Innovation Caucus

UNDERSTANDING CLUSTER GROWTH POTENTIAL

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About the Innovation Caucus

The Innovation Caucus supports sustainable innovation-led growth by promoting engagement between the social sciences and the innovation ecosystem. Our members are leading academics from across the social science community, who are engaged in different aspects of innovation research. We connect the social sciences, Innovate UK and the Economic and Social Research Council (ESRC), by providing research insights to inform policy and practice. Professor Tim Vorley is the Academic Lead. The initiative is funded and co-developed by the ESRC and Innovate UK, part of UK Research and Innovation (UKRI). The support of the funders is acknowledged. The views expressed in this piece are those of the author and do not necessarily represent those of the funders.

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EXECUTIVE SUMMARY

UK Government has committed to ensuring that Research and Innovation investment contributes to the growth of innovation clusters across the UK and levelling-up. To deliver on this, policymakers and their delivery agencies need to understand where the best opportunities lie and how national support can best be deployed to drive local economic impact.

The support must respond to the specific circumstances of each cluster. Understanding innovation clusters at the local level is therefore vital to defining the opportunities.

This project delivers user-friendly resources to assist policymakers and their delivery agencies in understanding place-based clusters. These include a framework to understand future growth opportunities and the aspects that merit further focus to strengthen a cluster's contribution to economic growth. The framework is based on literature on situating and surveying clusters, cluster life cycles, and the relationship between absorptive capacity and cluster growth. The framework has been tested in three case studies. A topic guide and interpretive framework are also included.

Our recommendations include:

- **Identifying the cluster** – Involve local stakeholders and remain flexible and open minded when characterising the innovative segments of place-based economies and their relationships to sectors.

- **Be guided by evidence** – Use qualitative observations in addition to the relevant data available. Where possible, comparisons should be made over time (rather than with other clusters) to establish rate of change and growth potential.

- **Map the knowledge base** – Understand the key actors for knowledge creation, the structures and relationships within the cluster, the culture for openness and collaboration, and gain contextual insights on how knowledge flows through the cluster and region.

- **Unpack skills-based competitive advantages** – Probe to understand the cluster's skills-based competitive advantage as well as pinch points that might constrain growth. The quality of talent pools in terms of metrics such as educational attainment or years of experience matters less than their alignment with the needs of firms. Understand the higher and further education institutions that are best placed to enhance skills pipelines.

- **Establish the role of higher and further education** – Involve the institutions that contribute to the knowledge base and cluster leadership through specialised programmes, collaborative initiatives, and events. These could be large and well-funded higher and further education institutions or smaller, highly engaged institutions with relevant research facilities, labs, course offerings, or infrastructure.

- **Understand the focus of supporting organisations** - Concentrate on how supporting organisations shape or respond to cluster development strategies, including how they interface with structures of a more general nature (such as incubators with broad mandates) or in other tangentially related industries.

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- **Situate the existing role of Government** - Enumerate any national, local or regional public sector initiatives that have directly or indirectly supported cluster development. Draw on Government's visibility into other synergistic clusters and relevant programmes to identify the clusters that might benefit from interventions or are failing to leverage opportunities.

- **Highlight critical infrastructure** – Review whether infrastructure is appropriately provided, maintained, and accessible in accordance to the cluster. Some clusters will be very reliant on specific publicly provided infrastructure - such as ports or transport networks - while others will rely on infrastructure that may be privately provided. Sometimes critical infrastructure needs will be taken for granted, e.g., high speed internet.

- **Critically evaluate financial accessibility** – Published finance data should be interpreted with caution and enhanced through further consultation. Published finance data gives insights on those types of firms that are attractive to external financiers and overlooks other firms that are struggling to find appropriate resources to innovate and grow, sometimes as existing financing structures are not well suited to their needs.

- **Trace localised networks** – Assessing cluster networks will be highly subjective. Cluster stakeholders are usually willing to highlight weaknesses because everyone benefits from addressing them. Draw on the experience of assessing and working with other clusters in order to diagnose the interventions that may be most effective in a particular case.

- **Culture characterisation** – We are most interested in assessing openness to collaboration, knowledge sharing, and learning. While these are difficult to assess quantitatively, cluster stakeholders are often able to articulate a dominant attitude and identify the advantages and disadvantages of this mindset.

- **Forecast market potentia**l – It is critical to establish the alignment between the cluster's resources, assets and governance and the expectations for global market evolution. How local stakeholders characterise their future market expectations provides an indication of the strength of cluster stakeholders' strategies.

- **Envision cluster evolution** – Note where the cluster is in terms of evolutionary path and consider the next likely phase(s) of evolution. Evaluate how effectively positioned the cluster is in terms of its strategic vision and current resources to move along the developmental pathway.

- **Interrogate absorptive capacity** – Recognising that absorptive capacity is difficult to assess in practice at the cluster scale, it is important to consider how likely firms are to have access to, adopt, and adapt knowledge created within the cluster and from beyond. This is related to insights on knowledge creation, networks and flows, and firm and cluster level capabilities in strategic leadership and management.

While this research focused on building a framework for gathering evidence about innovation cluster growth potential, it could be expanded to develop additional policy tools. Next steps might include:

- Developing an evaluative framework for comparing different clusters based on the known information about their emergent characteristics and growth potential;

- Developing a methodology to synthesise lessons across cluster case studies to inform national policy priorities and strategies. For instance, commonalities on skills pinch points seen across clusters could be aggregated to inform national skills and training policies.

1. INTRODUCTION

This project aims to develop a framework to understand the future growth opportunities of place-based innovation clusters, what aspects of these clusters merit further investment to strengthen their contribution to GVA, and potentially also contribute to the levelling up agenda.

This report contains three sections. First, a Background and Context section elaborates key concepts through a series of “deep dive” literature reviews. It contains three subsections with the following objectives:

- Situating and Surveying Clusters provides background on the concept of clusters, identifying clusters, and some key measures to evaluate them.
- Understanding Cluster Evolution sets out the literature on cluster growth paths and trajectories of cluster development.
- The Relationship between Absorptive Capacity of Firms and Cluster Growth introduces the concept of absorptive capacity and discusses how it will be used in the context of our framework.

