3. The evolution of business networks and clusters.

3.1 Introduction.

The idea of the business cluster as an agglomeration of related production activities has a long history, yet remains pertinent today, albeit in an evolved form and context. Evolution can be seen in two ways: the nature of what comprises a cluster has evolved over time as technologies change and the economy becomes more globalised, and also individual clusters also evolve and change over time. So individual clusters follow life-cycles of growth and decline against a backdrop of macro changes in the nature of the technologies and organisational characteristics. Examining clusters over time helps us to understand the dynamics of industries and regions as these two processes of evolution interact. So whilst a cluster may shift into a phase of decline according to its own internal trajectory, this may be exacerbated by external technological development which influence what is needed for cluster success in the economy as a whole. Central to the process of evolution is the nature of a cluster as a knowledge community: the key characteristic is not just an agglomeration of related businesses, but one where the flows of knowledge create competitive advantage. Policy has also become more important in recent years as governments seek to reinforce or even create clusters, whereas in previous generations clusters were largely organic in their development. More recent conceptualisations of the cluster lifecycle sees it as a form of complex adaptive system with multiple possible outcomes. Some of these issues are briefly explored through a narrative of the shipbuilding and offshore cluster in the North East of England. This chapter seeks to integrate literatures from business history, strategy, economic geography and innovation studies to illustrate the evolution of the idea of the cluster and speculate on current developments and appropriate policy formulations.

The idea of the business cluster as an agglomeration of related production activities has a long history, yet remains pertinent today, albeit in an evolved form and context. While the study of clusters burgeoned in the 1990s following the publication of Porter's *Competitive Advantage of Nations* (1990), and cluster policies became a core element of national and regional economic development policy, the academic roots of clusters stretch back to Alfred Marshall whilst economic geographers had taken a great interest in the role of geographic concentration of industries in innovative regions in the decade or so before Porter's book.

This chapter examines the evolution of business clusters. Evolution can be seen in two ways: the nature of our understanding of what it is to be a cluster has evolved over time as technologies change and the economy becomes more globalized; and individual clusters themselves evolve and change over time. Individual clusters seem to follow lifecycles of growth and decline against a backdrop of changes in the nature of the technologies and cluster characteristics. Examining clusters over time helps us to understand the dynamics of industries and regions, as these two processes of evolution interact. History is critical to the understanding of clusters (Popp and Wilson, 2007). So, whilst a cluster may shift into a phase of decline according to its own internal trajectory, this could be exacerbated by external technological developments which influence what is needed for cluster success in the economy as a whole.

Central to the process of evolution is the nature of a cluster as a knowledge community: the key characteristic is not just an agglomeration of related businesses, but one where the flows of knowledge create competitive advantage. In recent years the evolution of the cluster concept has seen changes in the ways in which knowledge flows – from simple face-to-face flows based on

proximity and localized labour markets to facilitated cluster organizations and the use of ICTs. Policy becomes more important in recent years as governments seek to reinforce or even create clusters, whereas in previous generations clusters were largely organic in their development. More recent conceptualizations of the cluster see it as a form of innovation system that is sectorally and spatially defined which brings in a stronger role for public investment in knowledge production, but also the norms and values that underpin flows of knowledge in the innovation process. The chapter seeks to integrate these literatures from business history, strategy, economic geography and innovation studies to illustrate the evolution of the idea of the cluster and speculate on current developments and appropriate policy formulations.

3.2 The origins of the cluster concept and its evolution

There is no single body of theory explaining the idea of the cluster; rather, there are a number of theoretical accounts to explain a phenomenon of spatial agglomeration around inter-related businesses. The nature of these accounts have developed and changed over time, but they form a loosely consistent body of overlapping theories, even if there are differences in explanation and conditions. This diversity of explanation is sometimes held as a problem, eclecticism being seen as 'chaotic' (Martin and Sunley, 2003). Alternatively, though, these multiple theorizations may simply reflect the attempts to develop a vocabulary to explain a phenomenon which is complex and varied in form. Benneworth and Henry (2004) draw upon Barnes' (2000) idea of hermeneutic theorising to argue that no one vocabulary is perfect, while diverse vocabularies or explanations facilitate theoretical conversations on interpretation of the cluster.

We are consequently faced with a phenomenon in which particular places witness the development of agglomerations of firms which either offer similar products and services, and/or form value chains of inter-related activities, such that there seems to be localized processes of learning and the formation of advantages to being in that agglomeration, various explanations have developed over time (Newlands, 2003). These include:

- Economic agglomeration theory (Marshall, 1920);
- Growth pole theory (Peroux, 1955);
- Flexible specialization, untraded interdependencies and industrial districts (Piore and Sabel, 1984);
- Transaction costs theory and the new industrial spaces of the California School (Storper and Christopherson, 1987; Scott, 1988);
- The GREMI group with a focus on innovative milieu (Aydalot & Keeble, 1988; Camagni, 1995);
- Institutional and evolutionary economics, innovation systems (Nelson and Winter, 1982, Cooke 1992) and learning regions (Rutten and Boekema, 2007);
- Strategic management (Porter, 1990).

This multiple theorization begins to indicate that here we have a phenomenon which is complex in nature, which might have multiple explanations, and which might take different forms in different places at different times. It is in part this flexibility and adaptability of the concept to varied times and places which helps to make it attractive to policymakers looking to identify growth possibilities.

