Wind Farms in Construction or Operation



Source: UK Crown Estates 2012, p. 10.

Figure 6.2 UK Offshore Wind Farm Projects under Development



Source: UK Crown Estates 2012, p. 11.

To begin the top-down deconstruction of the previous episodes state-led national regulatory and enabling market environment, the Coalition Government consulted, commissioned and published a series of alternative horizontal strategies and policies, including the *National Renewable Energy Action Plan* (2010), *Renewable Energy Roadmap* (2011) and amended Energy Bill (2012) as part of the national reform of the domestic energy market. The new Energy Bill aimed to build a stable electricity supply in the future, principally through the construction of a new set of nuclear power stations in a more progressive “pro-nuclear” stance than the previous government administration (HM Government 2012). Aside from the apparent shift backward and forward by national state institutional and political actors and structures to strengthen previously incumbent energy path dependencies, the changing rules

and regulations set by the previous state administration created two negative factors and implications to the North East's expanding offshore wind pathway (Howarth 2012). First, the Energy Bill proposed a delay in setting decarbonisation targets under the UK Climate Change Act. The indecision by national political actors and interruption to the macro institutional and regulatory environment caused uncertainty amongst the North East's offshore wind industry, and more widely, influenced decisions of investors to search and select alternative sources of energy production in the interim period (Essletzbichler 2012; CEO SMD Hydrovision, Author's Interview 2012; Ernst & Young 2013).

Second, the Coalition Government initiated a consultation process with the energy industry as part of a UK-wide Electricity Market Reform (EMR) programme. Initially, the EMR exercise was considered a proactive step by the Coalition Government to create a competitive market structure in which low carbon technologies could compete fairly on price (DECC 2011a). However, significant delays by the Coalition Government in setting the contracts for difference (CfD) price point, an additional policy layer designed by the state to provide generators of electricity a fixed price for electricity produced from offshore wind sources, created further indecision in the offshore wind pathway (Business Development Director Shepherds Offshore Services, Author's Interview 2011). As a net result:

“In 2010 it looked like we had certainty with the Government aiming for 18 gigawatts of new offshore wind by 2020. Back then we thought the market would really have taken off by now...but investor confidence has lapsed due to Government indecision over the level of support for offshore wind. There is no funding available, the banks are not interested in lending and Government needs to put in place firm financial instruments in order to generate and support the industry. It's hard to make anything happen until the investment situation becomes clearer” (CEO TAG ES, Author's Interview 2011).

Amidst concern with CfD amongst industry over the length of contracts and proposed digression rates at which state fiscal support for offshore wind power would be reduced over time, the confusion and delays over CfD, along with an increasingly incoherent fiscal policy mix of ROCs and FITs still required by the offshore wind industry to underpin what constituted an uncompetitive energy sector in comparison to alternative forms of energy generation, the episode restated the influence and impact national institutional actors, and

particularly the national political economy and policy, performed in failing to set broader enabling conditions, supportive regulatory frameworks and “common standards” (Geels 2005) in support of the regional offshore wind pathway (Dawley *et al* 2015).

6.1.2 National State Innovation Policy: Erosion of Strategic Niche Management of the Plastic Electronics Pathway

In contrast to the path development episode in which printable electronics had been identified by the then Labour Government as one of a number of key strategically important technologies and potential industries of the future in which the UK possessed an international competitive advantage, the temporal period between 2010 and 2012 following the election of the Coalition Government signalled a qualitatively different trajectory in national state institutional and political support to the developing regional printable electronics pathway (Technopolis 2008; BIS 2009b). Whilst state support at the national level to the regional offshore wind pathway had fluctuated over the two years of Coalition Government hegemony, national state institutional and political actors, structures and networks removed printable electronics as a national innovation priority, and with it, began to dismantle and eradicate the previously created strategic niche environment that had nurtured the regional and national printable electronics pathway (Head of New Ideas De La Rue, Author’s Interview 2011; Head of Technical R&D 3M, Author’s Interview 2012). Thus:

“despite the fact that the UK led the world in plastic electronics research through the 1990s and 2000s, this new growth industry was lost to the nation largely because of the failure to rally UK companies around a standardisation strategy for the new technologies. This would have defined an agreed way forward for a UK plastic electronics industry, providing the confidence needed to make large scale investments. Unsurprisingly, the opportunity was grasped elsewhere and the bulk of manufacturing value is now located in Russia and Germany” (HM Government 2012a, p.101)

As a result of a more “market-led” (Director of PETEC, Author’s Interview 2011) and “placeless” (Marques 2011; Barca *et al* 2012) approach to stimulating knowledge creation, innovation and industrial sectors by national political institutions, printable electronics was initially omitted in favour of synthetic biology, energy-efficient computing, energy harvesting

and graphene in the Coalition Government's *Innovation and Research Strategy for Growth* (2011). The death of printable electronics as a state priority at the national level was later followed by exclusion in the TSB's "eight great technologies" and BIS' reconfigured vertical sector-based strategies that represented the UK's most promising, and economically important, areas of technology, innovation and industrial value to the national economy (TSB 2014). For the developing pathway in the North East, the removal of printable electronics from national innovation and industrial policy culminated in the reduction of research funding by the EPSRC and TSB to local and regional actors. Furthermore, the abandonment of printable electronics as a policy priority at the national scale resulted in the withdrawal of funding to territorially-specific innovation and business support programmes, including those delivered by the Northern Way, and also the re-purposing of the UK DLKTN which had been an important platform in the early path development episode in stimulating "collective learning processes" and collaboration between multi-scalar firm and non-firm actors in the printable electronics sector (Lundvall 2000; Professor Physics Durham University, Author's Interview 2011).

To partially fill the institutional and political vacuum left by the Coalition Government, national leadership to the domestic printable electronics community emerged through the creation of the voluntary national Plastic Electronics Leadership Group (PELG) (PELG 2014). Indeed, the creation of PELG network served as an institutional "band aid" by connecting together multi-scalar actors from academia, industry and government (Essletzbichler 2012). Operating three overarching work streams focussed on indigenous creation and support for firm diversification activities, knowledge exchange and development of skills and training to the industry, the establishment of PELG during the temporal episode illustrated elements of recombination in which private and public sector actors, within and external to the North East, sought to redefine their roles and adapt to changing state priorities and associated depletion of resources by filling the policy void left by the absence of national and quasi-state agencies (Martin 2010). As per the formation of the Flexynet and UK DLKTN collaborative networks in the earlier path creation and development episodes, prominent North East-based entrepreneurial actors, including the Chief Scientific Officer of DuPont Teijin Films, Professor of Physics at Durham University and the Director of PETEC, performed important roles in recombining knowledge, capabilities and networks into creating PELG. Importantly for the printable electronics pathway in the North East, the presence of local and regional firm and non-firm actors maintained a limited degree of economic

momentum and connectivity between the printable electronics pathway in the region and extra-regional institutional actors, structures and networks (Director of PETEC, Author's Interview 2011; Chief Scientific Officer DuPont Teijin Films, Author's Interview 2011; Dawley *et al* 2015).

6.1.3 Summary: Diminishing Role and Form of National Institutions in Path Dependency

In the context of the emergent and developing printable electronics and offshore wind pathways in the North East, the “hollowing out” (Jessop 2002) of the state from above reaffirmed the influence and exposure of state-led path creation on, but not exclusive to, peripheral regional economies (Morgan 2012). Following a period of contextual and territorially-specific policy support to the expanding industrial trajectories, the Coalition Government's recentralisation of science, innovation and industrial policy as part of a wider repatriation and “rolling back” of state institutions, structures and regulations to the national level restructured and disabled the pathway's previously supportive institutional and enabling environments (O'Neill 1997; Peck & Tickell 2002; Peck & Theodore 2007). In the regional offshore wind pathway, as part of a shift by the Coalition Government towards an extended neoliberalism philosophy based on open and competitive markets, the reconfiguration of national state institutional structures, regulatory environmental frameworks and ongoing changes to existing policy levers illustrated the destabilising role the state performed in delivering “institutional consistency” (Howarth 2012) e.g. common rules, regulations, organisational structures etc., and a balanced and carefully timed mix of policy interventions (Essletzbichler 2012). In stark contrast, the intervening period of national state power illustrated the disabling effect social and institutional agency, and particularly the national political economy and changing policy priorities, played in dismantling, stalling and ultimately eroding, the strategic niche conditions which had served to enable and incubate the printable electronics pathway in the North East during the path development phase (Martin 2010).

6.2. LOCAL AND REGIONAL INSTITUTIONAL ACTORS, FACTORS AND SETTINGS

6.2.1 Introduction

As illustrated in Chapter 6.1, as part of the rescaling of state power the Coalition Government instigated a series of economic development policy reforms driven by immediate and long-term planning for deficit reduction (Pugalis 2011). In marked contrast from the path development episode which had highlighted the importance of social and institutional agents, and the national political economy of the UK state and the power geometries of its regional governance architecture to enact, stimulate and support the mechanisms through targeted policy interventions at the regional spatial scale, the Coalition Government's radical policy reform of the sub-national politico-institutional structures instigated a dual process of renationalisation and decentralisation to the sub-regional and local level (Mackinnon *et al* 2009). The following section examines the implications of the Coalition Government's sub-national reforms, beginning with the decision by national state actors to disband ONE and the SfS innovation programme, on the developmental trajectory of the North East's offshore wind and printable electronics pathways.

6.2.2 Sub-Regional Institutions and Governance: From Regional Development Agencies to Local Enterprise Partnerships

After a year in power the Coalition Government instituted a more radical, localist approach to the governance and delivery of economic development in England. The "region", New Labour's preferred scalar platform for the governance and spatial unit for managing economic development intervention in the earlier path development period, was rebuked in favour of the Coalition's "new localism" philosophy and political agenda (Bentley *et al* 2010). As part of the political rescaling strategy and deconstruction of Labour's top-down regional policy architecture, the Coalition Government embarked upon a systematic dismantling of regional institutional and state governance bodies, beginning with the closure of ONE, which initiated the start of a "policy vacuum" in the stimulation and development of the offshore wind and printable electronics pathways in the North East (Dawley 2013; Dawley *et al* 2015).

In the context of connecting over a decade of strategic regional policy intervention to stimulate and enable processes of path creation and development, the hollowing out of the policy environment from below as part of the abolition of ONE and termination of the SfS and Northern Way innovation programmes had profound implications on purposive local and regional policy and strategic intervention in the development trajectories of the offshore wind and printable electronics industries (Dawley 2013). At a strategic level, ONE had performed an important “boundary-spanning” (Cohen & Levinthal 1990) role in stimulating both pathways by creating, nurturing and coordinating local and regional institutional actors, structures and networks by aligning state policy at the macro scale with directed and contextual policy intervention at the micro and meso level (Asheim *et al* 2011).

The deconstruction and re-scoping of the regional institutional architecture and policy environment from above witnessed the closure of ONEs SfS and Northern Way programmes, halting the policy intervention and delivery of the largest science and innovation programme in the English regions (Perry 2010). In particular, the future remit, governance arrangements and core funding of NaREC, PETEC and CPI in actively supporting and intervening in the mechanisms stimulating the regional offshore wind and printable electronics pathways was thrown into doubt (see section 6.2.2) (Head of Energy & Environment ONE, Author’s Interview 2011). Moreover, “softer” policy interventions to the regional innovation system, including the creation of NOF Energy, which had been created to provide intra-regional learning, knowledge exchange and promote extra-regional linkages in support of the regional offshore wind pathway, was discontinued. Similarly, the termination of the NWIP plastic electronics programme resulted in the withdrawal of four of the five North East-based companies which had received on-going R&D finance from the Northern Way. In the example of Durham-based High Force Research which immediately scaled back the firm’s plans:

“there was £5m put in and I think the Northern Way was generally seen as very successful. It got a lot of people together, it got us into a new area that we didn’t really know anything about but it’s the same core skills that we use for doing pharmaceutical chemical molecules so it opened us up to a new business area that was growing. However, without Northern Way funding we weren’t able to continue. We did apply for further R&D grant funding but were rejected. For a small company like ours we can’t take the risk of doing this ourselves and need government stimulus to

continue supporting R&D and help stimulate the market” (CEO High Force Research, Author’s Interview 2011).

The closure of ONE during the temporal episode illustrated the damaging role changing national political economy and associated reconstituted sub-national governance structures and shifting policy approaches played in constraining the offshore wind and printable electronics pathways in the North East (Mackinnon *et al* 2012). To fill the space vacated by the abolition of the nine English RDAs, the Coalition Government instituted a more radical political approach to sub-national economic development under the rubric of the “localism” agenda (Localism Act 2011). RDAs were swiftly replaced by Local Enterprise Partnerships (LEPs) as the state’s key strategic and delivery vehicle at the sub-regional and local scale (HM Government 2010). Signalling the “death of the region” as an organising principal for policy activity (Bentley *et al* 2010), two sub-regional LEPs were formed in the North East: Tees Valley LEP (TVLEP) and the North East LEP (NELEP). For the offshore wind and printable electronics industries in the North East, the introduction of TVLEP and NELEP offered limited institutional capacity, resources and political strength to provide strategic policy support and harness “local and regional assets” to promote, support and stimulate both regional path trajectories (Bentley *et al* 2010; Pike *et al* 2012; Dawley 2013; House of Commons 2012).