The literature in these three sections informed the development of the framework. Throughout each of these contributions we provide guidance about how policymakers and their delivery agencies can “apply the principle” in their cluster research and assessment exercises. Note that while these sections discuss potential approaches to measuring and quantifying these factors, these are elaborated in more detail within the Interpretive Framework (Section 4.2).

The second phase of the project involved applying the framework to three cluster case studies to road test and refine our investigation process. In order to test the framework for the variety of cases it may be applied in we selected three clusters of different ages, technological focuses, and geographical locations in consultation with Innovate UK:

The 3 case studies

Marine and Maritime in the Solent

Centred on Southampton and Portsmouth and their ports. Longstanding population of maritime firms active in range of sectors including logistics, defence, construction and marine biotech. *(David Legg/Jen Nelles)*

Medical Technologies in the East Midlands

Particularly concentrated in Nottingham, with related activity in Leicester, Derby and Loughborough. Covers a range of activities i.e. product development, contract manufacturing, contract research. *(Julian Bowery/ Paul Vallance)*

Cyber Security in Belfast

Centred around c.100 firms primarily located in Belfast, with some related activity across Northern Ireland, who provide products and services within the cyber security sector. It has strong international connections and FDI flows, particularly from the US. *(Lorraine Acheson/Tim Vorley)*

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Each of these case studies provides a sample cluster analysis and demonstrates how the framework can be used to organise findings and structure analysis. Note that while these were written to function as standalone pieces to be disseminated to the clusters themselves to spark conversations, it is also evident how they can be analysed as a group to generate deeper understanding about cross-cutting challenges. Our framework does not include a tool to engage in cross-cluster synthesis, but it may be useful to periodically adopt this practice to look for opportunities to combine programmes and leverage economies of scale.

The final section contains the framework, which comprises two tools. The first is a topic guide to help structure interviews with cluster stakeholders. The second is an interpretive framework, which outlines how each question can contribute to fleshing out a report on the cluster (such as the ones in Section 3). This includes suggestions about indicators and metrics that might be useful to consider for each thematic section as well as guidance about how to use these to assess cluster growth potential.

This project ultimately delivers user-friendly resources to assist policymakers and their delivery agencies in learning about place-based clusters and to structure their thoughts about how these might be better supported. This was not meant to be an evaluative or comparative exercise and, as such, we do not provide instructions on how to rank or prioritise clusters based on these results. We suggest that developing a more evaluative framework might be a valuable next step. However, this might be best accomplished after several rounds of cluster analysis so that it can be based on a robust evidence base.

2. BACKGROUND AND CONTEXT

2.1. Situating and Surveying Clusters

Measuring and developing place-based and contextual advantages has been a policy focus since the 1990s as concepts of national (Freeman 2004, Lundvall 2008) and regional innovation systems (Asheim and Coenen 2005, Cooke et al. 2011, Asheim, Smith, and Oughton 2011), industrial clustering (Delgado, Porter, and Stern 2015, Martin and Sunley 2003, Porter 1998a, Fornahl, Grashof, and Söllner 2018), and others related to agglomeration economies (Duranton and Puga 2004, Combes, Duranton, and Gobillon 2011, Porter 1996) began to dominate economic development discourse. This group of concepts all attempt to capture the factors that combine to characterise places and catalyse growth, entrepreneurship, and innovation and centre on the idea that a critical mass of collocated firms in related industries generates superior innovation outcomes compared to more dispersed and diverse local economies.

While each term cited above emerges from a rich academic literature, in this report we concentrate on clusters and innovation (eco)systems. In this conceptualisation, clusters are industry or sector specific. They comprise groups of firms and intermediary organisations involved in related activities and the focus of inquiry is generally on understanding how the group benefits, and contributes to collective benefit, from collocation with each other. Where clusters focus on specific industrial groupings, innovation (eco) systems are more generalised and can benefit multiple types of economic activity. As such, a basic relationship between these concepts positions clusters as specific manifestations of spatially concentrated economic activity that exist within broader innovation systems or ecosystems.

This first deep dive outlines the literature on identifying clusters and the framework conditions that are frequently used to describe, assess, and compare them. While we present some options for quantifying clusters in evaluation processes, we also stress that many of the factors are not easily measured. As such, we designed the research framework (Section 3) to rely primarily on interviews supplemented, where appropriate, with data.

2.2. Identifying clusters

A first step in assessing cluster growth potential is defining its geographical boundaries and its constituent actors. The literature identifies and utilises a wide variety of quantitative, qualitative, and hybrid approaches, each with their own advantages and disadvantages.

Quantitative approaches are a gold standard for cluster studies and typically rely on industrial and enterprise statistics. Techniques such as locational quotients (LQ) – which usually compares an industry, or group of industries, total employment to the national average – are useful for pinpointing areas of industrial concentration. More complex variations of this approach involve multiple calculations to determine degrees of specialisation and concentration (Kopczewska et al. 2017). However, these often rely on data structured around traditional industries and can yield misleading results in the case of clusters that include firms from a variety of industry subsectors. Similarly, in order to be as comprehensive as possible, they require prior knowledge of which industries figure in the cluster and are, as such, not always appropriate for discovering the full range of cluster participants, particularly in emerging clusters. There is also no clear threshold LQ above which a grouping can be declared a cluster. Finally, they also require pre-defined geographies, which is a limitation for clusters that extend across statistical/administrative boundaries.

Other basic quantitative approaches include using physical distances between firms (Ripley's K), export data and input-output analysis. These again require a prior understanding of which firms to include and exclude from the cluster and are primarily useful for comparative analysis. They also suffer from data limitations, particularly difficulty getting comparable data at the appropriate scale and, for the latter two, weakness in assessing co-location (European Union - CoR 2010). These approaches all suffer from being highly firm-centric and do not delve into the network dimensions that are defining traits of clusters. Network analysis can overcome these limitations by including a wider set of actors but relies on detailed survey data and tends to be labour intensive to analyse. Increasingly, scholarship is seeking broader data sources, and combining databases (e.g., patents, literature, and business data), for network construction (Xu et al. 2020).