The central theoretical issue regarding clusters is the importance of agglomeration and external economies. Without external economies there is no benefit from proximity or agglomeration, and hence no cluster economies. Marshall (1920) defined external economies as location-specific economies of scale which are available to all firms in that place, taking us back to the origins of the

cluster idea in Marshall's industrial districts. Whilst Marshall used the term industrial district, he considered this to be more than merely a localized industry which is one that is concentrated in a particular locality. Concentration could be a result of resource endowments, the 'patronage of a court' or urbanization. However, these initial forms of localization can be transformed into an industrial district through a number of mechanisms which build sustained advantages: hereditary skill, the growth of subsidiary trades specialized machinery and local markets for special skills, industrial leadership and novelties in the production (Belussi and Caldari, 2009).

These external economies can also be grouped into three forms: local knowledge spillovers; local non-traded inputs which are subject to scale economies; and labour pool benefits (McCann, 2008). In each case, a greater agglomeration of business in an area creates greater benefits with returns to scale. The more firms there are in an area, especially within the same industry, the more knowledge will be flowing 'in the air' which other firms can access through a variety of means, including the hiring of staff, informal discussions, imitation, etc. Similarly, a large market allows for the existence of specialist service providers in the local area which can benefit producers. Local agglomerations also create labour pools with greater specialization, and with greater potential for the development of specialist training services. External economies can also be split between two main forms, depending on whether the benefits are experienced by all firms within a locality – urbanization economies such as exist in large cities – or localization economies which are experienced by certain sectors only. A cluster could be some variable combination of the two, although with the assumption there is always some element of localization economies, but perhaps not always significant urbanization economies where a cluster is in a less urbanized region.

The concept of agglomeration remained important in economic geography throughout the twentieth century, as part of industrial location theory, and particularly in the growth pole theory of Perroux in the 1950s. Perroux argued that development was inherently uneven, and that growth was concentrated in particular growth poles in economic space. This was then translated into a geographical model in that the assumption was made that growth may be transmitted from a key firm to the surrounding area, in a sense making the argument for the formation of clusters around value chains.

A direct theoretical and empirical descendent of Marshall, which became a popular concept in the 1980s was the Italian industrial districts, (Becattini, 1979; Brusco, 1982; Piore and Sabel. 1984). The Italian districts continued an earlier form of development around large numbers of small firms operating in complex production systems with high levels of mutual trust and informal contracting. High levels of specialization existed in particular cities and rural regions – textiles, machine tools, ceramics, etc, in each case typified by the proliferation of small owner-managed businesses, with extensive social interaction. The success of such districts in terms of economic growth and innovation pointed to the external economies in knowledge exchange and specialist labour markets, as well as a culture of subcontracting and sharing out production between firms, with transaction costs reduced by the high levels of trust between firms. Marshall had recognized the value of industrial districts for small firms, pointing out that they 'will be at a great disadvantage relatively to large unless many of them are collected together in the same district' (Marshall and Paley Marshall, 1879: 53)

Parallels were drawn in the 1980s between these traditional industrial districts and newer forms of development in high technology regions where clustering and entrepreneurship was driving development. In the United States, the case of Silicon Valley was seen as a form of new industrial district, but other examples of flexible specialization were proposed. Hollywood has been a longstanding cluster for the movie industry, but the 1980s saw a shift from the domination by large

studios to a new form of agglomeration based on vertical disintegration. Anti-trust actions, technological changes and other sources of instability forced the studios to divest themselves of various activities, creating a new system in which they sat at the heart of constantly shifting networks of small firms – specialists that flexibly recombined to deliver projects in the form of films (Christopherson and Storper, 1986; Scott, 2005). This central argument about the emergence of new forms of production networks as a response to the crisis in Fordist production became a major theme for economic geography in the 1990s. New production processes underpinned by developments in IT allowed for greater flexibility, enabling disintegrated production using subcontracting to be fleeter of foot than Fordist mass production. These new artisanal ensembles included high technology as well as more traditional sectors, and took the form of new spatial agglomerations, described as new industrial spaces, typified by various industries in California. The driver of the spatial agglomeration was the uncertainty and instability as a result of increased flexibility and the need to manage effectively transactions and minimize transaction costs (Scott, 1988).

Meanwhile, in Europe the GREMI research network sought to create an understanding of permanent systematic differences in production between regions. Innovation was placed at the centre of their analysis, as collective, complex and interactive, built from both generic and specific competencies, and territorially organized (Bramanti and Ratti, 1997). The focus on innovation took cognisance of the institutions, norms and governance structures and the interactions and learning processes which shaped innovation in regions. Proximity is central to the innovative milieu, but extends beyond simple geography to include industrial similarity, organizational connections, culture and temporal synchronism. Rather than providing an economic explanation of agglomeration, the emphasis here is placed more on institutional rules and routines rooted in social interaction of untraded interdependencies (Storper and Walker, 1989).

Porter's cluster model built on this earlier literature with a more strategic focus on competition, with clusters being characterized by a combination of competition-driven learning and collaboration. At the heart of Porter's approach is a model of competitiveness derived from strategic management in which the success of export-oriented firms depends on firm strategy and rivalry, factor input conditions, demand conditions and access to related and supporting industries. If firms have intense interactions with other firms to realize these benefits, then they can be expected to achieve higher productivity. Geographic concentration is held to be important for the intensity of these interactions. The Porter model is thus something of a melange of previous approaches: a bit of agglomeration economies, transaction costs, knowledge and information flows and labour market effects. It is presented though in a less theoretical, policy-friendly manner: as a tool for managers and policymakers (Martin and Sunley, 2003). This is seen by some as problematic, being both an analytical concept and policy tool, because the adoption of clusters as policy tool leads to criticisms that the policy tail wags the conceptual dog. The presentation of the cluster model as being 'deliberately vague and sufficiently indeterminate as to admit a very wide spectrum of industrial groupings and specializations' (Martin and Sunley, 2003: 9) leads to a reliance on faith, rather than rigorous analysis and a creative process in defining and delimiting clusters.