Offshore Wind

In the absence of strategic leadership and capacity of strong and suitably-designed state sub-regional governance actors necessary and able to create the requisite enabling conditions for growth, the episode in the path development of the offshore wind industry in the North East illustrated alternative public sector institutional actors at the local, sub-regional and regional scale displaying characteristics of layering, conversion and re-orientation to serve the offshore wind pathway (Boas 2007; Martin 2010). During the period, local authorities in the North East adopted a more prominent role in filling the void left by ONE in setting the structural conditions to stimulate and support investment in the offshore wind pathway (Martin 1999; Head of Energy & Environment ONE, Author’s Interview 2011) (see Table 6.1). For instance, in an example of local authorities “recoupling” (Dawley 2010) infrastructure, facilities and resources to catalyse and expand on the burgeoning regional offshore wind pathway, Newcastle City Council and North Tyneside Council secured funding

from European and national state sources to undertake the physical regeneration and recombination of former industrial sites on the North bank of the River Tyne (DCLG 2013). Furthermore, local authorities also displayed signs of transitioning away from inter-local competition towards strategic partnership working with Newcastle securing a “city deal” package with neighbouring Gateshead to create an accelerated development zone (ADZ) designed to secure:

“£500m in private sector investment from the marine and offshore sector, with the potential to create 8,000 jobs across the North East” (Newcastle City Council 2012).

The example of layering and conversion within the NELEP sub-region during the episode was similarly repeated in the south of the region with TVLEP forming a partnership with PD Ports, owner of the Port of Tees, to capitalise on Tees Valley’s heavy engineering and manufacturing base, portside assets and capital incentive benefits to stimulate the mechanisms of diversification, branching and transplantation (Martin & Sunley 2006) (Area Regeneration Manager Northumberland County Council, Author’s Interview 2011; Arch 2013).

Table 6.1 Local Authority Commitment to the Offshore Wind Industry

Local Authority	Vision Statement
Sunderland City Council	“The offshore wind sector is a long-term economic opportunity for Sunderland with particular opportunities within heavy engineering, construction and maritime activities” (Sunderland City Council 2010)
Newcastle City Council	“Newcastle [can] play an important role in the North East becoming a world-leader in the rapidly expanding offshore wind sector” (Newcastle City Council 2010-2011)
Hartlepool Borough Council	“A number of Hartlepool firms are already servicing offshore wind farms across the UK and there are currently major inward investment opportunities to further develop the sector” (Hartlepool Borough Council 2010)
Northumberland County Council	“Northumberland can become a central hub for wind energy in the UK...with onshore and offshore proposals

	being developed” (Northumberland County Council 2010)
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Source: Author 2013

In the context of the changing scale, structure and diminishing power of state sub-regional politico-institutional actors, the temporal episode also witnessed private sector actors and local and regional institutions recombine knowledge, experience, skills and configure new partnership arrangements to redefine alternative roles in a new brand of “place renewing leadership” (Bailey *et al* 2010). As an example of institutional recombination that sought to “absorb and adjust to path-breaking economic change” (Bailey *et al* 2010, p.462), Energi Coast was established by NOF Energy in 2011 as a business-led offshore renewables group representing over 20 North East-based offshore wind companies (Energi Coast 2013). The rationale behind the creation of Energi Coast was intended to “take up the slack left by ONE in promoting the North East’s offshore wind industry” (CEO TAG ES, Author’s Interview 2011). In legacy of purposive policy activism from the earlier path development episode, Energi Coast’s core aim was to support the candidate path mechanisms of firm diversification, branching and transplantation in order to harness related technologies, products and services to promote the competitive offering of the North East’s energy and engineering industries, key infrastructural assets and labour market (Boschma & Frenken 2007; CEO TAG ES, Author’s Interview 2011; Dawley 2013). In many respects:

“Since ONE effectively ceased trading, the region has effectively lost a little bit of profile as far as offshore wind goes and NOF Energy has recognised this and brought together leading companies...there has been quite definitely a loss of momentum and other areas such as Scotland seem to be getting all the profile...there comes a time when you have to move away from the public sector. The private sector is driving this. It will be the private sector that makes this successful” (CEO TAG ES, cited in Dent 2011, p. 1).

The example of the formation of Energi Coast and leadership displayed by the Chair of Energi Coast and CEO of TAG ES illustrated the redefined role of key entrepreneurs and firms during the path development period as important “agents of change” in industrial contexts and multi-scalar institutional settings (Boschma 2006).

Printable Electronics

In contrast to the institutional recombination and adaptation of public and private sector actors in the North East positioning themselves to stimulate, promote and take advantage of increasing economic development opportunities in the expanding offshore wind industry, contextual politico-institutional support and policy intervention at the local and regional scale to the regional printable electronics pathway during the temporal episode was withdrawn (Boschma 2009; Director of PETEC, Author's Interview 2011). In the absence of ONE, and without an explicit focus by either NELEP, TVLEP or alternative local, sub-regional or regional institutional actors in support of emerging technologies and innovation, the region became reliant, as it did predominantly in the initial path creation phase, on informal networks and "communities of practice" within and between industry, academia and the CoE to sustain momentum to the printable electronics pathway in the North East (Brown & Duguid 1991). To partially fill the strategic institutional vacuum in the region, Business Durham seized the initiative. Consequently:

"without ONE, and with the NELEP still to decide what it will concentrate its innovation and industrial activity on, it's up to us [Business Durham] to continue promoting the printable electronics industry in the region. Our strategy will continue to focus on using NETPark as a base to encourage indigenous business and inward investment as we are good at supporting companies like Polyphotonix to grow. Our inward investment approach will remain the same...we don't expect Samsung to come to NETPark and build a big manufacturing plant as an anchor tenant. I think we are past that model of investment. But I do think we can build a credible business case for Samsung to locate an R&D project team here to access the expertise and kit at PETEC. This is the type of investment we want and I think Business Durham and NETPark are well equipped to play a leading role in coordinating and delivering printable electronics activity in the region" (Director of Business & Investment Business Durham, Author's Interview 2011).

The example of Business Durham highlighted the adaptive capabilities of formal institutional actors at the local and regional scale to add new roles, functions and processes to stimulate, facilitate and enable new growth paths (Mackinnon 2012). In many respects, the emergence of Business Durham as the North East's principal, and only, advocate for printable

electronics was understandable given the significant political and financial capital invested in PETEC and NETPark by Durham County Council (Director of Business & Investment Business Durham, Author's Interview 2011). More broadly, the removal of over a decade of institutional support at the regional level to seed the creation and development of printable electronics in the North East restated the inherent danger faced by state-led peripheral regional economies, such as the North East, that continued to be shaped by the political economy of the UK state and the power geometries of its governance of local, sub-regional and regional economic development (Dawley 2013).

6.2.3 Centres of Excellence, R&D and Innovation

As highlighted in section 6.2.2, the decision to abolish ONE and the SfS innovation programme as part of a series of steps taken by the Coalition Government to recentralise UK science, innovation and industrial policy raised doubts over the long-term governance, fiscal arrangements and sustainability of the “regional” CoE. Although ONE had retained legal independence from the centres, NaREC, PETEC and CPI remained dependent on Single Programme funding to finance the large capital asset base, proposed infrastructure development programme and core operating costs associated with collectively employing over 280 highly-skilled staff (Goddard *et al* 2012). For instance, just prior to the transfer of national state power, ONE had committed £13.5m in Single Programme capital expenditure to support the purchase, build and installation of a 100m blade test facility and drive train testing rig at NaREC (Head of Energy & Environment ONE, Author's Interview). Similarly, ONE had allocated a further £5.8m of regional state funding to PETEC to build additional infrastructure and innovation capacity (ONE 2011b). With the phased repatriation of Single Programme funding to Whitehall and neither CoE generating sufficient private sector income to become self-sustainable, ONE brokered, and secured, interim agreements to transfer the governance, financial commitments and liabilities of NaREC, PETEC and CPI over to the TSB (Innovation Manager ONE, Author's Interview 2011).

Although considered a temporary solution at the time, the contractual arrangements between the TSB and ONE was important in the context of maintaining and embedding the strategically important innovation assets of CPI, NaREC and PETEC in the regional pathways but also critical in light of the Coalition Government's centralisation and increasingly place-neutral approach to UK science, innovation and industry policy (Head of

Innovation, Industry & Science ONE, Author's Interview 2011; Barca *et al* 2012). Indeed, upon entering power the Coalition Government initiated a strategic review, and endorsed, CPI, PETEC and NaREC as key national UK technology and innovation centres (TIC) (Hauser 2010). In the case of NaREC:

“the New and Renewable Energy Centre (NaREC) which has received £30m of investment over the past five years from One NorthEast is recognised in the renewable energy industry as one of the lead centres of excellence worldwide for offshore wind technology development and provides employment for 115 people, many whom have graduated from the region's leading universities. It has major clients in Europe, Asia-Pacific and the U.S. and international R&D collaborations in 10 countries. It was also appointed technology advisor to the UK Crown Estate in relation to the Offshore Wind Round 3 programme in 2010 and by the end of 2011 will have the largest onshore physical test asset base in the world constructed at a cost of £100m. It has played a part in attracting inward investment including ClipperWind Power's \$65m offshore wind turbine development project” (BIS 2010, p. 21).

The early positioning of NaREC, PETEC and CPI at a macro-political scale came to a head in 2012 with both centres “regional missions” (Head of Energy & Environment ONE, Author's Interview 2011) replaced by new roles as integral parts of the TSB's national catapult network of TICs (TSB 2011). The High Value Manufacturing Catapult (HVMC) was the first to form and included CPI and PETEC as one of seven national research centres selected by the TSB to receive a share of over £140m to develop new advanced materials and stimulate manufacturing in the UK (Head of Electronics & Photonics BIS, Author's Interview 2012). Similarly, NaREC was subsumed into the £50m Offshore Renewable Energy Catapult (OREC) to form part of a UK wide consortium of offshore wind stakeholders (Scottish Enterprise 2012; Laing 2012).

Although the ramifications of CPI, PETEC and NaREC becoming national innovation assets on the path development of the regional offshore wind and printable electronics pathways requires future longitudinal evaluation, the altered role, function and implications of the state's restructuring of the North East's local and regional institutional and organisational structures, enabling conditions and former contextual innovation policy programme highlighted a binary distinction. On the one hand, the transition to national strategic

innovation assets in the UK catapult network secured an immediate future for the CoE and provided a stable platform for further layering and re-investment in the offshore wind and printable electronics pathways in the North East (Simmie 2012). For instance, between 2010 and 2012 PETEC completed a £20m re-investment in new and existing testing and prototype facilities. Thus:

“our [PETEC’s] approach has always been about creating a national technical and innovation centre...we have taken a UK supply chain approach but with a large payback for the region as a location that possesses significant potential to diversify the existing chemical and process manufacturing business stock but also to attract new investment to the region...the benefits of having a nationally recognised centre in the North East, having seen what little public R&D infrastructure was here before, is largely down to ONE” (Director of PETEC, Author’s Interview 2011).

In the context of the regional offshore wind pathway, NaREC completed construction of its 100m blade turbine test facility, secured £25m from the Energy Technology Institute (ETI) to establish a 15MW drive train test rig, and secured planning permission from the UK Crown Estates and investment from BIS to begin installation of a 100MW grid connected offshore wind demonstration platform off the Blyth coastline (TSB 2011; Director of Technology and R&D NaREC, Author’s Interview 2012; NaREC 2013). Importantly, the proposed large-scale investment in an offshore wind demonstration site returned Blyth to the position last experienced in the path creation phase of utilising the localities place-based assets, capabilities and historical track-record in supporting the ongoing development of the regional offshore wind pathway. Moreover, NaREC’s sustainable footing provided the TIC with increasing “organisational adaptability” (Sydow *et al* 2014) as NaREC branched into complementary and related disciplines, including the creation of NaREC Capital in 2011 which was formed to provide capital, reduce risk and supply insurance services to the offshore wind industry (Director of Technology and R&D NaREC, Author’s Interview 2012; Dent 2012).

On the other hand, the transfer of power and control to national state institutional and political actor’s weakened institutional capacity of the TICs to stimulate the mechanisms of path development and support territorially-specific processes of innovation, learning and knowledge-exchange between firm and non-firm actors in the North East offshore wind and

printable electronics pathways (Morgan & Nauwelaers 1999; Lundvall 2000). For instance, the protracted negotiations between ONE and the TSB in the early period of transition to national state ownership caused NaREC significant delays in planning, construction and installation work on key offshore wind innovation assets with the national centre in “real danger of the missing the boat” (Pearson 2011, p.5). Moreover, in the absence of sub-regional political leadership, institutional capacity and power by NELEP and TVLEP to influence, enable and integrate mechanisms of path development at the local and regional scale with the national missions and increasing global client base of CPI, PETEC and NaREC, the temporal period in the path trajectories of the printable electronics and offshore wind industries in the North East appeared to be:

“emblematic of a longer-term divergence between its high-level R&D and testing functions with extra-regional clients and the absorptive capacity of the industrial base through firm diversification and transplantation” (Dawley 2013, p.105).