Where cluster assessment is intended to be exploratory qualitative methods may be more appropriate. These involve expert interviews, snowball sampling, and/or focus groups. Because they are not data-driven, these approaches permit a more nuanced and expansive definition of which actors, firms, and industries are part of the cluster – perspectives that can be independently verified by consulting multiple sources. They also enable more flexible geographies, which can cross jurisdictional boundaries or be much smaller than administrative areas. Much of the early research on clusters focused on specific case studies (e.g., Silicon Valley and Route 128 in the United States) and this approach remains popular in policy analysis (see, for instance, The Royal Society 2020).

Ideally, cluster evaluation studies use a combination of methods – qualitative methodologies to zero in on firms and industrial structure complemented by quantitative methods to establish the significance of the cluster nationally and/or internationally. However, where comparative analysis is not required, qualitative approaches alone may be sufficient.

2.3. Cluster Framework

Michael Porter's famous "diamond" (Porter 1998b) was one of the first influential models of the sources of cluster competitive advantage. Since then, frameworks to map, analyse, and evaluate cluster performance have proliferated. While they are numerous there is remarkably little variation in the headline factors identified as important, although they do differ in the factors they emphasise as critical, level of detail, operationalisation, and measurement.

This literature review aims to provide a high-level overview of framework conditions to serve as a starting point from which to construct a framework to assess UK cluster growth potential. While this review covers a wide range of factors, it will focus the most on elaborating local conditions with a specific emphasis on discussing measures of cluster development and potential.

2.3.1 Actors

Actors are often the focal point of cluster and ecosystem analysis because they are the ones that innovate, grow, lead, and advocate within the system.

While noting the presence of these actors is important, it is also useful to explore their significance, roles, and impact.

Critical mass of firms

Clusters require a critical mass of firms engaged in related activities – whether competing or up or downstream in supply chains, drawing on related knowledge bases, or relying on specialised service providers. In part, determining whether there is a critical mass of firms is part of the cluster identification process, particularly when reliant on quantitative approaches. However, even then, there is no clear consensus about how many firms are required to constitute a cluster. Furthermore, this number can (and should) vary depending on stage in cluster evolution and life cycle.

Importantly, the literature takes pains to emphasise that clusters (and their innovation systems) are much more than a critical mass of geographically and economically proximate firms. Things like interdependence and network effects cannot be effectively read from lists of firms alone (Xu et al. 2020), which is why these dimensions are often separated out. This is even more difficult in nascent clusters where there may be potential for both firm creation and growth as well as the development or deepening of network dynamics with public support.

That said, it is important to establish the core economic actors in the space and reflect on what their number, size, and other characteristics signify for cluster maturity and potential. While there is no known specific magical firm type or mix of firm types, scholarship on firm structures and innovation points to a series of characteristics that influence investment, engagement, and intrapreneurship decisions. Factors such as firm size, for instance, influences a variety of investment decisions. Larger firms are more likely to invest in research and development (Shefer and Frenkel 2005). Firm age affects things such as the propensity for the organisation to undertake risky, and potentially more innovative, knowledge searches (Coad, Segarra, and Teruel 2016); generate innovative output (Sørensen and Stuart 2000), often measured in terms of patents; and adopt innovations (Balasubramanian and Lee 2008). These factors are also affected by firm sector, technological profile, position in the supply chain, and past innovation performance.

Applying the principle

The approach we propose relies on selecting case studies that are likely to exhibit this critical mass and to define the cluster in partnership with local stakeholders. We acknowledge that because it is difficult to make these assessments a priori, some of the cases selected may ultimately turn out not to be clusters in their own rights, but subclusters of some other cluster or, alternatively, in a nascent or emerging state of evolution. This finding, however, is an important part of the assessment process and can help policymakers and their delivery agencies to rethink how to characterise the innovative sectors in place-based economies and their relationships to sectors.

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Higher and further education institutions

Universities and other higher education institutions are regarded as key anchors and actors in innovation systems. The term 'anchor' refers to the relative fixity of these entities in contrast to more footloose private firms. Their engagement with and embeddedness within the regional economy stems from their status (usually) as large employers, (often) large owners or tenants of real estate, and (typically) strong historical connection with the place and its economy. These entities generate positive externalities and relationships that can support wider economic activity within the locality (Benneworth, Pinheiro, and Karlsen 2017). Partly as a product of these interests and partly to support their core missions, these institutions will often deepen their involvement in the local economy whether through civic engagement, strategic partnerships, consulting relationships, public engagement programmes, or collaboratively developing regional knowledge infrastructure. As such, they can make important contributions as active and strategic participants in cluster development and evolution.

In addition to being important foundations and engines for the regional economy, universities are also sources of important artefacts such as talent and skills and contributors to the local knowledge base. They are also significant in their capacities to attract firms, talent, and investment to the region. For instance, in science-based industries such as the life sciences, it is increasingly the location of research and development (R&D) related infrastructure such as research-intensive universities and laboratories that encourages the continued clustering of firms in these areas as these organisations with a reputation for excellence function like magnates for firms in related industries (Gertler and Vinodrai 2009, Cooke 2005a).

One important note, however, is that the presence of universities alone, for example, is not an excellent indicator of significance. There is no guarantee, for example, that universities will have research expertise in areas of existing or emerging cluster focus and, as a result, they may not be as active in cluster development. However, the presence of an higher education institution generally signals the potential for targeted programme, research, and infrastructure development that places without such resources might lack. They are likely also either already engaged in place-based economic development initiatives and visioning exercises or have the potential to become engaged and so again confer important advantages.

We can measure higher education institutions by counting them and/or by evaluating them based on national rankings. Another way to get at this is to measure the significance of knowledge generating organisations through tracking research funding (e.g. using Innovate UK data). This type of data can also help identify research-intensive anchor firms. Membership in, or leadership of, significant civic organisations and networks is an indicator of institutional engagement.