The significant interest inspired by Porter in the policy community also stimulated greater attention within the innovation systems community, where there were strong connections between the concept of the regional innovation system (RIS) (Cooke, 1992; Asheim and Isaksen, 1997) and the cluster. The RIS concept developed from the evolutionary economics perspective on the national innovation system (Freeman, 1987), with a focus on national level systems of rules and routines (Nelson and Winter, 1982) and a variety of institutions (North, 1990) which guide and shape

innovation behaviour. Institutions reduce uncertainty, promote collaboration and provide incentives for innovation (Edquist and Johnson, 1997). At a regional level, this literature has been combined with the industrial districts, GREMI etc, in providing an alternative account of the importance of regional-level institutions in the rise of particular innovative regions. Regional innovation systems may also display a combination of local buzz and global pipelines (Bathelt et al, 2004). Local buzz in this context is the knowledge exchange that takes place within a district in the form of the Marshallian atmosphere or knowledge spillovers, often also focused around more tacit forms of knowledge. The global pipelines are the more formalized knowledge networks of the multinational firms and the sourcing of knowledge external to the region, perhaps via university networks and in a more codified form. The successful cluster will be able to combine these local, in-person, buzz connections with the ability to source knowledge globally when needed, perhaps through the interconnections between related clusters in different parts of the world.

Finally, the cluster can be seen as not just a collection of firms or a system of institutions, but as a form of knowledge community (Tallman et al, 2004). Taking the case of Motor Sport Valley in the UK as a globally significant cluster, Henry and Pinch (2000) explore its form as a 'spatially constituted knowledge community' within which the creation and exchange of knowledge among a community of engineers forms the basis of the cluster's success, rather than the survival of individual firms. The processes of cooperation and competition operate at the level of the individuals who move between firms within the region, seeking out the best opportunities, and in which the high churn of firms co-exists with growth and success of the cluster. The knowledge base is thus the key asset of the firms, and the cluster.

How then do we deal with this conceptual plurality? It can be argued that the different perspectives and disciplinary foundations compensate in part for the weaknesses of each other. Agglomeration economies are unable to address issues of causality, but can demonstrate generalizable tendencies, whilst institutional theories are rooted in the specifics of individual cases (Gordon and McCann, 2000). By integrating explanations from different theories, an account may be constructed for an individual cluster which is theoretically informed, even if not the outcome of a simple rule-based approach. The value of multiple perspectives, then, is the way in which these different explanations build richer understandings (Benneworth and Henry, 2004).

3.3 Some definitional problems

Whilst Porter's definition of the cluster has become relatively well adopted, there are a profusion of definitions by other authors, all with variations on concentration, interactions between firms, institutions, and some form of sectoral focus – collaboration and competition often feature as well. (see Martin and Sunley, 2003) for a set of alternative definitions). Linkages between firms and geographic proximity are the two core characteristics, but these led to questions over how to delimit a cluster – how to draw the geographical and sectoral boundaries to say which firms lie inside and outside the cluster.

This is the key challenge of the cluster concept, because despite the wails of frustration that no rigorous definitions can be produced (Martin and Sunley, 2003), it is hard to see how such boundaries can ever be made rigorous. All theories of clustering and agglomeration place the interactions between firms as the central focus, and all state that such interactions are heterogeneous, both in terms of the content of the linkages and the intensity. Some will be concerned with supply chain links, some with collaborative learning, some with learning from competitors, and some through labour market processes, including poaching. Similarly, the intensity will vary greatly, as will the people involved, whether it is senior managers or informal links between

operational or technical staff. Emphasis may be placed on strong ties, but as Granovetter (1973) has shown weak ties can be more important for the exchange of new information. There is no means by which a formal boundary can be proposed for diverse linkages to say some firms are in the cluster and some are not. Equally, within a particular industrial district, some firms may choose not to interact with others, whilst some at a distance make great efforts to build connections. The geographical boundary is an empirical judgement based on the pattern and intensity of linkages for a particular cluster. Some clusters may consequently be very tightly drawn geographically, in small towns in the 18th century, or in specific city quarters in the 20th century, whilst others may extend over large regions, especially in countries where there is a propensity to travel large distances on a daily basis. Identifying and defining clusters, then, becomes more of an art than a science. Top-down analyses based on input-output models reify industrial classifications and can miss important inter-firm relationships; they are also limited by pre-existing geographical boundaries. Bottom-up methods chasing the linkages of a set of firms risk being arbitrarily defined.

3.4 Cluster lifecycles and internal evolution

As our understanding of what it is to be a cluster or industrial district has evolved and developed, then part of that definition is the recognition that clusters themselves are dynamic and subject to change. Clusters must emerge from some preconditions, they become more mature, and, in some cases, they eventually experience some form of decline, even disappearance. This is simple empirical observation. How can we characterize this evolution of an individual cluster? Is there a lifecycle? Are there common processes that account for the apparent maturity and decline that some clusters experience? Is there a standard pattern, or do different clusters, explained by different theories, experience different drivers of change?