As an instrument of national state actors to stimulate and deliver innovation and industrial engagement, PETEC, CPI and NaREC radically altered their business models away from stimulating endogenous mechanisms of path development and the attraction of exogenous resources to the regional offshore wind and printable electronics pathways and instead placed greater emphasis on generating income from extra-regional sources (see Table 6.2). As a consequence:

“we [PETEC] have to change our business model drastically. We are short of funds next year by a large sum of money so we have to grow our commercial sales income far faster than we expected or projected we would need too. That is just reflecting the political and economic reality in the North East and elsewhere. Ideally, I would have liked to have carried on with the mixed funding model for a bit longer in order to build up traction with regional and national companies but we are going to have to be creative and focus our business activities on larger [MNC] players which are more often than not located outside of the region” (Business Development Manager PETEC, Author’s Interview 2011).

The withdrawal of organisational support and intentional policy intervention to the regional printable electronics and offshore wind pathways by PETEC, NaREC and CPI, including the

renounced decision to refrain from supporting or entering into partnership with Energi Coast and other North East-based initiatives and networks, further illustrated the divergent role of the TICs in the regional economy and unconstructive consequences of the place-neutral stance and extra-regional control exhibited by national political actors in shaping the developmental trajectories of both pathways during the temporal period (CEO TAG ES, Author's Interview 2011; Mackinnon 2012; Dawley 2013).

Table 6.2 PETEC Extra-Regional Client Base, 2010-2012

Company	Company HQ	Technology/Industry
Nano ePrint Ltd	Manchester	Electronic devices in printable electronic applications
Novalia Ltd	Cambridge	Interactive displays using printing and conventional electronics
Peakdale Molecular Ltd.	Derbyshire	RFID tags to drug packaging
Polyphotonix Limited	Durham	OLED products for medical conditions
Trackwise Designs Limited	Gloucestershire	Flexible PCBs
Oxford Advanced Surfaces Limited	Oxford	Advanced materials and surface modification technology
Polar OLED Limited	Leeds	Liquid crystal-based polymer materials
Print Yorkshire Limited	Yorkshire	Electronic printing
Optek Systems Limited	Oxford	Precision laser processing of optical fibres
Multi Sensor Systems Limited	Cheshire	Electro-chemical materials and analysis
Polysolar Limited	Cambridge/Durham	Building integrated transparent photovoltaic cells
Nomad Engineering Design Limited	Yorkshire	Unknown
Contact Print and Packaging	Stockport	Plastic electronics and flexible circuit boards
Inside 2 Outside	Cambridge	Integrated electronic circuitry to

		school plastic canopies
Menai Medical Limited	Sussex	Unknown

Source: PETEC 2013

6.2.4 Summary: Weakened and Adjusted Role of Local and Regional Institutional Actors in Path Dependency

Illustrating the broader context and importance of multi-scalar social and institutional agency that shape, and are shaped by, the mechanisms of path creation and development, this section unpacked the influence and impact of the unravelling of the state’s regional governance architecture and “contextual policy” environment following changes to the national political economy of the UK state and radical restructuring of sub-national organisations and policy frameworks (Boschma 2009; Mackinnon *et al* 2009; Asheim *et al* 2011). After a sustained period of intensive, targeted and embedded policy interventions by ONE which reflected the industrial history and institutional composition of the North East, RDAs were disbanded by the incoming Coalition Government and replaced by LEPs as a part of a national rescaling and re-scoping of sub-national economic development functions and delivery (Neffke *et al* 2011; Boschma *et al* 2012). As highlighted by North (1990), institutional change at the macro-scale can have profound implications on the evolutionary trajectories and change over time on formal and informal institutions at the local and regional scale. The hollowing out of the North East’s policy environment from above and below, and clear rupture in over a decade of regional strategic “policy-on” (Dawley 2013) activity, resulted in the formation of TVLEP and NELEP akin to the creation of a regional “north-south divide”, which stalled support to the mechanisms of diversification, related variety and transplantation (Head of Energy & Environment ONE, Author’s Interview 2011). In the absence of an overarching regional strategic framework and limited institutional capacity and resources of NELEP and TVLEP to stimulate and enable both industrial trajectories, the offshore wind pathway exposed local and sub-regional firm and non-firm actors and institutions recombining and redefining roles in continuing support of the evolving pathway. In contrast, the reconfiguration of the regional institutional landscape and previous period of tailored policy support to the printable electronics pathway was systematically eroded and replaced by Business Durham as the solitary sub-regional organisational actor that neither possessed the

institutional scale, capacity or resources to mediate and enable the pathway to progress forward (Cooke 2012).

Within the context of the rescaling and reorganisation of the North East's politico-institutional environment, the removal of ONE and termination of the SfS innovation programme signalled the end of over a decade of building innovation capacity, "institutional thickness" and purposive policy intervention to the North East's science, innovation and industrial base (Amin & Thrift 1994; Asheim *et al* 2011). Whilst still early to judge the precise implications for the offshore wind and printable electronics pathways in the North East, as part of the Coalition Government's place-neutral "national innovation system" and network approach, the transition of NaREC, PETEC and CPI to strategically important national technology and innovation assets illustrated the strength of regional political leadership, capacity and delivery in the earlier path development phase (Lundvall 1992). Nevertheless, in the absence of strong sub-regional institutional and political structures and actors to connect path mechanisms at the local and regional scale to the TICs new national role and function, the ensuing period to 2012 illustrated the increasingly conflicting role of NaREC, PETEC and CPI on the regional offshore wind and printable electronics industries. In particular, the temporal episode highlighted the divergence between the Catapult's high-level R&D and innovation activities with extra-regional clients and fulfilling the original aims of the CoE by addressing the regional innovation paradox by stimulating the candidate mechanisms within the local and regional industrial base (Oughton *et al* 2002; Dawley 2013).

6.3. PATH MECHANISMS

6.3.1 Introduction

With reference to Chapter's 5.4 and 6.3 which investigated and examined the candidate mechanisms of path creation and development in the offshore wind and printable electronics industries in the North East, this section repeats the logic and approach in applying, comparing and contrasting the candidate mechanisms from the previous temporal episodes to explain the processes and causality which underpinned the regional path's trajectories between 2010 and 2012 (Sydow *et al* 2009). Importantly, the section unpacks the importance and implications of the removal of multi-scalar institutional and policy support, and

specifically the closure of ONE and adjusted functions and influence of NaREC, CPI and PETEC, on the existing momentum of both industrial pathways during the episode.

6.3.2 Related Variety and Branching

Despite the removal of much of the North East's supportive politico-institutional structures and actors within the regional offshore wind industry during the episode, including the closure of two business support programmes delivered by NaREC to stimulate diversification and branching of the local and regional industrial base, the North East's offshore wind pathway exhibited increasing momentum with increasing volumes of firms from technologically-related sectors branching into the offshore wind sector (Boschma & Frenken 2009; ONE 2011b). Experienced local and regional firms from across the supply chain i.e. from advanced engineering (electrical, mechanical and civil) and sub-sea solutions to power, transportation and professional and business support services, secured commercial contracts with offshore wind project contractors, wind turbine OEMs and, importantly, multi-scalar state institutional actors in a further example of state-led market development (Cooke 2010; CEO Alnmaritec, Author's Interview 2013) (see Table 6.3). Indeed, the candidate mechanisms of related variety and branching displayed during the temporal episode also exhibited elements of firm "upgrading" (Martin & Sunley 2006). For instance, illustrating the overlapping nature of the mechanisms, subsea engineering company CTC Marine, which had previously diversified into the offshore wind industry in the earlier path development phase, developed a new electrical cable capable of being submerged into harder clay materials in recognition that offshore wind farms were becoming installed in deeper waters and more challenging terrain (Business Development Manager CTC Marine, Author's Interview 2011). Similarly, from an initial position of related diversification to stimulate upgrading of the firm's product base, SMD Hydrovision patented and commercialised a new seabed ROV for the offshore wind industry utilising similar robotics technology sold to companies involved in mining, marine salvage, telecommunications, oil and gas sectors (CEO SMD Hydrovision, Author's Interview 2012). Furthermore, SMD Hydrovision was synonymous with other technologically-related firms during the period of path development and dependency which began to place a greater emphasis on securing external knowledge and strategic partnerships, with SMD Hydrovision acquiring intellectual property and technology by investing in Darlington-based Blade Offshore Remote Drilling in order to provide complementary

technical solutions to the firm's existing seabed technology (CEO SMD Hydrovision, Author's Interview 2012).

Whilst North East-based SMEs from multiple related sectors identified branching opportunities, the scale of the commercial opportunity in the UK Crown Estates Round 3 offshore wind programme and burgeoning domestic offshore wind market also witnessed some of the region's MNC's branching into the regional offshore wind pathway. Following the mothballing and divestment of Teesside Cast Products, Corus announced the intention to invest £31m and create 220 jobs in the production of offshore wind steel foundations by recombining the firm's existing site, knowledge and experience of steel fabrication (Business Development Manager Corus, Author's Interview 2010). Although the investment by Corus in "Project Kraken" failed to materialise, the firm subsequently went on to invest £2m in the Corus Offshore Processing Centre in Hartlepool to supply steel components to offshore wind turbine foundation structures (Cape 2011). Corus was joined by a number of other regionally-based MNCs during the period including A&P Tyne, Duco and Wellstream that had historically supplied components, project management and services to the oil and gas industries. For instance, demonstrating linkages between place-based knowledge transfer and technological relatedness, Offshore Group Newcastle (OGN) announced a £50m investment to diversify away from manufacturing oil production platforms which OGN had typically supplied during the boom years of the 1980s and 1990s, to produce steel foundations and offshore wind turbine parts in Wallsend, North Tyneside, creating 600 jobs in the process (Hill 2011). In a further example of indigenously-rooted knowledge stimulating the mechanisms of related variety, International Paint (IP) developed and commercialised a new finished coatings product for offshore wind turbines based on IP's existing proprietary technology and solutions for offshore structures (Business Development Manager International Paint, Author's Interview 2011). As part of opening up the firm to a "mixed portfolio" of market opportunities, IP created a new offshore wind business development unit in 2011 marking a significant shift towards diversifying away from supplying products to oil and gas drilling rigs and power substations (Boschma & Frenken 2011). In the examples of OGN and IP, the path dependent episode in the regional offshore wind pathway once again restated the importance of key local and regional actors in matching local and regional assets, related knowledge and technical capabilities to new market and diversification opportunities (Garud & Karnoe 2003).

Table 6.3 Regional Firm Branching and Offshore Wind Contracts, 2010-2012

Company	Location	Origins of Company	Project	Client
JDR Cables	Hartlepool	Manufacturer of high voltage cables and umbilical's for oil & gas	Wave Hub	South West of England Regional Development Agency
McNulty Offshore	South Shields	Oil & gas platform fabricator	Greater Gabbard Substation mounting platform	Siemens
Heerema	Hartlepool	Manufacturer of offshore platforms and structures	Greater Gabbard Substation mounting platform	Siemens
JDR Cables	Hartlepool	Manufacturer of high voltage cables and umbilicals for oil & gas	Greater Gabbard Windfarm	Fluor
McNulty Offshore	South Shields	Oil & gas platform fabricator	Lincs substation Platform	Siemens
McNultys Offshore	South Shields	Oil & gas platform fabricator	Gwyn-T-Mor transformer jacket & topside	Siemens
JDR Cables	Hartlepool	Manufacturer of high voltage cables and umbilical's for oil & gas	London Array	Dong/Eon/Masdar

Heerema	Hartlepool	Manufacturer of offshore platforms and structures	Sheringham Shoal Substation mounting platform	Areva
HTB Electrical	Sunderland	Electrical product installation and testing	Electrical contracts on Lynn & Inner Dowsing	Centrica
CTC Marine	Darlington	Cable trenching and laying for telecommunications industry	Bard Offshore 1	NSW/Bard
MTL	Blyth	Steel fabricators for defence industry, construction, rail and quarrying	Transition piece manufacture/engineering	BiFab
Alnmaritec	Blyth	Vessels to oil & gas and O&M industry	Manufacture of aluminium offshore support vessels	Various
IHC Engineering Business	Tyne	Materials handling and cabling for oil & gas	Beatrice project	Talisman Energy
Senergy Econnect	Newcastle	Electrical grid connection to renewable energy industry	Electrical grid connection studies	DECC

Roballo (Rothe Erde)	Durham	Slewing bearings for multiple industries	Bearings	Various wind turbine OEMs
International Paints	Gateshead	Materials and coatings to multiple industries, structures and products	Coatings on Thanet, Gabbard, Lincs and London Array offshore wind farms	Various
Osprey Shipping	Tyne	Marine, transportation, cargo and logistics supply to oil & gas/nuclear industry	Barging on a number of offshore projects including Thanet, Dudgeon & Ormonde offshore wind farms	Various
SKM Consulting	Tyne	Consultancy firm to multiple industrial sectors	Environmental impact assessments (EIA) services on offshore demonstration project	NaREC
Parsons Brinkerhoff	Tyne	Engineering and project management to multiple industrial sectors	Electrical studies on offshore wind demonstration project	NaREC

Mech-Tool	Tees	Production of fire, blast and noise products for nuclear and oil & gas	Construction of buildings, cladding and weather louvres for Lincs substation	McNulty Offshore
Tyne and Wear Marine	Tyne	Marine and civil engineering to oil & gas industry	Fit out of offshore barges for wind	Dalby Offshore services
Sub Aqua Diving Services	Tees	Diving services to oil & gas and marine civil engineering	Diving services - North Hoyle, Lynn & Inner Dowsing, Robin Rigg offshore wind farms	Various

Source: ONE 2011a, p. 6.