Applying the principle

While data can provide important insights, in our framework we suggest policymakers and their delivery agencies concentrate more on understanding which institutions contribute most to the knowledge base of the cluster and contribute to its leadership through specialised programmes, collaborative initiatives, and events. The presence of multiple or large and well-funded higher and further education institutions in a region can have important benefits to clusters. However, it is also true that a single highly engaged institution with cluster relevant research facilities, labs, course offerings, or infrastructure can be very influential. Understanding higher and further education roles, level of current engagement, and plans for future can give useful clues about how well positioned the cluster is for growth and development.

Supporting organisations

Cluster and innovation system development is also influenced by the support structures that facilitate knowledge production, value creation, and act as key nodes in networks that facilitate knowledge spillovers. Innovation support systems include resources for business including incubators, accelerators, innovation agencies, tech/science parks, technology transfer infrastructure and industry associations. Occasionally, specific individuals are included in this category, in their capacity as brokers, dealmakers, and specialists in firm startup and scale up processes (O'Connor 2012, Clayton, Feldman, and Lowe 2018). These organisations and entities typically exist for the specific purpose of supporting local businesses and so are highly active and embedded in the local economy. While support structures can be extraordinarily helpful in increasing business startup and survival rates they are typically regarded as second-generation organisations in the innovation process – they are features associated with more established innovative regional economies but are often the outgrowth of early informal initiatives by supportive agents. They can be integral to sustaining innovation performance over time.

These organisations tend to enable all phases of the innovation process. Incubators, accelerators, and higher education technology transfer organisations focus on facilitating early stages of innovation and particularly on entrepreneurial aspects and other vectors of commercialisation. Technology parks, tech poles, industry/cluster associations, and innovation agencies provide support to existing firms and tend to count firms of various ages as members, from startups to mature anchor firms (Clarke and Ramirez 2014, Molina-Morales and Martínez-Cháfer 2016). These organisations are particularly relevant for their brokerage capabilities (Belso-Martinez et al. 2018, Dedehayir, Mäkinen, and Roland Ortt 2018). That is, their ability to connect business with the resources (e.g., financing, expertise), people (e.g., partners, thought leaders), or information that they need to grow their idea or business.

Applying the principle

The difficulty here is the alignment of actors to the existing or emerging cluster. There is a difference between support structures that have evolved with and been tailored to a specific cluster and the presence of structures of a more general nature (such as incubators with broad mandates) or in other unrelated industries. As with higher and further education institutions, policymakers and their delivery agencies should concentrate on learning how supporting organisations contribute to driving cluster growth and interface with other actors to shape or respond to cluster development strategies.

Governments

While the mere presence of local, regional and national governments are not indicators of cluster activity it is important to acknowledge their contributions as actors in the broader ecosystem. The policy actions of governments can have direct or indirect effects on cluster development. Their direct role can be as participants in cluster organisations, visioning exercises, and as partners in developing targeted research and innovation policies (i.e., through investments meant to support a cluster specifically). This kind of intervention is less likely in nascent clusters but can occur. In that case, the presence of supportive interventions or participation in cluster planning is a strong indicator of government engagement and, potentially, leadership. Indirectly, governments are responsible for shaping the institutional environment within which innovative activities take place. These include generalised support programmes, such as R&D tax credits, that are open to all eligible firms but also include regulatory frameworks such as tax, employment, environmental, and trade policy (among many others) that can influence incentives and behaviours.

Applying the principle

Exploring the role, and potential role, of Government is the main focus of this exercise. As such, enumerating the Government departments and the programmes that have directly or indirectly supported cluster development can help develop an understanding of impact to date and what has worked. While national programmes will have important impacts, there may be barriers to their effectiveness or difficulties in adapting them to local and cluster needs that are not obvious until closer inspection. Local governments and regional authorities can also play supportive, or constraining, roles on cluster growth. The ability of policymakers and their delivery agencies to have visibility into other synergistic clusters and a deep awareness of Government programmes, current and planned, makes them uniquely positioned to identify where clusters might benefit from interventions or are failing to leverage opportunities

2.3.2 Resources

These include tangible and intangible resources, technological and non-technological resources, and other types of system inputs and outputs, including innovations themselves (Granstrand and Holgersson 2020). One interesting dimension of resources as a broad framework condition is that the literature on place-based innovation tends to emphasise local stocks of these assets as essential. However, actors within the ecosystem can access most of these from outside of the region (e.g., labour markets are not strictly local, certain types of knowledge can be accessed from anywhere, etc.). Obviously, local stocks can confer competitive advantage and benefit the broader ecosystem but not all of these resources are likely to develop at the same pace. Consequently, exploratory and evaluative research might productively investigate the potential for either developing these resources locally or accessing them from elsewhere.

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Talent and skills

So much of what makes a region successful is embodied in the people that make things happen. A place's human capital - collective skills, knowledge, or other intangible assets that individuals possess that can be used to create economic value for themselves, their employers, or their community – is an incredibly important driver of innovation. This type of capital is associated not only with knowledge and skills but also creativity and innovation capacity (Pasban and Nojedeh 2016, Kerr 2018, Stam 2013).

In addition to their contribution to the knowledge pool, and through this the innovative capacity of their employers, skilled workers also have broader impacts on the innovation economy. Skilled workers are important vectors for knowledge transfer as they move from firm to firm. As they develop new skills, and often tacit knowledge, in one workplace they carry these skills with them enhancing the effectiveness of their new employers (Spigel 2020, Dahl and Pedersen 2004). Skilled workers are also potential entrepreneurs within the ecosystem, whether through firm or individual spinout activities or forces of entrepreneurial recycling (Spigel and Vinodrai 2020, Dahl and Sorenson 2014). This talent is crucial for firm growth and scaling. Firms that lack their own talent pipelines grow more slowly and must devote more resources to training and skills attraction. Thus, places with deep labour pools in appropriate skill sets enjoy a comparative advantage conferred by generally lower personnel-search transaction costs over places that do not.