The response to these issues has been the development of lifecycle perspectives on clusters (for example, Swann, 1998; Pouder and St John, 1996; Menzel and Fornahl, 2010; Popp and Wilson, 2007; Trippl et al, 2015), building on longer traditions of lifecycles such as Vernon's (1966) product lifecycle, industrial product and process innovation cycles (Utterback and Abernathy, 1975), or Markusen's (1985) profit cycles. At a macro- level, we also understand long-term shifts in technologies and industries in the form of Kondratieff long waves (Marshall, 1987) which drive the rising and declining fortunes of regions.

A simple hypothesis would be that clusters follow the dynamics of their core technologies or industries. Clustering is important in the growth phase of an industry when diversity and innovation are high, in a Schumpeterian period of creative destruction, but less important in the mature phase when geographic dispersion may take place (Swann, 1998). According to this view a new cluster will emerge with a new industry as disruptive innovators appear potentially in new locations to the core of the old industries they replace. A cluster develops around a group of new firms as in the case of semiconductors in Silicon Valley, but then as the industry grows production plants are established elsewhere and as the industry matures more of the output is located elsewhere, with the core cluster perhaps only retaining some HQ and R&D functions. If the industry is replaced at some later stage, then the core of the old cluster might collapse. In this we can link the cluster with the product and profit cycle, as well as with the shift to FDI and spatial divisions of labour.

However, not all clusters by any means follow the fortunes of technologies or industries so closely, with some clusters emerging around established technologies, or declining whilst others grow, and others making transitions between technologies. This suggests alternative lifecycle forces relating to the institutional foundations of the cluster, or to the changing levels of externalities in specific place-based innovation systems. It is this sense of a lifecycle related to core cluster characteristics and

internal dynamics which has stimulated greatest interest and potentially draws out the full implications of cluster theories . As with other aspects of cluster theory, though, the characterization of the cluster lifecycle takes many forms, and a variety of stages are identified, although the basic process may be similar.

All models of lifecycles start off with some form of **emergence** (Fornahl and Menzel, 2003), the formation of **critical mass** and **takeoff** (Swann, 1998; Popp and Wilson 2007). In these first stages the key elements of the cluster assemble in a region and some form of Marshallian externalities develop, leading to a virtuous cycle as firms in the nascent cluster gain advantages over firms elsewhere, increase sales and profits and begin to attract and spin off new firms (Trippl et al, 2015). Such emergence may be partly due to chance, but also can emerge from the application of existing capabilities and institutions in the region to new products, the valorization of key regional assets, or may be stimulated by government action and investment.

Once the cluster is growing, the next stage is a period of sustained development usually described in terms of **growth**. Maggioni (2005) uses the term **golden age** as this is essentially the classic cluster phase where all the advantages and benefits of the cluster concept are realized. Popp and Wilson (2007) use **cooperative competitiveness** in recognition of the balance between the collective benefits of clustering and the competitive advantages given to the firms in the cluster. It is in this period when the Pouder and St John (1996) idea of clusters as 'hot spots' is most apparent, and here also when cluster firms behave most differently to firms outside of the cluster, drawing on collective learning and agglomeration economies. The cluster will at this point be showing significant growth both in the number of firms, but also on the part of individual firms within the cluster. Firms based elsewhere might seek to move into the cluster, or if they are multinationals establish an investment in the cluster – this might take the form of a research or product development unit, seeking to access the knowledge spillovers of the cluster, sometimes more of a listening post to pass knowledge back to the home base.

The key element of a lifecycle perspective is that this period of growth cannot continue indefinitely, and has to slow down and move into a phase of **maturation**, or **exhaustion**, when there is a convergence with the wider national economy. There are a variety of explanations of why this should be, although obviously there are limits to growth due to the scale of demand for the industry. In some cases congestion costs develop, and external diseconomies set in, perhaps due to the rising costs of labour (Menzel and Fornahl, 2010; Malmberg and Maskell, 2007). More typically, though, the technological dynamics of growth become replaced by product stability as sunk costs limit the level of change firms are willing to accept and innovation switches to purely incremental development. Menzel and Fornahl (2010) stress the importance of heterogeneity and diversity among cluster participants in preserving its dynamism, as variety brings new knowledge and promotes innovation. It is when this variety is lost that a cluster loses direction and becomes less innovative.

This phase is associated with cognitive lock-in, as firms inside the cluster succumb to groupthink or cognitive bias (Grabher, 1993) and institutional isomorphism (Dimaggio and Powell, 1983), with local institutions being configured around certain technological approaches and solutions to the neglect of other alternative approaches. The techniques and approaches that made the cluster successful are assumed to be the most appropriate and cluster firms almost become anaesthetized (Bergman, 2008) and reluctant to recognize new opportunities and adjust to changing external markets. Thus, firms outside of the cluster may be more likely to develop more radical or disruptive innovations drawing on novel combinations of knowledge, hence undermining the advantage of the cluster.

This is a crucial issue as the assumption is that the advantage of the cluster turns to disadvantage, allowing firms from outside to achieve faster growth rates based on innovation. The slowdown can turn into a downward spiral as new clusters emerge elsewhere, perhaps associated with paradigmatic changes in a technology, or just linked to an enhancement of competitiveness. Lock-in can have multiple natures – cognitive, functional, political or structural – and as it is constructed so can it be overcome through a combination of contingency and agency (Popp and Wilson, 2007). Faced with such external competition, though, the cluster may be unable to respond as it is locked into an older paradigm, without the new combinations of technology and practices, and with structural barriers to making those changes. Like the incumbent firms faced with disruptive innovators (Christensen, 1997), the mature cluster focuses on its existing markets and seeks to make incremental, sustaining innovations, rather than rip up its sunk investment to meet the challenge of disruptive innovation. Cognitive isomorphism leads to place-dependent, cluster-specific technological lock-in and innovation passes to non-clustered firms, whether incremental or disruptive, reducing the advantages of the cluster and leading to decline. (Pouder and St John, 1996).