In addition to the ongoing diversification and branching of firms from related sectors into the regional offshore wind pathway, the temporal period also exhibited public and private sector organisations in the North East mobilise resources to improve hard infrastructure, skills and training in support of the expanding industry. Reflecting the importance of practical investments in “infrastructure, natural resources and logistics” (Steen & Karlsen 2014) to generate, stimulate and attract business growth, the North East offshore wind pathway experienced diversification and re-investment of portside assets, facilities and equipment at the Ports of Tees, Tyne and Hartlepool which were considered vital to supporting and attracting additional offshore wind investment (Business Development Manager International Paint, Author’s Interview 2012). To encourage, support and underpin the territorial offshore wind pathway, formal higher and further educational institutions in the North East also began to address labour, skills and training needs within the wider offshore wind ecosystem. For example, to address a shortage of qualified and skilled apprentices entering into the offshore wind industry, Hartlepool College invested £53m in the Centre of Offshore Wind Excellence (Professor of Energy Newcastle University, Author’s Interview 2011; TVLEP 2012). During the same period, NaREC constructed a 27m offshore wind training tower in Blyth and Newcastle College entered into a strategic collaboration with Shepherds Offshore Services to build and operate a Renewable Energies Academy on the North bank of the River Tyne (Black 2010; Newcastle College 2010).

Unlike the increasing diversification and branching of firm and non-firm actors entering into the offshore wind pathway in the North East, the disintegration of multi-scalar actors and policy support to the developing printable electronics pathway proved decisive in disassembling the initial progress made in the previous path creation and development episodes (Senior Specialist Advisor Emerging Technologies ONE, Author’s Interview 2011). Transitioning from a period in which multi-scalar state-led actors and purposive policy programmes had catalysed latent potential in the North East’s industrial base to diversify and branch into the printable electronics industry, the removal of state and quasi-state agencies, and particularly the removal of ONE and the Northern Way, left an institutional and policy vacuum in creating and maintaining strategic niche management opportunities within the pathway. For instance, the closure of the NWIP plastic electronics programme and disassembly of policy intervention in strategically manipulating an emerging supply chain in the North of England resulted in North East-based MAPP Systems discontinuing with developing a new printing process for the creation of a modified keypad (Director of PETEC,

Author's Interview 2012). With the cost of R&D into new materials, components and adaptation to new manufacturing processes remaining prohibitively high for local and regional firms without state-led policy intervention, firms including High Force Research, Faraday Printed Circuits and Merlin Flex-Ability that had explored new market diversification opportunities in the path development episode returned to product experimentation and previously established market verticals (Sales Director Faraday Printed Circuits, Author's Interview 2011). Reflecting the experience of a number of electronics, printing and chemical firms during the episode that returned to a period analogous to the pre-formation and path creation phase of development:

“we started to look at printable electronics and manufactured some products for the market but the issue was in the different base substrates used and the cost of altering our current production process. Printable electronics uses polyester-based materials as opposed to most electronic applications which use polyimide. The problem for Merlin and all PCB manufacturers is polyester flexible substrate is very cheap and you've got to produce a lot to make your money [in comparison to polyimide which is more expensive but requires less quantities].... You are also looking at a very small carbon footprint to produce new products but some of our equipment is quite the opposite. It also runs at very low temperatures so trying to run polyimide alongside it you would really need some form of separate facility as opposed to merge it with our core business...without financial support from the UK Government or ONE there was no way we could pursue this technology ourselves” (CEO Merlin Flex-Ability, Author's Interview 2011).

By the end of 2012, the only remaining firms in the North East which had branched and remained in the pathway were DuPont Teijin Films, which had re-invested in the firm's existing R&D centre at Wilton to manufacture the Mylar PET polyester thin-film, and Thorn Lighting which continued to scale-up R&D activities into OLED and P-LED lighting products (Chief Scientific Officer DuPont Teijin Films, Author's Interview 2011; Research Team Lead Thorn Lighting, Author's Interview 2011). In short, the temporal episode had demonstrated the consequential influence, interconnectivity and effects of removing multi-scalar social and institutional agents, and particularly contextually-specific policy intervention delivered by ONE and the Northern Way, in constraining the mechanisms of

variety and branching on the regional printable electronics pathway (Martin & Sunley 2008; Coe 2010; Mackinnon 2012).

6.3.3 Exogenous Investment and Transplantation

Picking up from a relatively successful time period in the path development phase which had been illustrated by ONE building targeted inward investment pipelines and attracting strategically important transplantation into the North East offshore wind pathway, the period from 2010 to 2012 exhibited a marked contrast in the role and type of transplantation as a candidate mechanism of the path's progression. Initially, ClipperWind Power's European centre for R&D and manufacturing in Blyth had represented the first offshore wind turbine OEM investment in the UK and acted as an attractor for overseas and domestic firms to explore inward investment opportunities into the North East. As a result, ONE fielded FDI enquiries from leading OEM offshore wind turbine firms in the early period including Siemens, Gamesa, GE and Vestas, with proposed R&D inward investments disproportionately concentrated at NaREC and subsea, offshore foundations and turbine manufacturing projects spatially concentrated at the Ports of Blyth, Tyne and Tees (Business Development Manager Siemens Wind Power, Author's Interview 2011) (see Table 6.4). However, as a consequence of the shifting national political landscape and closure of ONE's skilled, knowledgeable and experienced offshore wind and inward investment teams, the intervening period radically altered the role and capability of North East-based institutional actors to stimulate transplantation as a mechanism for the path's on-going development (Head of Energy & Environment ONE, Author's Interview 2011). Amidst a time of enhanced competition from Scotland and other competing European locations for offshore wind investment, intra-regional competition between NELEP and TVLEP in pursuit of exogenous investment resulted in a period of "inherent wastefulness" (Cheshire & Gordon 1998; Malecki 2004) with neither LEP possessing the institutional capacity to "developmental target" (Young *et al* 1994), attract and convert multiple offshore wind enquiries into inward investments. Thus:

"without ONE it's difficult to make things happen. You have LEPs competing against each other. You have the [UK] Government which is based 250 miles away and you're trying to bring people to the region...how do you even arrange a visit to see the right people? At least with ONE, and not everything was perfect, but in my

experience it would be a lot more difficult talking to a range of organisations than being managed by one central point. It's political dogma in my eyes. When you come to an area like the North East people and organisations should work together which assists me as an inward investor" (CEO ClipperWind Power, Author's Interview 2011).

In a further illustration of the declining force of the North East to attract FDI into the offshore wind pathway, after courting 110 possible sites in the UK and Europe, including three sites in the North East, Siemens announced its decision to invest £80m in a wind turbine manufacturing plant in Hull creating 700 jobs (Dawley 2013). In contrast to latecomer localities, such as Yorkshire and Humber, that possessed a limited track-record in offshore wind-related activities, the North East also lost out to more established localities during the episode with Gamesa selecting the Port of Leith in Scotland, rather than Hartlepool, for the company's £125m offshore turbine manufacturing plant based on a significant financial grant aid package, strong national political commitment by the Scottish Government to capture the "R&D of all big offshore wind turbine players" (Scottish First Minister, cited in UK Offshore Wind 2011) and ambition to achieve an all renewable energy market in Scotland by 2020 (Bolger 2011). The episode in the path's development trajectory illustrated the institutional deficit left behind by the closure of ONE and demonstrated the power of MNCs to cultivate "locational tournaments" (Bolger 2011) from established and "new" FDI localities seeking to attract and embed exogenous investment in local and regional industrial pathways (Mytelka 2000).

Within the context of the differential and contesting power relations involved in establishing strategic couplings between key firms within GPNs and host communities, the North East's increasingly challenging position to attract and embed exogenous offshore wind investment in the offshore wind pathway was further compounded in August 2011 when ClipperWind Power announced the abandonment of the firm's European offshore wind turbine R&D and manufacturing programme following liquidity problems (CEO ClipperWind Power, Author's Interview 2011; Coe & Hess 2011). As a consequence, ClipperWind Power cancelled the proposed offshore blade, nacelle and drive train R&D facility in Blyth and ended plans for a manufacturing plant at Shepherd Offshore Services Neptune Energy Park, with the loss of 1,000 projected direct jobs and associated supply chain and clustering benefits. Later on in the same year, ClipperWind Power was acquired by U.S. conglomerate United Technologies

Corporation which cancelled ClipperWind Power's offshore wind R&D programme and redirected the firm's attention towards obtaining a foothold in the onshore wind market (CEO ClipperWind Power, Author's Interview 2011).

Despite the important loss of ClipperWind Power to the North East offshore wind path, the strategic interventions by ONE in the earlier path development phase proved important in cementing and building up sufficient economic momentum in the mechanism of transplantation to attract increasingly specialised tier 1 and tier 2 supply overseas firm's to the region (Douglas Westwood 2006; Dawley *et al* 2015). For instance, during the period Teesside attracted subsea cabling and installation businesses, including exogenous investment from VSMC and Global Marine Energy to complement the emerging cluster of subsea and turbine base firms in the south of the region (TVLEP 2012). Similarly, within the NELEP sub-region, the mechanisms of transplantation exhibited characteristics of firm specialisation with companies including Technip Offshore Wind, Flexlife and Bernhard Schuller Shipping Management predominantly engaged in project engineering, O&M and installation activities on the Banks of the River Tyne (Keighley 2012). Amidst complementary but ultimately competing inward investment offerings between NELEP and TVLEP, in the absence of strategic regional institutional leadership, capacity and resources the path development episode also witnessed further intervention by the national political economy in coordinating transplantation at the sub-regional scale with the Coalition Government identifying both North East LEAs as two of six LEA sub-regions to receive national Centres for Offshore Renewable Engineering (CORE) status (HM Government 2012b). The empirical findings in the ongoing positive developmental trajectory of the offshore wind pathway in the North East highlighted the importance of previous regional institutional actors and conditions in enabling the mechanisms of transplantation to accelerate, whilst the example of Clipper WindPower served, once again, as a "stark reminder of the potential fallibility of attracting and embedding inward investment within peripheral regions" such as the North East (Dawley 2013, p.29).

Table 6.4 ONE Offshore Wind FDI Enquiries, 2010-11

Company	Offshore Wind Sub-sector	Project Description	North East Location of Interest to Company	Area Required (ha)	Final Investment Destination
Gamesa	OEM	Design, R&D and manufacturing site	Port of Tyne and Middlesbrough	30-100ha	Port of Leith, Scotland
2 B Energy	OEM	Prototype blade R&D	Blyth (NaREC)	Unknown	Fife Energy Park, Scotland
Alstom	OEM / tier 1/ O&M	Blade design, testing and assembly	Multiple sites (Blyth, Tyne)	40ha	Multiple sites in France
XEMC Darwind	OEM	Prototype 5MW turbine and manufacturing for onshore and offshore turbines	Port of Blyth	6ha	U.S.
GE Energy	OEM	R&D, demonstration site and manufacturing for 5MW offshore turbines	Multiple sites (Blyth, Tyne & Tees)	50ha	UK investment decision on hold
Mitsubishi Heavy Industries (MHI)	OEM	Prototype build	Multiple sites	60ha	Glasgow, Scotland

Oceanus	Fabrication & Assembly	Engineering and operations	N/A	Unknown	Unknown
PM Piping	Fabrication & Assembly	Steel foundations	Unknown	Unknown	Surrey, UK
Sany	Fabrication & Assembly	Offshore turbine R&D centre	NaREC	Unknown	U.S.
Siemens Wind Power	Fabrication & Assembly	5MW offshore turbine manufacturing	Port of Tyne	100-200ha	Port of Hull
Sinovel	Turbine	Unknown	Unknown	Unknown	Unknown
Skykon	Turbine base and subsea	Monopile production	Teesside	Unknown	Company entered administration
Vestas	OEM	R&D and offshore turbine manufacturing	Port of Blyth and Tyne	200ha	Unknown (pulled out of Kent in June 2012)

Source: Author 2012

In contrast to a sustained period of exogenous investment into the regional offshore wind industry, the removal of multi state actors at multi-scalar levels caused a negative effect on the inflow of overseas printable electronics firms entering the regional printable electronics pathway. Mass production of TV, laptop, mobile phone and tablet displays had already been lost to East Asia and the pattern of manufacturing more advanced printable electronics displays in Asia was anticipated to continue into future decades (Professor of Physics Durham University, Author's Interview 2011; IdTecEX 2012). In the absence of proactive inward investment activity by ONE, the MNCs that had been targeted and engaged during the path development episode, including Samsung, LG, Phillips and Osram, failed to establish a physical presence in the North East (Senior Specialist Advisor Emerging Technologies, Author's Interview 2011). Instead, the mechanism of transplantation exhibited a changing role and type of FDI to that previously illustrated in the path development phase. Thus, highlighting the changing nature of TNCs in entering into "collaborative open innovation practices" (Chesbrough 2003) and the importance of spatial proximity to place-based innovation assets for knowledge creation, the episode witnessed global firms, including Phillips, forging loose couplings with the region through the development of collaborative "explorative knowledge" (Boschma 2005) projects, product prototyping and locating mobile R&D teams at PETEC, CPI and Durham University (Professor of Physics Durham University, Author's Interview 2011). Similarly, the pursuit of developing "global pipelines" (Owen-smith & Powell 2002) was reflected by Polysolar, a Cambridge-based OPV glass manufacturer and Novalia, a Cambridge-based interactive printed media firm, whom both co-located footloose R&D operations at NETPark in order to access the specialist resources and "star scientists" at PETEC, CPI and Durham University (Zucker & Darby 1996).