Localised human capital is often measured in terms of the educational attainment of the workforce, and this remains a useful metric through which to understand the mix of skills available in the economy. This attainment level will, in part, be related to factors such as the strength of anchor institutions such as colleges and universities. However, much as with the knowledge base driver the important impacts of the human dimension of economy is rife with nuance. For instance, since previous work experience invests individuals with important tools and tacit knowledge acquired outside of educational institutions, the stock of experienced workers across skills profiles provides important insights into the innovative potential of a region (Solheim, Boschma, and Herstad 2020).

Applying the principle

As with many of the other framework conditions, context matters. The quality of talent pools in terms of metrics such as educational attainment or years of experience matters less than their alignment with the needs of firms. Since an adequate supply of skills is a crucial fuel for innovation and growth, we encourage policymakers and their delivery agencies to probe to understand the cluster's skills-based competitive advantage as well as current or predicted pinch points that might constrain growth. Also important is understanding which higher and further education institutions are best placed to enhance skills pipelines. Commonalities across clusters can be aggregated to inform national skills and training policies.

2.3.3 Knowledge base

Although knowledge can come from many different sources, we are principally concerned with the pool of endogenous (localised) knowledge that forms the base from which individuals and firms inspire and develop new ideas. Rather intuitively, a wealth of research suggests that depth of regional knowledge bases is closely correlated with innovative activity (Asheim and Coenen 2005).

We define the regional knowledge base as the store of information that is produced by and embedded within the knowledge-generating organisations and firms within the region. The types of knowledge that emerge and anchor a region are strongly dependent on, on the higher education side, the strength and engagement of local anchor institutions – which includes universities, labs, and other non-firm knowledge facilities. The regional knowledge base produced by firms is largely a product of the sectoral structure of the economy.

Research and development (R&D) spending across various sectors of the economy is frequently used as a measure of the knowledge base. Various metrics, including business enterprise research and development (BERD), higher education research and development (HERD), and, more generally, gross domestic expenditure on research and development (GERD) provide comparative insights into regional knowledge bases. While these are the most commonly used measure of stocks of regional knowledge they are not often effective indicators of cluster knowledge bases as these tend to be sub- or cross-sectoral.

Furthermore, knowledge produced locally can be privileged or access limited, meaning that only certain actors benefit directly. Therefore, it is important to consider degrees of knowledge accessibility, flows, or openness as potential drivers of, or barriers to, innovative activity (Antonelli, Krafft, and Quatraro 2010).

Applying the principle

In our framework, we have asked respondents to identify key actors involved in knowledge creation and innovation but also ask questions about how knowledge flows through the cluster and region. These questions interrogate not only the robustness of research and innovation practices but also structures of relationships within the cluster and cultures of openness and collaboration. That clusters would benefit from increasing knowledge access, collaboration, and informal interaction is a common conclusion from cluster evaluations but how these can best be supported are highly contextual. Furthermore, detailed insight into knowledge exchange dynamics cannot be fully assessed without speaking to firms, which is not always within the scope of these research exercises. Policymakers and their delivery agencies will have to rely on the observations of cluster stakeholders and their recommendations for supportive interventions and may wish to set up workshops or present findings to firms in the cluster to confirm these assessments.

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2.3.4 Infrastructure

Infrastructure can mean a lot of different things in regional economies. Most frequently, it refers to the quantity and quality of (often specialised) physical spaces and assets as well as publicly provided hard infrastructure. The former includes things like office and production spaces suited to local firms and their growth potential, specialised lab and manufacturing spaces. Note that these do not necessarily have to be privately provided – e.g., universities often partner with firms for lab-based research or processing. These assets should ideally be well-located relative to workers (on arteries/transit routes) and hard infrastructure such as fibre optics and logistics corridors.

So much of the innovation process relies on flows – the flow of goods, services, knowledge, ideas, resources, people. While there are sometimes downsides to extreme openness and mobility, on balance, reducing the friction involved in these kinds of flows yields positive returns (Bentlage, Lüthi, and Thierstein 2013). These flows exist on two different if intersecting planes – the tangible (people, things) and intangible (knowledge, experience) – which to varying degrees both rely on physical and digital infrastructure to facilitate and encourage circulation.

Trade relies on the circulation of goods and services. Products need to get to consumers and supply chains need to be connected. The advent of just in time production processes and expectation of overnight delivery means that a large part of competitive advantage now relies on the effectiveness and efficiency of logistics systems, which are themselves dependent on (largely public) infrastructure that connects places (Feder 2018). National and regional assets and facilities such as ports, freight rail, airports, and motorway/road networks provide vital links that support industry and is a sector that has itself undergone waves of innovation. The movement of people is equally important. Employees use some of the same networks to commute to work relying on publicly sustained roads, public transportation networks, and airports to get to work and for other business travel. As important as internal circulation is external connectivity, which connects business with other parts of the world and function as the global pipelines of knowledge, investment, and best practice is also critical to enabling innovation.

Intangible flows have increased in importance in the modern economy. Networks as vectors of knowledge circulation between organisations and individuals have always been invisible but now also extend and replicate across very real and physical digital infrastructure (Rodríguez-Pose and Crescenzi 2008). Telecommunications networks and the energy grids that sustain them are essential to innovation. But while these are ubiquitous, quality, reliability, and access can be uneven creating crucial barriers to connectivity. Regional connectivity can be measured in terms of availability and effectiveness of physical and digital infrastructure. These include travel times between locations; proximity and access to airports/roads/rail; and export and import data (as a proxy for global connectivity and reach). Digital connectivity can be measured by extent and access to 4G+ and ultrafast broadband networks.

Applying the principle

The importance of infrastructure, and what respondents will interpret as critical infrastructure, will vary by cluster. Some will be very reliant on specific types of publicly provided infrastructure - such as ports or transport networks - while others will rely on infrastructure that may be privately provided. In other cases, infrastructure needs will be minimal or taken for granted (e.g., high speed internet). The most important task in applying the framework is to determine if required infrastructure exists and is appropriately provided, maintained, and accessible. In some cases, questioning whether that provision is equitable will also be appropriate.