All may not be lost, though, as some clusters can revive themselves (Swann, 1998) through a phase of **renaissance,** whilst others move into long term decline, or what Bergman (2008) terms **petrification**. The few examples of renaissance are usually exalted as success stories, as new clusters emerge from the ruins of the old, with new technologies and industries which owe some debt to the heritage of the old cluster, but still represent a considerable shift. More typically, as a cluster shrinks to irrelevance, the regional host either develops a more diversified, but less dynamic industry structure, or sees the continued development of other clusters which may have co-existed with the one that declined. Regions can of course have more than one cluster, as well as a large base of non-clustered businesses.

The notion of the lifecycle is not unproblematic, though, and Martin and Sunley (2011) critique the notion of the lifecycle as a metaphor drawn from a biological model of a single organism. Clusters are a constantly shifting population of firms, so whilst a cluster experiences some form of evolution, it is a composite system. As a phylogenetic form of evolution relating to a population, there is no inevitability about the trajectory and the development path may vary, depending on the heterogeneity of firm dynamics within the cluster. ‘Approaches to cluster lifecycles should allow for the fact that “history matters” but also that history does not entirely restrict possible development paths. To follow evolutionary thinking then means that the development of a cluster can be explained only ex post but not ex ante since the future course of a path is open.’ (Trippl et al, 2015: 2033). Indeed, the idea of the lifecycle can be seen less as a deterministic model, but as a heuristic device to organize empirical cases, even though their development might not pass through the stages as proposed.

Instead, Martin and Sunley (2011) suggest that a cluster can be represented as a complex adaptive system, as it has numerous heterogeneous components which have complex inter-relationships, yet with a shared identity and connectedness. Clusters also like complex systems have fuzzy and open boundaries with constant interactions with the wider environment. Again, like complex systems, clusters are characterized by non-linear dynamics due to feedback effects, leading to path dependencies. They display properties of emergence and self-organization, as the actions of individual firms in response to external stimuli lead to changes in the nature of the cluster. So, the macro-structure of the cluster emerges from micro level decisions and behaviour of the firms, but these structures then reshape the micro-level in an ongoing process of adaptation. As a consequence, clusters have multiple possible evolutionary trajectories and unpredictable outcomes.

Thus, Martin and Sunley take a standard adaptive cycle model and augment it to develop six basic possible trajectories for a cluster. The standard cycle resembles other cluster lifecycles in four 'periods' or stages. An **exploitation** period sees growth and the sizing of opportunities as the cluster emerges and develops. This then matures into a **conservation** stage where the cluster settles down to a period of stasis and increasing rigidity, with high levels of connection between firms which would be a period where cognitive lock-in might start to develop. The third stage is the **release** stage as contraction and decline sets in as low resilience and adaptability accompanies disinvestment. Finally, there is a **reorganization** stage of experimentation and restructuring in which a new cluster may emerge. This cyclical approach provides an alternative to other cluster lifecycles, but also has limitations in assuming a standard and somewhat deterministic process. Hence, a modified adaptive cycle is proposed in which a cluster can break out of this four-stage model at various points, either stabilising at a particular stage or breaking down and disappearing.

A cluster could therefore **constantly mutate** and shift orientation without settling into a steady growth process, continually being rejuvenated and modified, highly resilient due to its adaptability, but without establishing a mature system. Alternatively, a mature cluster might also **stabilize** for many years and then crash into renewal or replacement without a long process of decline. Another outcome for a mature cluster could be for firms to **reorientate** themselves to a new industrial and technological specialisation and essentially form a new cluster. **Failure** and the **disappearance** of the cluster can also take place during the decline period, but also at the emergence point. This model consequently offers a variety of routes and cycles subject to the contingencies faced by specific clusters and the development of their underpinning industries, technologies, and indeed particular place-based factors.

Trippl et al (2015) also pose a number of significant challenges for cluster research, grouped into three main areas, relating to place specificity, multiscalar attributes, and agency. Different clusters within an industry may take on very different characteristics as a consequence of the interaction between the firms and the specific characteristics of the region and its wider regional innovation system (see, for example, Saxenian's (1994) comparison of Silicon Valley and Route 128 as electronics clusters). If the nature of cluster innovation is determined by the heterogeneity of knowledge resources within that region, then the varied presence of related and unrelated industries, the nature of the research infrastructure, institutional 'thickness', and alternative public policies may all influence the form and development of the cluster. Bridging social capital, linking outside of the cluster, can be particularly important for both the renaissance of a locked-in cluster, as well as for the emergence of new spin off clusters. The characteristics of the regional innovation system thus offer a key insight into the way clusters may evolve and there are varied ways of categorising such systems. One perspective contrasts regions as either organizationally 'thick' or 'thin', and as specialized or non-specialized (Isaksen and Trippl, 2014), characteristics that help to shape cluster development paths. This emphasis on place fits well with recent place-based policy perspectives and the emergence of smart specialization theory which is examined in the next section.