6.3.4 Summary: Branching, Transplantation and Divergent Path Mechanism Outcomes

In comparison to the path development episode which had illustrated the causal links between multi-scalar institutional contexts and enabling policy intervention in stimulating and engaging mechanisms of diversification, transplantation and branching, the period between 2010 and 2012 illustrated the important factors of endogenous industrial momentum, capital accumulation and positive external market dynamics on the regional offshore wind pathway. Catalysed by the strategic intervention of ONE in the earlier path development phase which had accelerated and bolstered the "mechanisms of diversification, branching and

recombination which the path's trajectory had become dependent" (Dawley 2013, p.29), the expanding regional offshore wind industry exhibited experienced, technologically-related North East-based actors branching into the marketplace, developing deeper "inter-sectoral linkages" and securing long-term transactional arrangements with OEM, offshore wind farm developers and project contractors (Boschma & Iammarino 2009; Neffke *et al* 2011; CEO ClipperWind Power, Author's Interview 2011). The account of the period of rapid path development restated the accuracy of Klepper's (2007) "heritage theory" in confirming local and regional actors with experience in related fields were better equipped to diversify into new pathways than strategic agency without related experience. In addition to firm branching and recombination, the temporal period also highlighted the important and progressive role, and varied form, of transplantation to the regional offshore wind pathway. However, highlighting the susceptible nature and place dependency of exogenous investment in peripheral regional economies, the decision by ClipperWind Power to divest from the North East highlighted the differential power relations involved in forging strategic couplings between key anchor firms and host communities, and further demonstrated the diminished power and agency of local and regional economic development bodies to attract and retain offshore wind firms in the regional offshore wind pathway (Dawley 2007; Coe & Hess 2011).

After a decade of multi-scalar institutional and intentional policy support to the printable electronics industry in the North East, the "rupture" and removal of state institutional actors, structural layers and purposive policy intervention resulted in a period of latent stasis and ultimate retreat back to the former phase of path creation (Bathelt & Boggs 2003). Without strategic agency at the local and regional scale to establish and fortify "strategic niche management settings" (Martin & Sunley 2008), the mechanisms of firm diversification and branching experienced a stark regression with only a handful of related firms from the previous path creation and development phase sustaining a presence in the pathway due to a combination of securing "niche differentiation" (Jovanovic 2009) in the marketplace and benefiting from economies of scale associated with MNC ownership (Silvestre 1987; Phelps & Waley 2004). More importantly, in contrast to the previous episode which was symbolised by ONE orchestrating actors, agents and networks within and across the region towards "structured coherence" (Harvey 1985), the temporal episode also highlighted the weakened role of local and sub-regional firm and non-firm actors to mobilise and attract exogenous investment from the printable electronics industry due, in part, to the altered type and nature of the industry which increasingly illustrated loose couplings between industry and

regionally-rooted knowledge, capabilities and innovation assets in the North East (Cooke 2005).

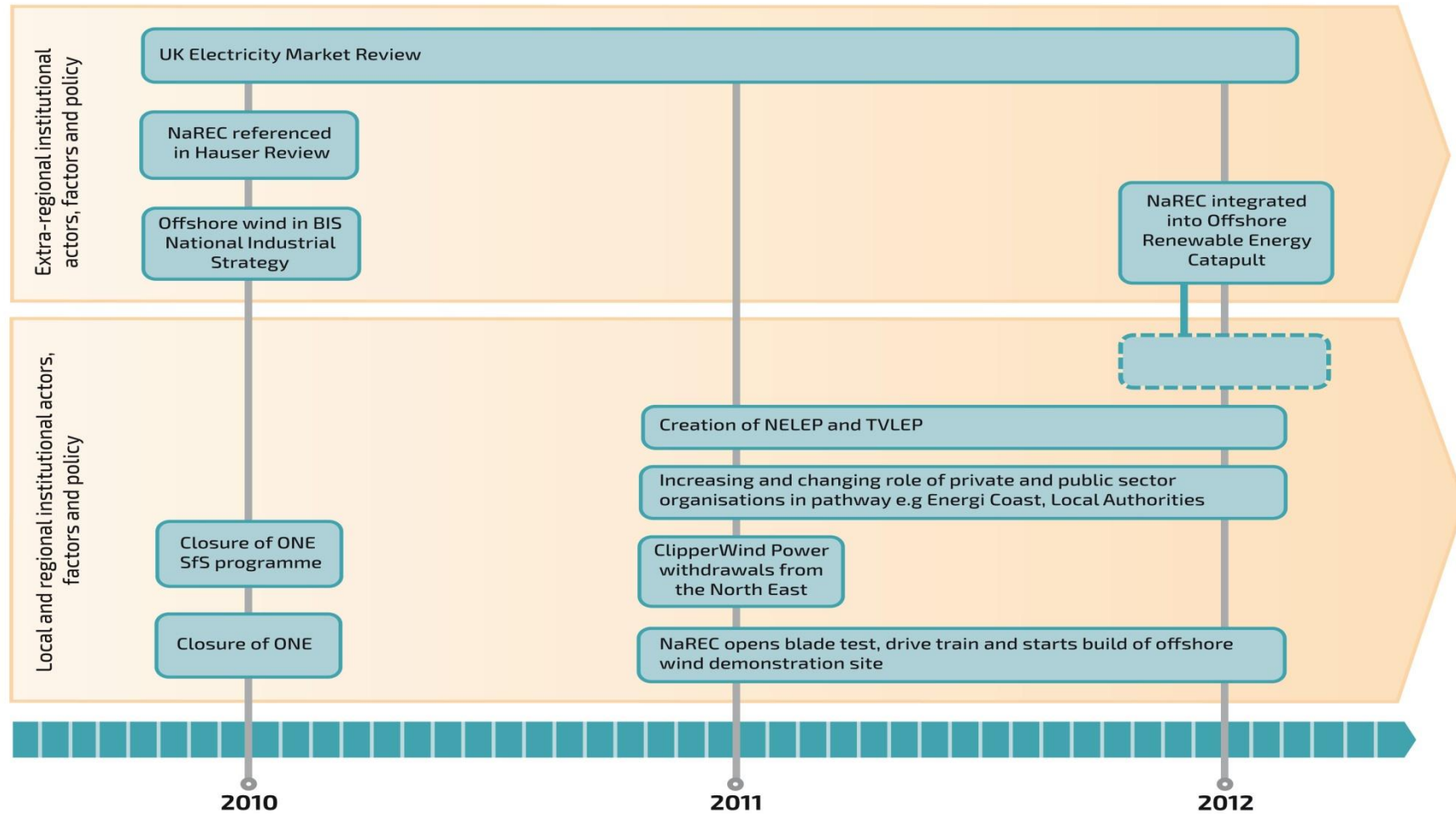
6.4. CONCLUSION

By the end of 2012, the rescaling and reshaping of the North East's politico-institutional environment from above and below by the national political economy of the UK state had hindered over a decade of supportive, place-based policy interventions which had led the offshore wind and printable electronics industries to reach a self-reinforcing point of ongoing path development, dependency and adaptation (Martin 2010; Dawley 2013). Within the background of the changing multi-actor and multi-scalar institutional and policy framework, this section draws the temporal episode to a close by positioning the empirical findings of both path trajectories within the context of the reconfiguration and removal of multi-scalar social agency and purposive policy intervention on the candidate mechanisms of the offshore wind and printable electronics pathways in the North East.

Offshore Wind: Multi-scalar Actors, Mechanisms and Policy in the North East Offshore Wind Pathway

The episode in the path dependent trajectory of the offshore wind industry illustrated the varied form, interplay and impact of multi-scalar social, institutional and political agents on the mechanisms stimulating the North East's growth path. Importantly, the temporal period in the path's ongoing development illustrated three important but interconnected features to a deeper understanding of the processes, mechanisms, agents and conditions that support (or constrain) path creation and development at a local and regional scale. First, the episode in the regional offshore wind pathway provided greater clarity of the multiple roles of actors at multi-scalar levels in providing enabling or constraining environments for the mechanisms of path creation (Martin 2010). In particular, in the context of intense sub-regional competition to attract, nurture and retain offshore wind investment, the offshore wind pathway in the North East exhibited and illustrated elements of recombination in which private and public sector actors, including local authorities and private sector networks, redefined and adapted their roles to secure exogenous investment into the regional offshore wind industry (Harvey 1985; Martin 2010) (see Figure 6.3).

Figure 6.3 Path Dependency of the North East Offshore Wind Industry: Timeline Analysis, 2010-2012



Source: Author 2014

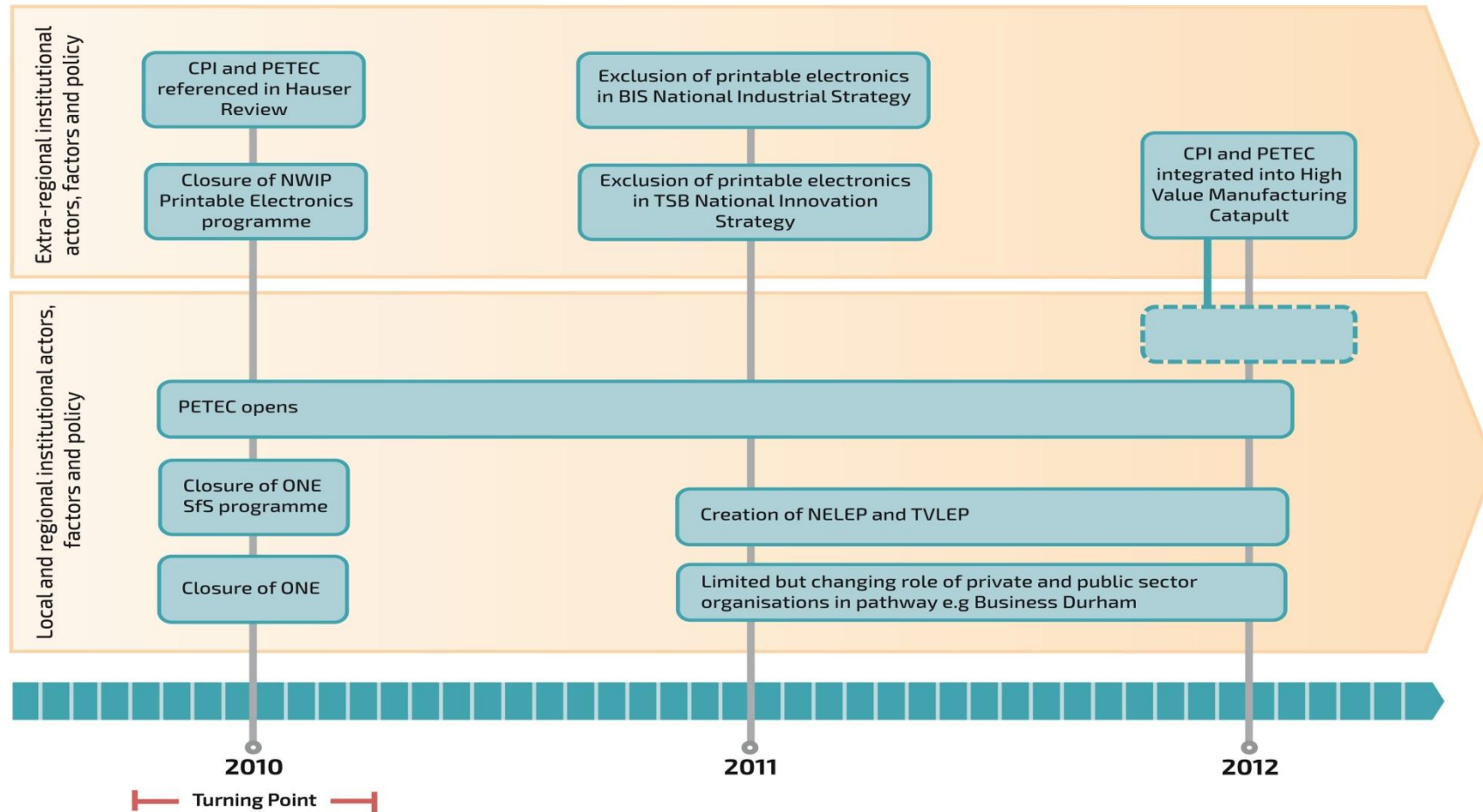
Second, during the episode the regional offshore wind industry illustrated the negative implications of reconfiguring and removing multi-scalar state institutional layers and contextual policy intervention to an emerging and developing local and regional industrial growth path. At a national institutional and political scale, the change of Government and subsequent ideological shift towards austerity measures involving the introduction of a new competitive allocation mechanisms and changing horizontal and regulatory policy temporally destabilised the developmental trajectory of the regional industrial path. At a local and regional scale, the abolition of ONE and its replacements, NELEP and TVLEP, offered limited resources and capacity for strategic policy intervention in supporting and promoting the North East's offshore wind activities (House of Commons 2012). Moreover, the closure of ONE and recentralisation of UK science, innovation and industrial policy marked the termination of the SfS innovation programme which had been successfully based on the "platform policies" of place-based assets, history and related variety (Asheim *et al* 2011; 2013). As a result, the temporal episode in the regional offshore wind trajectory illustrated the role and importance of purposive policy intervention by socio-institutional actors and "novel agents" during the path dependent episode in identifying, matching and supporting diversification and branching opportunities of local and regional firm and non-firm actors to territorial and global market opportunities (Morgan 2012).