2.3.5 Finance and capital

Investment is a crucial enabler of innovation. Firms require capital to fund expansion, research, take risks, and bring products to market (Ferrando and Lekpek 2018). While capital is arguably important at all stages of firm development, it is especially vital to support startups and for new path creation. Sources of finance include venture capitalists, angel networks, other types of investor networks, private equity, and investment banks. While the presence of localised networks of investors has been identified in high profile clusters, Chemmanur and Fulghieri (2014) note that VC and other sources have become increasingly internationalised as globalisation simultaneously widened the pool of investment opportunities and technology lowered monitoring costs.

Notably, financial resources are not only available through private sources and networks. Government programmes, such as research and development tax credits, loans, and grant schemes can also contribute to financing innovation pipelines. While there are some advantages to local sources of finance in their proximity to and knowledge of specific industries, their needs, and practices (Cooke 2001) access to these resources is important.

Applying the principle

Firm growth can be constrained by their ability to access finance and firms often report that existing financing structures are not well suited to their needs. This is another factor that is difficult to assess without speaking with firms directly and that is likely to be different for firms based on size and market functions/position in supply chains. Data can be misleading as the presence of firms that have been successful at closing funding deals may obscure other firms that are struggling to find appropriate resources. That said, cluster stakeholders are likely to be aware of firms that have successfully completed funding rounds and also of common complaints about finance aired during cluster events. These observations should be interpreted with caution as they may only apply to certain types of firms and may be best confirmed through further consultation. Interviews with key local sources of finance, if they exist, such as VCs may yield additional insight.

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2.3.6 Network structure and characteristics

Clusters within effective innovation systems are more than just the sum of their parts. Their dynamism is defined by a presence of a critical mass of actors and also in the characteristics of the interactions between them. These interactions can manifest through market mechanisms – engagement in supply chains etc. – but in more mature and consolidated cases involve interaction in governance networks. Cluster assessment exercises should investigate whether these kinds of synergies are present and their actual and potential contribution to cluster development.

Networks

It is widely accepted that social, civic, and business networks have a positive impact on innovative activity, and literature on economic development and innovation has spawned a rich literature that explores the catalytic and transformative power of these invisible forces within regions. The capacity for networking is seen as essential for tapping into the shared intelligence of both the individual firm and organisation, as well as a collectivity of firms within a given geographic space. In contrast to the more conventional forms of inter-firm relations — markets and hierarchies — this alternative form of resource allocation is characterized by transactions that “occur neither through discrete exchanges nor by administrative fiat, but through networks of individuals engaged in reciprocal, preferential, mutually supportive actions” (Powell, Staw, and Cummings 1990).

The interaction between diverse groups of actors participating in networks takes the form of sharing information, knowledge and perspectives, as well as coordinating their activities to achieve and implement more effective solutions to problems — particularly in situations where the solutions lie beyond the capacity of any one party to achieve (Nelles and Wolfe Forthcoming). In addition to these critical coordinative functions, in innovation and diffusion processes networks are important knowledge transmission functions and influence knowledge spillovers. They also connect actors with the information, advice, and resources (Christopherson, Kitson, and Michie 2008). Networks that function at the regional scale act as bridges between regional resources (knowledge, labour etc) and regional innovation processes. Networks emerge and knowledge percolates through iterated interpersonal or business interaction in physical or virtual spaces (such as social networks or using digital communications) (Rutten and Boekema 2007).

Networks are notoriously difficult to measure and typically require in-depth qualitative research to determine their extents, contours, and influence (Doh and Acs 2010). Often researchers use data on industry organisation membership and, to the extent that it is available, frequency of business and industry networking events/conferences. Measures such as the spatial density and clustering of workers and industries can also provide an indication of the vibrancy of the networks at play.

Applying the principle

In this context, assessing the strength of cluster networks will be highly subjective. In our experience, cluster stakeholders are willing and even eager to highlight weaknesses in networks because everyone benefits from recognising and working together to address them. In this respect, we feel that even a small number of interviews with actors engaged in the cluster will be illuminating. As noted above, diagnosing what types of interventions may be most effective in strengthening network relations and particularly cluster leadership will benefit from the experience of policymakers and their delivery agencies in assessing and working with other clusters.

Cultures

Innovation culture describes the collection of attitudes, outlooks, norms, and beliefs that inform the practice of innovation in regional economies. A broad consensus has emerged that the culture of a place plays an important role in the innovation process. Within places, these cultures develop over time and through a variety of mechanisms, a process often anchored by an international firm or a leading university and disseminated across the region through spinoffs and movement of workers from the major anchor organization to other firms. Saxenian's seminal study of the Silicon Valley and Route 128 in Boston highlights the power of (in this case, corporate) cultures to shape entire regions.

Broadly, innovation culture encompasses the social values and norms that promote risk-taking, creativity, collaboration, knowledge exchange, and openness that are critical for innovation success. For instance, innovation thrives in cosmopolitan cultures, characterised by openness to global interaction and social tolerance (Spigel 2016; Saxenian 1994). This increases the ability of actors to respond quickly to changing markets and to innovate by bringing together people with diverse backgrounds. Cultures that are supportive of and encourage risk taking and collaboration are particularly fertile to entrepreneurship, intrapreneurship, and open innovation. These promote a broader willingness to experiment and take risks, informality of work styles and high occupational mobility that tend to underpin higher levels of new firm formation and innovative activities in general. Innovation culture shapes the propensity for actors in the ecosystem to seek innovative solutions in research and discovery phases. It affects attitudes of actors involved in the value creation process towards risk and experimentation in implementation and commercialisation. Innovation culture plays a similar role in shaping attitudes and practices in the space of innovation adoption.

Culture is relatively difficult to measure and in innovation literature usually relies on surveys where possible and must default to proxies otherwise. Common proxies for innovation culture include indicators of open innovation such as prevalence of strategic partnerships and use of external knowledge; of entrepreneurship such as firm formation rates; and of attitudes towards (entrepreneurial) risk. The UK Innovation Survey collects data on firm knowledge and technology sourcing activities.