A second challenge requiring further research is the issue of multi-scalarity, and the nature of knowledge connections at different spatial scales. We have already noted the importance of local buzz and global pipelines in terms of localized and external knowledge flows, with a combination of both being important to the development of cluster learning. Too much proximity could restrict learning if it leads to cognitive lock-in (Boschma, 2005), and extra-regional networks are needed to foster new ideas. Place-based clusters are also embedded in national contexts, and the nature of the regional or cluster innovation system is partly shaped by the characteristics of the national

innovation system and its institutions. Within the EU, the international scale is also particularly important as policies and actions at EU level impact on the development of local clusters, particularly through regional funding, but in some cases through direct involvement of the EU's own research institutions.

In addition to the nested nature of multi-scalar systems, another important aspect of the external knowledge (and material) linkages of a cluster is the nature of the links between clusters, including whether there are particular hierarchical structures between clusters. If one cluster is dominant, such as Silicon Valley, then other clusters elsewhere in the world might develop particular relationships with that dominant cluster. There are consequently important connections between the electronics clusters in Israel and Taiwan with Silicon Valley, with technology entrepreneurs gaining from experience in Silicon Valley and accessing venture capital resources and contracts.

The third research challenge is that of agency and brings together questions of leadership, key individuals, and policy. If chance events can lead to the emergence of clusters, as Porter (2000) suggests, then individual entrepreneurs can play an important role in seeding new clusters and helping to build up critical mass. More significantly, though, the effect of collective actions by individuals and policymakers can configure the institutional system of the cluster, leading to 'a mutual dependence exists between higher-level structures, such as the regional innovation system, and actors, for example entrepreneurs' (Trippl et al, 2015). Whilst the path-dependent nature of the cluster structure appears to constrain individual agency, which has to work within existing development paths, there remains the potential for purposive action in which entrepreneurs can discover new opportunities, new pathways and make changes to the underlying framework conditions through policy intervention (Simmie, 2012). This assumption lies at the heart of recent European innovation policy, as described in the next section.

3.5 Recent thinking on clusters and smart specialization

In the last few years, innovation policy in Europe has adopted a framework developed by Foray and others termed smart specialization developed from a macroeconomic concern for the competitiveness of Europe and the trans-Atlantic productivity gap (Foray et al, 2009). Europe's opportunities were said to be likely to emerge in areas according to existing evolutionary pathways, and as a result of the discoveries of agents such as firms and universities. Smart specialization was therefore initially a form of national innovation system theory linked with a strong sectoral orientation. This was then applied to the regional scale in the expectation that regions might identify particular sectors of specialization, and smart specialization strategies were adopted by the European Commission as a condition for innovation funding in the ERDF for 2014-20 (Foray, 2015; Charles et al, 2012).

The origin was in an expert group established by the Research Commissioner in 2005 on Knowledge for Growth and a core question on how European regions could be made more attractive for R&D and innovation activities of multinationals (Foray and van Ark, 2008). The conclusions from this discussion was that specialized world-class hubs for innovation needed to be developed at a European level, overcoming the fragmentation that comes from national investments, and that countries and regions should identify priorities for investment that are particular to their own contexts, rather than attempting to duplicate what other regions were doing. Such specialization would help to achieve the agglomeration economies that would attract international investment and help establish growth in Europe (Foray, 2015). At the outset smart specialization wasn't a regional planning framework, but a process for identifying activities in particular places that would benefit from innovation support and offer opportunities for future growth. It was about capabilities for new

opportunity recognition rather than simply supporting existing strong regional clusters, but also ensuring that new developments built on existing regional skills and assets.

Although developed with limited practical evidence, the approach was rapidly taken up by the European Commission as a Europe-wide tool for a new generation of regional innovation strategies. In 2013, the Common Provisions Regulation set out the rules of the Structural Funds and established ex-ante conditionalities (EACs) which were requirements to be adhered to by member states in the implementation of the Structural Funds. One of these related to the adoption of smart specialization strategies and required a SWOT analysis to identify research and innovation priorities, stimulated private sector RTD investment and had some form of monitoring mechanism (Polverari, 2016). Thus, without a smart specialization strategy (RIS3) approved by the Commission, a region would not be able to draw down ERDF funding for innovation support. As a result, considerable effort was devoted to further developing the concept of smart specialization and its operationalization.

A core objective has been to 'adjust the local entrepreneurial climate' (McCann and Ortega-Argilés, 2014: 412) in Europe's regions, and this needs to be through bottom-up, place-based approaches, rather than centralized one-size-fits-all policies. Such a place-based approach was widely advocated in the late 2000s, having been adopted by OECD (2009) and the EU's Barca (2009) report. A place-based approach should deal with both the geographic and institutional specificities of regions (McCann and Ortega-Argilés, 2013). The aim of smart specialization is consequently to draw upon the agency of entrepreneurs and other actors, through their recognition of new innovative opportunities, to develop new clusters based on the existing strengths and assets of regions, which might lie in declining clusters. Action is aimed at a micro-level, focusing on small groups of firms and knowledge institutions seeking to help them seed new clusters.

We might argue that there is both a distinction and an interdependence between strategy development at different scales: regional innovation systems, clusters and smart specialization. Leadership is needed to clarify how these levels interact within a particular region and ensure that they are mutually supportive. The regional innovation system can be seen as the holistic framework for innovation in a region encompassing knowledge infrastructures, existing interfirm networks and relationships and the underlying institutional structures which facilitate innovation of all kinds within a region. This provides a context for all other innovation policies in the region and provides an underpinning platform for innovation in all firms, whether they are part of clusters and smart specialization or not. Firms which are not currently part of a smart specialization strategy, but might become part of one in the future, will nonetheless operate in the context of the regional innovation system. A system will continue to exist even if not proactively managed, but might suffer from neglect, thereby weakening the opportunities for entrepreneurial discovery.