Third, despite the exposure of multi-scalar state-derived changes to the offshore wind industry, the regional offshore wind pathway had generated sufficient economic momentum that the mechanisms of diversification, branching and recombination continued to expand from the preceding path development phase into a phase of path dependency and adaptation (Neffke *et al* 2012). As such, irrespective of the complex settings and temporally varied periods in which they co-existed, the path dependent episode restated the overlapping nature and characteristics of the mechanisms of firm diversification and branching that supported the offshore wind pathway's ongoing development (Dawley 2013). More broadly, the temporal period reemphasised the increasingly recognised value and consistent application of policy intervention by practitioners that adopted mechanisms of diversification and branching as the basis for more embedded and sustainable paths of growth (Boschma & Frenken 2011; Mackinnon 2014).

Printable Electronics: Multi-scalar Actors, Mechanisms and Policy in the North East Plastic Electronics Pathway

In stark contrast to the earlier path development phase which had exhibited elements of local and regional increasing returns and networks externalities enclosed by a supportive multi-scalar and multi-actor enabling politico-institutional environment, the ensuing episode in the North East printable electronics displayed elements of “path regression”. The stalled nature and subsequent reversion from the phase of path development to characteristics and patterns of the earlier path creation phase illustrated three interconnected points which explained the disruption and irregularity in the unfolding local and regional printable electronics growth path. First, the degeneration of the pathway during the temporal period restated the important relationship between local and regional firm and non-firm actors and broader enabling environments, factors and multi-scalar actors in shaping and stimulating processes and causal mechanisms of path creation and development (Coe 2011; Cooke 2012). In particular, the transfer of state power to a Conservative Government illustrated the destabilising role national political institutional actors and policy played in removing the strategic niche environment previously incubating the developing printable electronics industry in the North East (Mackinnon *et al* 2009; Mackinnon 2012) (see Figure 6.4). As a result, the dismantling of the national regulatory institutional and policy architecture highlighted the critical role external influences, and particularly the UK state, perform on peripheral regional economies such as the North East that remain reliant on state-led interventions to stimulate innovation, adaptive capacity and growth (Pike *et al* 2009).

Figure 6.4 Path Regression of the North East Printable Electronics Industry: Timeline Analysis, 2010-2012



Source: Author 2014

Second, evolving from a decade of supportive local and regional socio-institutional actors and contextual policy intervention that shaped and stimulated the mechanisms of transplantation and branching, the later period in the path's evolution illustrated the debilitating effect the removal of regionally embedded institutional actors and policy practitioners displayed in hindering the printable electronics pathway's developmental trajectory (Neffke *et al* 2011; Boschma *et al* 2012). Thus, as a consequence of the rescaling and re-scoping of the North East politico-institutional environment by the political economy of the UK state, the closure of ONE removed regional political leadership, institutional capacity and targeted resources, primarily through ONE's state-led SfS programme and the Northern Way initiative, to mediate, enable and intensify the pathway's ongoing development (Asheim *et al* 2011). In the absence of alternative sub-regional institutional actors, political structures and purposive policy intervention of the scale and scope of the previous path development episode, the temporal period demonstrated the negative implications of "policy-on, policy-off" (Dawley 2013) episodes that exposed and illustrated the varying forms and impact of agency at different stages within the developmental trajectory of the evolving printable electronics pathway (Asheim *et al* 2012).

Third, the suspension and ultimate regression of the printable electronics pathway in the North East restated the inter-relations between multi-scalar social and institutional agents, factors, conditions and policy in shaping and enabling the mechanisms of path creation and development (Boschma & Frenken 2009). In particular, whilst the episode exhibited overlapping elements of firm diversification, related variety and transplantation from the previous path development phase, the rupture and removal of institutional layering and directive policy altered the role, form and provided limited support to the candidate mechanisms. As a consequence, as part of ONE's SfS innovation programme and creation of the global R&D innovation assets of PETEC and CPI, the TICs held an increasingly contradictory position in the North East's printable electronics pathway between acting as a strategic hook for extra-regional clients while simultaneously offering limited support and intervention to stimulating processes of diversification and branching amongst the local and regional industrial base (Martin 2010).

CHAPTER 7. CONCLUSION

7.1.1 Introduction

This thesis aimed to analyse the processes and causality of the evolutionary path creation and development trajectories of the offshore wind and printable electronics industries in the North East of England between 1978 and 2012. By situating and understanding the role of path creation as a latent element within a more open and dynamic understanding of path dependency and local and regional industrial evolution, the study moved beyond firm-centric accounts by identifying the multifaceted nature and interplay of multi-scalar social and institutional agents, causal factors and conditions that shaped the mechanisms of path creation in the regional offshore wind and printable electronics pathways. In parallel, the mechanisms were influenced by broader episodic and temporally varied socio-institutional, political and economic factors, contexts and policy interventions (*inter alia* Martin 2010; Martin & Simmie 2010). The empirical and conceptual findings offer important analytical insights to the expanding theoretical discipline of evolutionary economic geography by re-emphasising the importance of multi-scalar actors, institutional environments and relations within and beyond the firm, specifically the multi-scalar role of the state and contextual policy intervention, which envelop, mediate and stimulate mechanisms of path creation (Coe 2010; Garud *et al* 2010; Mackinnon 2012; Dawley 2013). Within this context, this thesis sought to answer three distinct but interrelated questions:

- 1) Which mechanisms stimulated the path creation and development of the printable electronics and offshore wind pathways in the North East?
- 2) What has been the role and influence of multi-agents at multi-scalar levels in the path creation and development of the offshore wind and printable electronics industries in the North East?
- 3) What role has the state and policy performed in stimulating the candidate mechanisms of the North East's offshore wind and printable electronics pathways and what are the lessons learnt for future policymaking?

Applying a mixed methods approach to complement existing work exploring the processes and causal mechanisms of path creation which have focussed predominantly upon aggregate

and quantitative approaches (*inter alia* Frenken *et al* 1999; Klepper 2001; Boschma & Wenting 2007), the thesis provided an analytical framework through which to interpret and understand the key candidate mechanisms, agents, factors and conditions that shaped the North East's offshore wind and printable electronics pathways over three episodic time periods. In so doing, this thesis addressed the limited understanding within existing path creation and local and regional industrial evolution studies of the varied form, characteristics and interconnectivity between the mechanisms of path creation. By situating path creation within a more open and dynamic "path as a process" approach (Martin 2010), the thesis addressed the absence within existing path creation studies of incorporating, interpreting and understanding the role of agency at multi-scalar levels, and particularly the role of the state and purposive policy intervention, in moulding and stimulating the mechanisms of path creation by providing operational clarity to the tensions that exist between enabling and constraining environments that shape path creation in episodic and temporary ways (Sydow *et al* 2009; Vergne & Durand 2010). The value of the conceptual and methodological approach developed was revealed through its analytical application to understanding over 30 years of heterogeneous path creation activity in the offshore wind and printable electronics industries in the North East of England.

The remainder of the chapter begins in 7.1.2 with a synthesis of the empirical findings presented in Chapter's 4, 5 and 6. In section 7.1.3, the empirical findings are understood within Martin's (2010) alternative conceptual model of path dependency and a multi-actor and multi-scalar approach to studying path creation is considered in relation to existing theoretical approaches of evolutionary economic geography. Connecting the theoretical considerations to the empirical evidence, section 7.1.4 poses some practical suggestions for practitioners and policymakers in adopting, utilising and applying evolutionary principles of path creation and local and regional industrial evolution in policy terms. Section 7.1.5 considers some new research frontiers for local and regional path creation based on the empirical findings of the study. The penultimate section in 7.1.6 illustrates the limitations of the research and section 7.1.7 draws the thesis to a conclusion.

7.1.2 Path Creation and Evolutionary Trajectories of the North East's Offshore Wind and Printable Electronics Industries

The empirical findings detailing the path creation and industrial trajectories of the offshore wind and printable electronics industries in the North East between 1978 and 2012 were chapter specific and summarised within the respective empirical chapters: Path Creation of Offshore Wind and Flexible Electronics Industries in the North East (Chapter 4); Path Development of the Offshore Wind and Plastic Electronics Industries in the North East (Chapter 5); and Path Development of the Offshore Wind Industry and Path Regression of the Printable Electronics Industry in the North East (Chapter 6). The purpose of this section is to synthesise the empirical findings to answer the thesis' three primary research questions.

First, a central aim of this research has been to transition beyond path creation studies based on previous notions of chance, spontaneity and firm-centric accounts by investigating, unpacking and understanding the varied, multifaceted and intentional role of social and institutional agents that shape mechanisms of path creation, and which they themselves are influenced by their position and relations within broader multi-scalar institutional environments and frameworks (Garud *et al* 2010). The empirical findings restated the role, importance and deliberative function of multi-scalar actors, within and beyond the firm, across different temporal episodes, contexts and settings, in stimulating and supporting (or constraining) local and regional path creation and evolution (Pike *et al* 2006). In the case of the regional offshore wind pathway, the progressive episodes in the developmental trajectory demonstrated the importance of “experienced entrepreneurs and diversifiers”, in both firm and policy organisations, that identified, coupled and coordinated local and regional assets to new market opportunities (Garud & Karnoe 2003; Boschma & Frenken 2009). For the printable electronics pathway in the North East, which shared similar characteristics to that experienced in the path development phase of the regional offshore wind pathway, the intermittent gestation period in the path creation episode, and eventual stalled and degeneration of the developing pathway restated the important co-evolutionary practices of firms, knowledge-based institutional actors and policy practitioners, at multiple spatial scales, in creating, adapting and de-locking from existing industrial trajectories in the pursuit of promising novel local and regional growth paths (Asheim & Cooke 2007).

Second, this thesis addressed the neglected role of the state and policy in mediating and stimulating the mechanisms of local and regional industrial path creation (Fornahl *et al* 2012). In particular, this thesis was concerned with unpacking and providing operational clarity to the stylised notions of enabling and constraining environments and a better understanding of the causal processes at play (Stam 2009; Dawley *et al* 2015). The empirical findings illustrated the multiple roles the state and policy actors and interventions performed, across multiple spatial scales and temporal episodes, in shaping path creation activities at a local and regional scale (Fornahl *et al* 2012; Essletzbichler 2012). Specifically, the analysis of the path creation and development episodes in the offshore wind pathway in the North East demonstrated the important role of the state and the dynamic ways in which national political support, through direct horizontal and vertical policies, interfaced with the governance of economic development at the regional scale, to deliver direct and contextual policy intervention via the SfS innovation programme in order to catalyse and enable the mechanisms of diversification, branching and transplantation (Chang *et al* 2013). Importantly, the analysis during the path creation and regression phases of the printable electronics industry illustrated the influence, and often absence, particularly in peripheral regional economies such as the North East that are more reliant on state-led interventions to stimulate “adaptive capacity and growth” (Martin 2012), of multi-scalar politico-institutional actors and policy frameworks that fail to apply, or critically remove, territorially embedded state actors and cultivated forms of “niche management” (Cooke 2012) that constrained the emerging printable electronics growth path in the North East (Boschma 2009; Mackinnon *et al* 2009).