Applying the principle

In our framework, the aspect of culture that we're most interested in assessing is openness to collaboration, knowledge sharing, and learning. While these are difficult to assess quantitatively, cluster stakeholders are often able to articulate a dominant attitude and identify the advantages and disadvantages of this mindset

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2.3.7 Public policy and regulatory environment

As discussed above, governments can exert important influence in innovation ecosystems through their direct and targeted policy interventions in specific places. However, most of their effects on regional development are through spatially agnostic policies – such as regional or national innovation programmes – and regulatory frameworks. Governments possess levers that can influence trajectories on multiple framework conditions. Education policy and funding, for instance, will affect availability and skills of workers. Likewise, immigration policies determine which types of workers are welcomed and sometimes where they will settle. Public research funding can influence which areas of the knowledge base are developed, under what conditions (e.g., applied or blue sky), and in support of what broader social goals, shaping the decisions of researchers, universities, and ultimately elements of the knowledge base. Of course, much knowledge is developed outside of the public research and higher education system. However, governments can still influence private decisions through national procurement policies, for example, which can shape market opportunities for domestic firms. Tax laws, R&D credits, and the availability of entrepreneurial finance are all also factors that can be influenced by the state. These are just a few of many ways that policy can shape ecosystems' growth trajectories – sometimes in unanticipated directions.

It is fair to say that a part of a cluster's growth potential will be determined by its compatibility with current and anticipated policy and regulatory structures. A latent capacity may exist in a given place, but the development of those technologies might be disincentivized. These might be as simple as regulations that make production in that location too expensive or that bar access to key markets or suppliers. Understanding the regulatory barriers, and possible missed opportunities, will be key to assessing the longer-term viability of the cluster.

Spigel (2020) notes that governments are one of the few actors that can break the status quo of a weak ecosystem through the provision of public goods, funding, and other initiatives. Although the literature is divided on exactly how they can most effectively support innovative and entrepreneurial places, understanding the influence of governments at all scales can help identify appropriate interventions or critical barriers.

2.3.8 Market (potential)

While the focus on local framework conditions in innovation systems and clusters often makes them appear as quasi-closed systems, economic growth within ecosystems depends on demand that is more often externally generated.

Ideally, some elements of the market are local. Porter's diamond model identified sophisticated and demanding customers (or sophisticated demand conditions) as important drivers of innovation (Porter 1996). The challenge of satisfying a demanding internal market encourages companies to innovate and possibly gain early insights into the future needs of customers elsewhere.

However, demand can and does come from outside of the ecosystem, and is no less crucial. As Asheim, Grillitsch, and Trippl (2016) point out, innovations occur all the time but fail for all sorts of reasons including the fact that they might require a number of complementary innovations, user behaviour needs to be adapted, or public demand is lacking. All of this means that ecosystems with strong knowledge and even innovation generating capabilities may falter if these are not adopted (somewhere) in the market.

Evaluating market potential can be quite difficult, particularly in new or emerging clusters. Predicting which technologies or innovations will break through is challenging and fallible. Some work on technological relatedness does engage in this kind of exercise (Kogler, Essletzbichler, and Rigby 2017), although much less to determine market potential than evaluate the innovative potential of existing knowledge spaces.

Applying the principle

Our framework concludes by asking respondents about how they expect market opportunities to evolve over the short- to medium-term. This is important to understand in order to determine whether cluster assets and governance are adequately positioned to promote growth. More importantly, these answers are indicators of the degree to which cluster stakeholders are thinking strategically about the future and their roles in it. In the framework, we invite policymakers and their delivery agencies to reflect on how well the responses and visions articulated align with their assessments of market opportunities.

2.4. Understanding Cluster Evolution

Before engaging in cluster analysis, it is useful to review how clusters can differ depending on their stages of evolution. The main point here is that because clusters have different characteristics at different stages of development, they cannot all be evaluated using the same standards. Similarly, level of cluster maturity can indicate the significance of a cluster's economic impact but may not yield much information about growth potential. An emerging cluster might have significant growth potential and a mature cluster might have weaker growth potential. While maturity indicates past success in adapting to market opportunities, continued growth is not a given. As such, while staying power provides some information, following on the market potential factor in the previous section we are more interested in evaluating how well clusters are positioned to adapt and grow.

Over the past decade the economic geography literature has taken a turn towards 'evolutionary' theories in which constant change is seen as a defining characteristic of local and regional economies (Boschma and Martin, 2010). Evolutionary Economic Geography approaches view clustering as a key process that helps explain why economic activities emerge and become concentrated in certain places and not others (Boschma and Franken, 2011). One of the core ideas here is that over time clusters progress through a series of phases that together form a 'life cycle' (Boschma and Fornahl, 2011). The exact conceptualisation of this life cycle varies, but most models consist of four stages: i) birth or origin, ii) growth, iii) maturity, and iv) decline (Audretsch and Feldman, 1996; Martin and Sunley, 2011; Ter Wal and Boschma, 2011). This sequencing allows variations in the presence and effect of the advantages that clusters bring across these different stages to be reflected.

The conventional understanding of clusters in the academic literature draws on a range of theoretical traditions with a common appreciation of clustering as a form of industrial organisation that generates external economies for individual firms through the shared benefits of localisation and increasing returns to scale (Benneworth and Henry, 2004; Vorley, 2008). As originally identified by Marshall (1890), these external agglomeration economies derive from features of industrial districts including local supply chains, specialised labour pools, and knowledge 'spillovers' between firms (Potter and Watts, 2014).

Life cycle models, however, begin with a birth/origin stage that precedes the formation of a critical mass of firms that enable these external economies to come into effect. The emphasis here therefore is on the processes behind the emergence of clusters in particular places and their transition into a growth stage (Fornahl et al. 2010). These growth processes are driven by the increasing returns generated by external economies that reinforce the cluster as a specialised development path for the regional economy (Martin and Sunley, 2006). As the cluster enters the maturity stage, however, this path dependence may start to have a negative effect on its development if it discourages firms from exploring potential market opportunities or technological innovations in other areas. The final stage of the life cycle model therefore refers to the possibility that for highly specialised clusters, the dominant network relationships, knowledge, and practices may eventually become a barrier to firms adapting to changes in the wider market environment, leading to a state of technological 'lock-in' and declining competitiveness (Grabher, 1993; Potter and Watts, 2011).