Within a region (or overlapping with other regions) there may be some clusters of interrelated and innovative businesses, which either have emerged without the support of policy or have received considerable policy support. Clusters often have their own governance structures and leadership – sometimes emergent leadership from within the business community, sometimes a form of imposed leadership from within the regional policy community in the form of a specialized cluster agency. The main priority of such leadership groups is usually to foster the development of the cluster, lobbying for supportive policies and encouraging collaboration within the cluster membership. This could be seen as largely about sustaining innovation as there are demands to ensure incumbent firms continue to be successful.

Smart specialization then adds to this by a regional effort to identify new combinations of largely disruptive or radical innovations, perhaps sitting on the fringes of or linking across clusters, as well as

drawing on the regional innovation system and linking with other regions. The task of identifying these new opportunities and developing bespoke policy support is thus distinct from the development of generic regional innovation strategies, or cluster support, with different leadership requirements. Whilst smart specialization has dominated regional innovation policy discourse in recent years, the other two forms of strategy development – RIS and clusters – will still be present in most cases.

3.6 Ships to subsea – cluster evolution in North East England

The form and varied outcomes of the evolution of a cluster as a complex adaptive system can be seen briefly through the example of the North East shipbuilding cluster from its ancient origins to its rapid development in the 19th century, long decline during the 20th century and a form of rebirth around offshore and subsea technologies in the late 20th and early 21st centuries. This is a particularly long-lived cluster, as the region has a long history of wooden shipbuilding particularly linked with another cluster, namely, that of the coal trade. By 1830, Sunderland was the most important shipbuilding centre in the UK; by 1840, there were 65 firms and by 1850 produced 150 ships in a year. The cluster specialized in colliers, robust sailing vessels for carrying coal down to London and elsewhere.

The 1850s saw the start of production of iron vessels, with the notable innovation by Palmer's shipyard of Jarrow on the Tyne of 'The John Bowes' sea-going iron screw collier in 1852 (Arnold, 2013), followed by rapid growth of other firms on the Tyne, Swan Hunter being the best known. The new iron-based technologies spread on to the Wear and Tees as well, making the North East one of the dominant shipbuilding areas in the world. The shipbuilding firms had strong links with local suppliers, both of basic materials and components, but also specialized technologies which reinforced the advantages of the region. Charles Parsons invented the steam turbine on the Tyne, used to power the ships as well as forming the foundation of a new cluster around electrical power. William Armstrong developed hydraulic and gunnery technologies which were then applied to warships, and the development of a specialization on a new generation of naval vessels. The Tyne had not been a major source of wooden warships, but became a key site for the new battleships, supplying international markets, including both sides of the Russo-Japanese war in 1904/5. Armstrong's acquired shipyards and became a major naval constructor, although rather than organising production as a standard industrial district, it was heavily vertically integrated from a huge works in Elswick employing 25,000. However, even though there was vertical integration, there remained a large and complex local supply chain and a set of local knowledge institutions to support the industry, such as the North-East Coast Institution of Engineers and Shipbuilders (Clarke, 1984). Specialized trades grew on the river and working in the shipyards became a tradition along the riverside communities in the same way as in the colliery villages inland: sons following fathers into the shipyards and into trades. It seems that even the social relations and perspectives of the shipyard workers on the Tyne developed a distinctive nature untypical of traditional proletarian workers, with an intrinsic interest in the building of ships and a desire for self-advancement (Brown and Brannen, 1970)

The industry moved into relative decline after WWI, with the notable closure of and destruction of the iconic Palmers shipyard in 1934, the event which led to the Jarrow March to London calling for intervention to create work. The yards revived during WWII, as industrial Tyneside always did well during wars, but then went into decline again, faced with growing international competition, the decline of the UK fleet and merchant navy, and labour unrest. The industry became locked-in to outdated technologies and processes, and was overtaken by developments elsewhere, typifying the

maturity and lock-in phase of the cluster (Lorenz, 1991). Part of the industry was nationalized in the 1970s, then later privatized again in the 1980s (Murphy, 2021). There was a brief experience of making supertankers on the Tyne, but the industry ended on the Tyne after the closure of all the Wear and Tees yards, with domestic naval orders including the two aircraft carriers Invincible and Ark Royal. In 2006, the work ran out and Swan Hunter closed, although A&P at Hebburn later made sections for the two new aircraft carriers.

So far this is a classic tale of the rise and fall of a cluster. However, as shipbuilding fell into terminal decline many of the supplier firms and the workforce moved into a new industry, offshore fabrication, supplying the topsides of oil production rigs for the North Sea. The closure of the shipyards left large flat sites along the River Tyne, ideal for the construction of offshore modules, and the skills of the region were ideal for the complex structures that were constructed. The simpler 'jackets' which sat below the water were mainly constructed elsewhere. Some ship-repair also continued, with some firms being involved in the conversion of ships to floating production vessels, essentially building topside modules on top of ships.