Third, a key contribution of this thesis has been to investigate and provide a deeper understanding of the complex, often overlapping, but temporally varied, mechanisms of path creation (Sydow *et al* 2010; Neffke *et al* 2011; Boschma *et al* 2012; Dawley 2013; Dawley *et al* 2015). The empirical findings illustrated the role and importance of strategic agency and policy interventions in stimulating and shaping the mechanisms of diversification, branching, recombination and transplantation. Indeed, the evidence of the regional offshore wind and printable electronics pathways restated the recognised value of industrial diversification and branching as the principal source of innovation, variety and foundation for more integrated, balanced and adaptable paths of long-term economic growth (Frenken *et al* 2007; Neffke *et al* 2009; Boschma & Frenken 2011). In the case of the North East’s offshore wind path, the empirical findings illustrated the interconnected relationship between mechanisms of

indigenous creation, diversification and branching and multi-scalar socio-institutional and political agents that catalysed and supported firm and non-firm actors in the regional offshore wind industry. As a result, the offshore wind pathway empirically and conceptually illustrated a classic path dependent trajectory from an experimental and demonstration path creation phase to progressive phases and economic momentum towards path development, dependency and ongoing adaptation (Martin 2010). In contrast, the North East printable electronics industry illustrated the interrelated linkages between the candidate mechanisms, key agents and local and regional contexts, and their relationship within broader technological developments, socio-institutional settings, power relations and market conditions to explain the irregular, and ultimately, backward retreat into the path creation phase that characterised the North East's printable electronics pathway (Coe 2011; Mackinnon 2012).

7.1.3 Conceptual and Theoretical Insights for Path Creation and Evolutionary Economic Geography

Referring back to Martin's (2010) more open and dynamic understanding of path creation, the empirical examination and analysis of the printable electronics and offshore wind pathways in the North East offered three core additions as part of a broader and deeper conceptual and theoretical understanding of path dependency and local and regional industrial evolution. First, the empirical analysis addressed the complex issue of "what" is evolving and unfolding in the local and regional economic landscape (Pike *et al* 2015, forthcoming). Within this context, the focus of the thesis was to identify and understand the candidate mechanisms for stimulating new growth paths set and shaped within their broader political, economic and socio-institutional contexts. At a conceptual and theoretical level, the empirical findings illustrated the diversity and fragmented nature of temporal paths in comparison to previous contributions to understanding local and regional industrial evolution e.g. industry life cycle model, by offering a better understanding of the dynamism of the individual mechanisms of path creation at different phases of a local and regional industrial growth path (Martin & Sunley 2006). More importantly, the episodic periods in the offshore wind and printable electronics industries highlighted, empirically and conceptually, the interconnectivity between the mechanisms during the developmental trajectories and how those mechanisms were framed, influenced and stimulated by a variety of indigenous and extra-regional actors, factors and conditions (Dawley *et al* 2015). Thus, the empirical

findings support the conceptual value in integrating and understanding the candidate mechanisms as overlapping constructs and interlinked processes, rather than solitary change agents, in providing causal explanations for the geographical unevenness and diversity of local and regional industrial path trajectories (Gertler 2010).

Second, the analytical findings have offered further evidence and understanding by unpacking the conceptual notions of enabling and constraining environments and their causality on the unfolding mechanisms of path creation and development over time and across space. By situating the path creation of the North East's offshore wind and printable electronics industries within broader socio-institutional structures, settings and factors, the empirical findings have added a further conceptual layer and comprehension of the importance of context and how social and institutional agents, including multi-scalar institutional actors, political governance structures and power geometries between multi-scalar levels and direct policy intervention, can enable and/or constrain new and emerging industrial pathways at the local and regional scale (Mackinnon *et al* 2009; Mackinnon 2012). For instance, evidence from the regional printable electronics and offshore wind pathways reiterated the conceptual and theoretical merits and importance of contextual "knowledgeable agents" (Simmie 2012), in both firm and non-firm settings, that can match pre-existing technological and economic conditions to activate "trigger points" (Streek & Thelen 2005) in the path creation phase to catalyse new market opportunities (Martin 2010). As a result, the empirical evidence from the offshore wind and printable electronics pathways in the North East restates and emphasises the conceptual and theoretical utility of integrating wider multi-scalar strategic agency, conditions, factors and contexts, incorporated from wider geographical political economy and institutional approaches, into a more comprehensive understanding of local and regional path creation within a theoretical approach to studying evolution in economic geography.

Third, the analytical findings from the North East's printable electronics and offshore wind pathways offered important conceptual and theoretical insights into the creation of new economic activity and de-locking of path and place dependant trajectories in a peripheral regional economy context. In particular, the thesis restates the importance of building new and/or adapting existing industrial trajectories based on the history, place-based assets and related technological, industrial and organisational composition of the local and regional economic base (Boschma & Frenken 2009). Despite the presence of those stated elements,

the regional printable electronics pathway exhibited characteristics of a path *not* or *unable* to be taken because of the difficulty in seeding related but relatively novel growth paths and the implications of broader multi-scalar political, economic and socio-institutional factors and contexts that continuously manipulate new and emerging local and regional growth paths (Schneiberg 2007). Indeed, extra-regional actors, linkages and changing market environments, reflected in the influence of the global oil and gas and semiconductor industries on the path creation of the printable electronics and offshore wind pathways in the North East, restated the conceptual value of reintegrating external shocks into a deeper understanding of the processes and causality of local and regional industrial evolution (David 1985; Arthur 1989). Therefore, although not prescriptive to peripheral regional economies, the conceptual and policy-related challenge remains to understand and strike a balance between the predominantly endogenous processes of intentional path creation, remaining adaptable to new market opportunities as they arise, and building and retaining a level of “resilience” (Pike *et al* 2010) within local and regional economic institutions to external ruptures in the global economic system (Meyer-Stamer 1998; Bathelt & Boggs 2003).

7.1.4 Policy Prescriptions for Path Creation Based on Evolutionary Principles

Despite increasing empirical data offering a better understanding of the processes and causality of path creation, policy prescriptions based on evolutionary principles has seemingly not kept pace because:

“it is difficult to draw general contemporary conclusions from the historical nature of evolutionary analyses and that success (however defined) can appear unique and difficult” (Boschma & Frenken 2007, p. 16).

However, the evolutionary path creation and development of the offshore wind and printable electronics industries in the North East offer four potential practical insights for practitioners and policymakers that seek to utilise theories, concepts and empirics associated with evolutionary economic geography to create, stimulate and condition new local and regional growth paths.

First, the empirical evidence charting the transition within and between the pre-formation and path creation phases in the growth paths of the offshore wind and printable electronics

industries illustrates the policy *process* through which policymakers select, engage and intervene in “promising” growth paths (Boschma 2013). Connected to the evolutionary notion of emergence (Martin & Sunley 2011) and policy based on smart specialisation (see, for example, McCann & Ortega-Argiles 2011), the initial focus of policymakers could be on the process rather than the outcome of unearthing new and emerging niche industrial growth paths through a process of self-selection or entrepreneurial discovery (Boschma 2013). For instance, the reformation of the printable electronics pathway was, in part, a consequence of a facilitated core group of firms and technology actors brought together by regional economic development agents. Although contrary to evolutionary policy principles based on variety rather than specialisation, the smart specialisation process itself shares overlapping characteristics of applying a platform approach to creating and stimulating new local and regional growth paths by recognising that every locality has the endogenous resources, assets and capabilities to catalyse new growth paths (Cooke 2007; McCann & Ortega-Argiles 2011). Therefore, while mindful of the pre-existing economic base, assets and competencies of a particular locality, the role of the state could be to ensure local and regional economic development actors and policy practitioners instigate and form “strategic collaborations” (Rodrik 2008) with a combination of endogenous and external private and public sector partners, voluntary actors and civil participants e.g. “quadruple helix model” (Leydesdorff 2012), to improve the “discovery”, process and delivery capacity to boost local and regional economic development by prescribing policies that are contextually-specific, demand-driven and offer genuine competitive advantage (Elola *et al* 2013).

Second, intentional and strategic policy intervention to the North East offshore wind and printable electronics pathways reaffirmed the value of the constructing regional advantage (CRA) approach and the importance of contextual policy in stimulating and seeding more open, novel and experimental evolutionary growth paths in local and regional economies (*inter alia* Asheim *et al* 2011; Asheim *et al* 2013; Chang *et al* 2013). In a rejection of “one-size-fit all” policies (Todtling & Trippl 2005) or starting new economic structures “from scratch” (Boschma 2009), policy practitioners and interventions could consider taking into account the history and place-based characteristics of each locality or region as a starting point “when broadening the region’s sector base by stimulating new fields of applications that give birth to new sectors” (Asheim *et al* 2011, p. 899). Supported by the evidence in the two empirical case studies which illustrated, for example, the important role knowledge-based institutional actors and external intermediaries such as ONE, NaREC and Durham

University performed as effective policy drivers in stimulating mechanisms of diversification, branching and transplantation, local and regional institutional actors, and particularly economic development agencies, could focus on policy interventions that stimulate the mechanisms of related variety and branching, but connect and present overlapping knowledge, innovation and economic opportunities for other co-evolutionary path mechanisms (Neffke *et al* 2011; Boschma 2013). In so doing, designing and delivering contextual policy interventions underpinned by the history, place-based characteristics and mechanisms of related variety and branching offers the potential to create new pathways, de-lock from negative path trajectories and build adaptability into existing local and regional growth paths (Aldrich & Foi 1994; Hung & Chu 2006; Boschma 2014).

Third, the broader enabling environment provided by ONE's SfS innovation programme also restates the importance and value in connecting emerging policy processes aimed at seeding novel growth paths and CRA policy interventions designed to stimulate those "selected" pathways with place-based institutional actors, approaches and interventions. Specifically, local and regional institutional actors could design and deliver contextual industrial and regional policies within an overall RIS-inspired strategic approach to initiate and provide the enabling conditions to instigate path creation (Asheim *et al* 2013). Indeed, such an approach combines RIS, industrial and regional policy based on institution-building and knowledge exploitation with evolutionary principles based on knowledge exploration and exploitation. Because local and regional institutional actors often understand the specific needs, available resources, existing knowledge, conditions and industrial base of a particular region, place-based economic development policymaking generated and administered by embedded local and regional institutional agents may better define the objectives of the policy intervention but also the specific form and timing of that intervention (Asheim *et al* 2012). Nevertheless, to do so requires sufficient scope, resources and capacity by local and regional economic agents to deliver specific contextual policy interventions (HM Government 2012a). To illustrate the point, the connection displayed between the capacity-building phase of NaREC's R&D facilities and ONE's offshore wind industrial policy programme highlight the important co-evolutionary role and function local and regional institutions perform in mediating interactions between pre-existing spatial variety, national governance systems and funding structures, and market-based selection mechanisms (Asheim *et al* 2011).

Fourth, the empirical evidence, particularly during the path dependency and regression phases of the offshore wind and printable electronics industries, illustrate the relationship, dynamic interplay and instability between local and regional economies and changeable extra-regional contexts, socio-institutional arrangements and power relations (Coe 2011; Mackinnon 2012). As such, the ruptures in the multi-scalar institutional, economic and political environment supporting the regional offshore wind and printable electronics pathways highlight the consequence of peripheral regional economies, such as the North East, which are influenced and subject to shifting multi-scalar institutional arrangements, inconsistent policy signals and continually shaped by the political economy of the UK state and hegemony of its governance of local and regional economic development (Spencer *et al* 2005; Kivimaa *et al* 2010). Although not prescriptive to peripheral regional economies, the dissolution of ONE illustrates the importance of ensuring the “missing space” between the local and national scale is addressed, particularly given that LEPs and local authorities often lack the necessary scope, depth and capacity to be effective, in ensuring local and regional firm and non-firm actors working within novel technology, innovation and industrial-based growth paths are nurtured and supported (Hildreth & Bailey 2014). This objective may be achieved either by the creation of reactive intermediate tiers of governance to stimulate industrial, innovation and regional policy and/or by building flexible, proactive and mobile policy units, comprising of local authorities, universities, businesses, financial institutions and others, which stimulate and encourage the emergence or de-locking of embryonic local and regional industrial growth trajectories (HM Government 2012a; IPPR and the Northern Economic Futures Commission 2012; Hildreth & Bailey 2014). Irrespective of the approach taken, the challenge persists to ensure local and regional institutional actors and contextual policy prescriptions designed to provide and foster an enabling environment for path creation at a local and regional scale become increasingly more adaptable and resilient to constantly evolving extra-regional socio-institutional and political structures and policy changes, technological developments, changing market conditions and global economic, political, social, regulatory and environmental factors (Mackinnon *et al* 2009; Elola *et al* 2013).

7.1.5 Recommendations for Future Research into Path Creation

The increasing propagation of broader conceptual and empirical understandings of the formative processes and causality of path creation within path dependency theory opens up space for additional research across a range of topics and issues which could usefully inform:

1) theoretical, conceptual and empirical interpretation of path creation and local and regional industrial evolution 2) methodological approaches to studying path creation within evolutionary economic geography and incorporation of additional theoretical frameworks; and 3) policy considerations.