In parallel, Tyneside had a British Gas engineering research station focused on pipelines, which spun off a business doing high-tech pipeline inspection. When BG decided to close the research station, with the loss of several hundred jobs, some of the engineers established small consultancy businesses. Some of these worked together in a cluster-based alliance called 'Pegasus', operating as a network of SMEs that developed pipeline specialization (Whitehurst, 2007). In addition, another business had spun out of Newcastle University to develop technologies for ploughing the seabed to bury cables and pipelines. Other firms had moved to the river in activities such as the production of underwater umbilicals for the oil industry, and these businesses began to form a sub-sea cluster that integrated with the offshore sector through various industry associations and a collective approach to marketing the region for the offshore and subsea sector (Siedlok and Andriani, 2005). The subsea sector has been a source of considerable innovation and resulted in the recognition by the region as a key area of smart specialization.

What is interesting here is that the new cluster which has emerged from the dying embers of the old is very different in nature. Rather than large businesses which have a high level of vertical integration, it is more focused on projects and vertically disintegrated supply chains with a number of relatively small specialist firms, even if some are now owned by foreign multinationals. The skills and knowledge base of the old sector helped foster the development of the new, but the industrial structure is very different. Rather than a monolithic associational structure, the new cluster has taken a variety of institutional forms - Northern Offshore Federation, Pegasus pipeline cluster, spin off subsea firms, and Subsea North East. This illustrates both the evolution and renaissance of the old cluster, but also the evolution of the cluster model, with aspects of the old continuing alongside a new smart specialization cluster: large multinational firms, project-based firms and their sub-contractors and small high-tech firms operating in constantly reconfigured networks.

3.7 Conclusions

Clusters can be seen as evolving on several different levels. Each individual cluster might evolve, as a complex adaptive system in itself, following different non-deterministic paths depending on the characteristics of the sectors involved, their organizational and institutional patterns and the contingencies of the places in which they are located. Some clusters have a classic pattern of growth and then slow decline, whilst others undergo renaissance or transformations as the central industry focus shifts, and others sustain production over many decades. However, what it is to be a cluster itself alters over time, with changes in underpinning technologies of interaction and communication,

the evolving of organizational forms such as the multinational enterprise, and the nature of institutions themselves change: a 21st century cluster underpinned by ICT is not the same as a 19th century cotton town. The geographical extent of clusters is one aspect that has changed over time as patterns of daily interaction have become more extended. Finally, our thinking about the conceptualization of clusters or similar such geographical agglomerations has changed, both in response to the changes in the nature of clusters but also through the continual development of theorization. The cluster might be a perspective informed by many different theoretical insights over time, but this is not a weakness in the concept, it is its very nature to be always changing and adapting.

Looking to the future, how might we see the nature of clusters evolve further? What are the possible effects of digital technologies on the geography of clusters? The world might still be 'spiky' (Florida, 2005), in the form of localized clusters of competitive advantage, but the 'spikes' are more closely integrated and firms outside the 'spikes' can more easily connect into the clusters. Will we see the much heralded, yet never realized, death of distance (Cairncross, 1997)? Whilst the local buzz of proximity might ensure that clusters retain an advantage, the continual improvement in the bandwidth of ICTs could erode some of those advantages, just as the post-pandemic shift to working from home partially frees employees from living close to work.

One particularly interesting development for the future is Industry 4.0 and the potential widespread adoption of additive manufacturing technologies. Such technologies promise to enable more localized production as they reduce the minimum efficient scale of production and offer the possibility for localized supply of more bespoke products. Production could thus be located closer to the point of consumption, rather than being in a central location. This could diffuse the employment associated with a cluster, such that the core knowledge activities could remain centralized, but production could be more distributed. Alternatively, it could enable clusters to retain production for longer, or even backshoring production which has been moved to lower cost locations (Dachs et al 2019). Clusters might not be made redundant, but their advantages could be more limited and more focused on the idea of the knowledge community, and production might not be so important.

More generally, our understanding of the evolution of both clusters and cluster theory leads to a need for more work mapping cluster histories against adaptive cycle models, with better understanding of the processes leading to renewal or replacement, as well as stable survival. Trippl et al's (2015) concerns for work on place, multiscalarity and agency are central to the needs for new work, and three specific questions arising from these themes may be developed here.

1. Clusters are often examined in isolation from the wider regional context even though the context of place is central to the theory. There is a need to understand the effects of wider regional innovation systems on cluster evolution and vice versa, and particularly how the geography of the cluster fits into the regional structures. Some clusters, such as the UK's Motorsport Valley seem to transcend several regions, whilst others are embedded tightly within regions, but the analysis of cluster dynamics and regional innovation systems are often separated and the mutual dependency between the two unexplored.

2. With regard to multi-scalar and relational effects, there is a need to explore how the balance of endogenous and exogenous knowledge flows have changed over time both in the evolution of existing clusters and in the evolution of the cluster concept. Have clusters needed to become more open to exogenous knowledge over time, and has this been facilitated by the changes in communication technologies over the last two hundred or so years? How might these developments

continue in future and will this affect the nature of the cluster, potentially undermining the integrity of the cluster?

3. Agency is a key theme for future research, both in understanding the role of agency in the development of new clusters and potentially validating current smart specialization policies in Europe, but also in understanding how agency is implicated in cluster evolution and responses to external shocks.

The chapters in this book present a range of examples of clusters and cluster building over time and in different sectors and spatial contexts, helping us to understand how they evolve and their effects on wider regional business environments. Despite a history of the phenomenon reaching back over a couple of hundred years, and many decades of more recent research, there remains a fruitful research agenda in exploring the history and evolution of clusters.

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