First, in terms of developing further theoretical, empirical and conceptual insights, an opportunity remains to refine my conceptual interpretation of local and regional path creation gleaned from the empirics into a deeper explanation and understanding of the processes and causality of path creation within the regional printable electronics and offshore wind pathways. Specifically, the variability in transitional phases of both pathways presents an opportunity for the research to empirically and conceptually re-examine and offer a deeper understanding of the interrelations between the path mechanisms (Martin 2010; Dawley 2013). Integrating broader institutional and geographical political economy perspectives, the research would benefit further from a deeper conceptual and empirical understanding of why novel technology-based industrial pathways, particularly in the case of the printable electronics industry, was unable to be initially de-locked by strategic agency in the path creation phase. In short, investigating the role of elements of “paths not taken” and what remain of those paths not taken tied to future re-combinations of local and regional industrial growth trajectories offers a further avenue of exploration (Neffke *et al* 2012). Within the context that “preceding paths may re-appear in the guise of new paths”, the path creation and development of the printable electronics and offshore wind industries also opens the empirical and conceptual question as to what extent either pathways were ultimately “new” paths or changes to existing paths (Cooke 2010, p.199). Finally, there is scope beyond a focus on knowledge-intensive and manufacturing industries examined in this research to explore alternative areas of economic activity, including the services industry and its overlap with manufacturing, as an avenue of future empirical investigation.

Second, from a methodological perspective, the research illustrates the unsettled consensus, difficulty and ongoing challenges in connecting embryonic mixed methods approaches to evolutionary theory, concepts, empirics and policy. However, rather than previously dualistic strands of evolutionary work which concentrated on quantitative *or* qualitative methodologies, the interaction and integration of both approaches offers an opportunity for a deeper exploratory reach and understanding of path creation and evolutionary change in the economic landscape (Barnes *et al* 2007). In the case of the printable electronics and offshore

wind industries in the North East, the research has, to a small extent, began to link those methodological approaches together by offering a largely qualitative, theoretically-informed empirical study in which to interpret and understand path creation, developmental processes and causal mechanisms through an inductive-deductive inter-play between theory and empirics. To provide a more comprehensive mixed methods approach to the study, future research would benefit further from a deeper integration of quantitative datasets, if applicable and where available, including the application of more statistically-oriented techniques e.g. “technologically relatedness” (see, for example, Boschma & Frenken 2010; Neffke *et al* 2011; Boschma *et al* 2012; Boschma 2013), together with comparable case study examples of new industrial path creation in peripheral regional economy contexts, to engage fully in “productive pluralism” and shed a brighter light on processes of cause and effect that influence and shape evolutionary industrial growth paths (Grabher 2009, p. 125).

Third, in relation to policy, notwithstanding the concern amongst the economic geography community that evolutionary studies are marked by a lack of comparative research that can be cross-referenced over space and time, the research would benefit further from additional case studies of emerging local and regional industrial growth paths, both in the North East but particularly related to comparable “old industrial”, “peripheral” and “branch-plant regions” that have been influenced and shaped by multi-scalar politico-institutional actors and policy to that exhibited in the North East offshore wind and printable electronics paths (Pike *et al* 2015, forthcoming). In so doing, understanding the role of the state and policy interventions in related socio-institutional, economic and political settings, particularly in peripheral regional economies that have historically demonstrated specialised path dependent industrial trajectories, lacked institutional adaptive capacity, exhibited territorially weak innovation systems and subjected to ongoing periods of state-led restructuring and intervention, will further illuminate effective policy prescriptions that can understand the interconnectivity between path mechanisms and provide appropriate and contextual interventions to stimulate the candidate mechanisms at different stages of a local and regional industrial path trajectory (Dawley 2013).

7.1.6 Limitations of the Research

Despite offering a novel research design and methodological approach to the study of local and regional path creation, a number of limitations and challenges existed in the research

design, process and execution. First, despite holding an epistemological position rooted in pragmatism, the identification and selection of offshore wind and printable electronics case studies was influenced by the presupposition that they were independently distinctive industrial pathways and followed different evolutionary trajectories (Bryman 2008). As a result, both empirical case studies offered a critical case through which to investigate and challenge conceptual and theoretical interpretations of the mechanisms of path creation proposed by Martin & Sunley (2006) and Martin's (2010) meso-level interpretation of path dependency (Barnes *et al* 2007). Consequently, both case study examples offered the benefit of rich empirical findings but also heavily weighted the research emphasis on contrast rather than similarities between the two industrial trajectories (Dyer & Wilkins 1991). Second, the majority of interviews and interviewees were retrospectively situated internal to the North East thereby limiting a full understanding and appreciation of the role and impact extra-regional actors, networks and relations performed in influencing and shaping the evolutionary trajectories of the offshore wind and printable electronics pathways in the North East. Third, the research suffered from a lack of available, reliable (positivism) and comparable longitudinal quantitative data to apply a complete QUAL + quant mixed methods research study. Therefore, the limited availability of primary and secondary quantitative data hindered the opportunity to interrelate the output and net effects (positivism) of path creation activity with causality (interpretivism) (Tashakkori & Teddlie 2003). As such, the future challenge for this research and other path creation studies remains not only to prove or disprove path-dependent development but also to determine its economic impact on the local and regional economy (Boschma 2004; Neffke *et al* 2012).

7.1.7 Conclusion

Situated within a broader conceptual understanding of path creation and underpinned by theoretical advances of an evolutionary approach in economic geography, this thesis examined and analysed the evolutionary path creation and development trajectories of the offshore wind and printable electronics industries in the North East of England between 1978 and 2012. Specifically, the thesis was concerned with understanding the formative processes of path creation and development, and particularly the role, type and influence of key agents, causal factors, conditions and mechanisms that shaped, and were shaped by, broader socio-institutional, political and economic factors, on the creation and developmental trajectory of the regional offshore wind and printable electronics pathways. The empirical findings

illustrated the importance and influence of multi-scalar actors, institutional contexts and contextual policy prescriptions in mediating the mechanisms and framing the tensions between enabling and constraining environments that shape path creation in episodic and temporary ways.

Positioning the printable electronics and offshore wind pathways in the North East within a more open and dynamic understanding of path dependency, this thesis has contributed to a limited body of existing literature on path creation in peripheral regional economy settings by examining and understanding the processes and causality of local and regional industrial evolution. More broadly, the study has added empirical and conceptual weight to further inclusion of multi-scalar social and institutional agents, within and beyond the firm, and particularly the role of state and intentional policy intervention, in understanding the interrelated processes and candidate mechanisms of path creation in future studies of local and regional growth paths within an evolutionary economic geography theoretical framework.

In the context of the evolutionary turn with economic geography, the notion and application of “paths” represents the latest in a series of concepts utilised by economic geographers to understand and explain the unfolding pattern of local and regional evolution. However, if paths are defined as institutional constructs that exhibit identifiable and predictable patterns by individuals, firms and organisations within a system, the analytical and conceptual evidence of the printable electronics and offshore wind industries in the North East has highlighted the spontaneity, emergence, variety and adaptability that characterise, shape and underpin new and emerging local and regional growth paths within interconnected and unending processes of path creation, dependency and destruction. As such, this thesis opens up, and in some respects, challenges the metaphorical suitability of utilising and applying “path” terminology within future path creation and evolutionary economic geography approaches to adequately interpret, describe and understand the creation and evolution of the local and regional economic landscape over time and across space.

Aside from questioning the metaphorical and conceptual value of utilising the notion of paths to examine and explain local and regional evolution, the empirical investigation and analysis of the offshore wind and printable electronics industries in the North East also provides a timely opportunity for a deeper critical reflection of the broader theoretical application of

path creation in interpreting, analysing and understanding the formation and adaptation of local and regional growth paths. Applying the empirical evidence from the two case studies to Martin's (2010) alternative model of path dependency, this thesis has illustrated the often distinct elements, functions and activities within sequential phases of a paths development that characterise and explain path creation and industrial evolution at a local and regional scale. Nevertheless, while Martin's (2010) paradigm proves useful in offering a basic theorisation of path creation, the North East's offshore wind and printable electronics industries also demonstrated the profound difficulties and challenges, particularly for peripheral regional economies like the North East, in seeding and developing new local and regional growth paths. In other words, path creation and local and regional industrial evolution may sometimes follow a linear trajectory from path creation to dependency and/or ongoing adaptation, but the empirical case study examined in this thesis also highlighted the inherent dangers in oversimplifying the theorisation of local and regional industrial growth paths. Instead, theoretical interpretation of the unfolding economic landscape over time and space is better served concentrating on understanding path creation as a complete path as a process approach by taking into consideration the creation, development, dependency, adaptation, fragmentation and destruction of a pathway to not only occur within each distinct phases of the path creation process, but recognition that all of those dynamic elements are equally present, unending and in a constant state of flux via continuous feedback loops within each phase of Martin's (2010) path dependency model.

The empirical findings from the North East's offshore wind and printable electronics pathways also restated the theoretical value and importance of incorporating multiple agents, factors, contexts and settings at multi-scalar levels that influence and shape, and they themselves are shaped by, local and regional industrial growth paths across different episodic and spatial frames (Dawley 2013). As displayed by previous conceptual models of path creation, Martin's (2010) alternative model of path dependency continues to be preoccupied with endogenous processes that interconnect with the mechanisms of path creation to understand and explain causality, with little regard or consideration of the varied, complex and interconnected relationships between multi-scalar institutional, political, economic and social forms and organisations, including the multiple roles of the state and policy, globalisation and wider market forces, and other external actors, factors and relations, in mediating and stimulating the mechanisms of path creation at a local and regional scale.

To address these conceptual and theoretical oversights in order to provide a more fuller, descriptive and nuanced interpretation of path creation and local and regional industrial evolution, this thesis has sought to address the extant gaps in the present path creation literature by incorporating, interpreting and understanding the role, type and influence of key agents at multi-scalar levels, particularly the role of the state and purposive policy intervention, key causal factors and conditions on the interrelated processes and candidate mechanisms within broader endogenous and extra-regional socio-institutional, political and economic settings, on the path creation of the regional offshore wind and printable electronics trajectories. In so doing, this thesis has restated the importance, and recommends for future research endeavour in path creation, the adoption and integration of geographical political economy and institutional approaches with evolutionary economic geography in order to provide a deeper, richer and complementary theoretical framework in which to comprehend path creation and local and regional evolutionary growth paths.

ACRONYMS

ADL – Arthur D Little

ADZ – Accelerated Development Zone

BERR – Department for Business, Enterprise & Regulatory Reform

BIS – Department for Business, Innovation & Skills

BWEA – British Wind Energy Association

CEGB – Central Electricity Governing Board

CENAMPS – Centre of Excellence for Nanotechnology, Micro & Photonic Systems

CEO – Chief Executive Officer

CfD – Contracts for Difference

CoE – Centre of Excellence

CORE – Centre for Offshore Renewable Engineering

CPI – Centre for Process Innovation

CRA – Constructing Regional Advantage

DECC – Department of Energy and Climate Change

DoE – Department of Energy

DRAM – Dynamic Random-Access Memory

DTI – Department of Trade & Industry

DWTC – Direct Write Technology Centre

EMR – Electricity Market Reform

EPPIC – Electronics, Photonics and Packaging Interconnections

EPSRC – Engineering and Physical Sciences Research Council

ERDF – European Regional Development Fund

ETI – Energy Technologies Institute

FDI – Foreign Direct Investment

FiT – Feed-in-Tariff

GIN – Global Innovation Network

GPN – Global Production Network

GW – Gigawatt

HEI – Higher Education Institution

HESIN – Higher Education Support for Industry

IEA – International Energy Agency

IP – International Paint
JV – Joint Venture
KTN – Knowledge Transfer Network
LEP – Local Enterprise Partnership
M&A – Merger & Acquisition
MBO – Management Buy-Out
MMO – Marine Management Organisation
MNC – Multinational Corporation
MwH – Megawatt per Hour
NaREC – New (National) Renewable Energy Centre
NDC – Northern Development Company
NECC – North East Chamber of Commerce
NEEC – North East Energy Cluster
NEELC – North East Energy Leadership Council
NELEP – North East Local Enterprise Partnership
NETPARK – North East Technology Park
NFFO – Non-Fossil Fuel Obligation
NOF – Northern Offshore Federation
NRST – Northern Region Strategy Team
NWIP – Northern Way Innovation Programme
OECD – Organisation for Economic Cooperation and Development
OEM – Original Equipment Manufacturer
OGN – Offshore Group Newcastle
OLED – Organic Light Emitting Diode
ONE – One NorthEast
O&M – Operations & Maintenance
PCB – Printed Circuit Board
PELG – Plastic Electronics Leadership Group
PETEC – Printable Electronics Technology Centre
PLED – Polymer Light Emitting Diode
PMI – Photonics Materials Institute
QUANGO – Quasi Autonomous Non-Governmental Organisation
R&D – Research and Development
RDA – Regional Development Agency

ROC – Renewable Obligation Certificate
ROI – Return on Investment
ROV – Remote Operated Vehicle
SEA – Strategic Environmental Assessment
SERC – Science and Engineering Research Council
SfS – Strategy for Success
SIC – Standard Industrial Classification
SME – Small to Medium Enterprise
STI – Science, Technology & Innovation
TIC – Technology & Innovation Centre
TNC – Transnational Corporation
TSB – Technology Strategy Board
TVLEP – Tees Valley Enterprise Partnership
UIC – University Innovation Centre
UNDP – United Nations Development Programme
WLO – Window of Locational Opportunity

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