As Martin and Sunley (2011) argue, life cycle models can lead to an overly stylised or deterministic view of the complex development trajectories that clusters of different types follow. Individual clusters do not emerge and evolve in isolation, but co-evolve with industries and leading firms (Ter Wal and Boschma, 2011). This means that multiple prospective clusters in the same emerging industry can potentially be present in different regions. Over time, however, differences in firm capabilities and network structure will form between these clusters and mean that only some will grow into leading centres of a maturing industry (Menzel and Fornahl, 2010).

Life cycle models also underplay the potential capacity of different actors in drawing on their shared institutional resources to change the course of path development in the cluster (Harris, 2020). In particular, a strand of the economic geography literature has focused on the ways in which mature clusters can undergo renewal to avoid lock-in to an inevitable trajectory of decline (e.g. Trippl and Otto, 2009; Njøs and Jakobsen, 2016). This includes appropriate measures taken by regional policymakers to encourage the established firms in the cluster to engage in ongoing learning and innovation (Hassink, 2005). This goal of transforming regional economics by concentrating research and development funding into new domains that will support the modernisation or diversification of established sectors has, for example, been pursued on a large scale by the European Commission through their Smart Specialisation programme (Foray, 2015).

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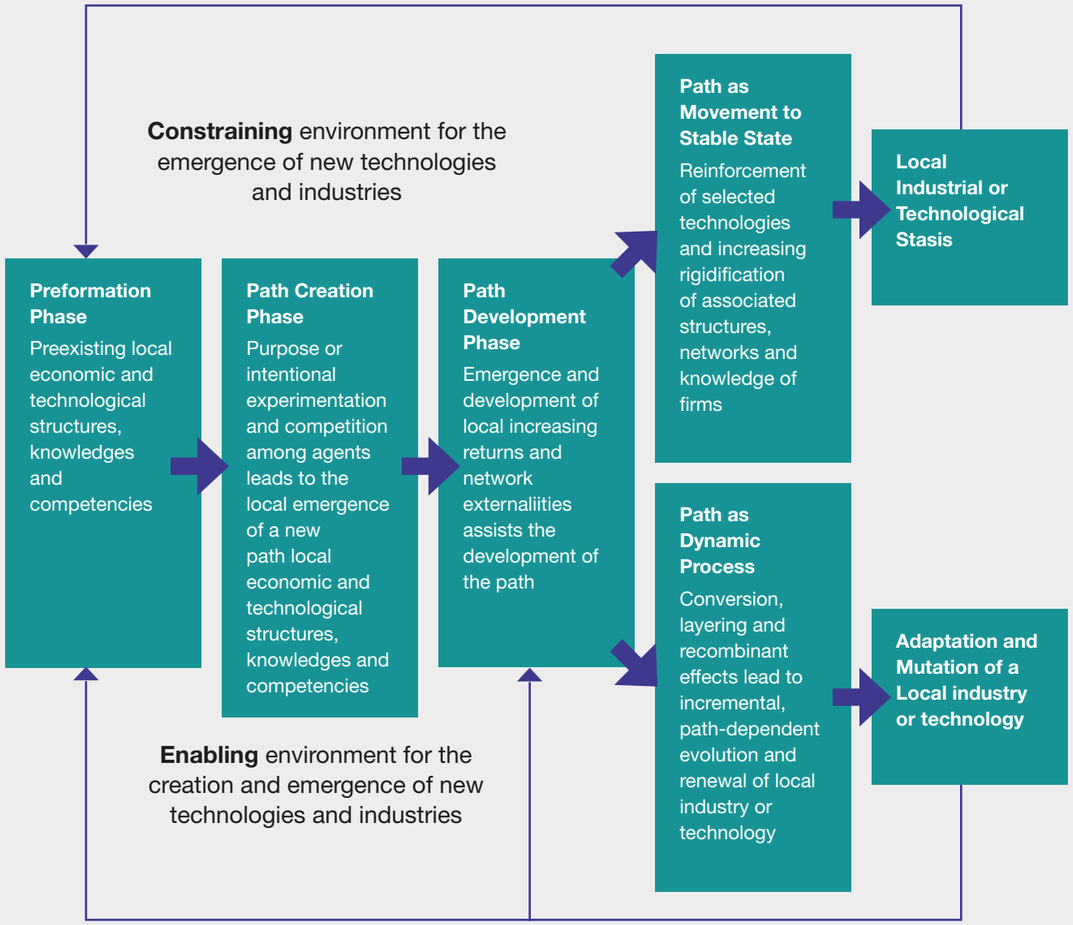
Figure 1: Path development model. Source - Martin (2010, p.21)

The contrasting directions that a regional economic path can take as it matures are captured in the model proposed by Martin (2010). As Figure 1 shows, following creation and development phases that generate local increasing returns and network externalities, the path can either progress into a stable state leading to local industrial or technological stasis, or into a more dynamic phase that enables the adaptation and mutation of these industries or technologies.



When this diversification leads to substantial entrepreneurial activity it can form the basis for a distinct new path in the regional economy (Grillitsch and Asheim, 2018). This process of 'regional branching' is more likely to occur when this path has a degree of relatedness to the technological base of existing local industries (Boschma and Frenken, 2009; Neffke et al., 2011; Tanner, 2016). Hence, regional economies with a mix of technologically-related industries – in other words a high degree of 'related variety' – are more conducive to the knowledge spillovers between these industries that facilitate novel forms of innovation and path development (Frenken et al. 2007). Conversely, new clusters can emerge that are unrelated to the existing industries in a regional economy. For instance, this can occur in technological domains that are driven by the generation and commercialisation of knowledge from universities or other organisations conducting exploratory research (e.g. Gherhes et al. 2021). This form of radical path creation is, however, comparatively rare and difficult for policy makers to engender even when their region possesses some distinctive academic research capabilities (Lester, 2005).

An earlier approach in economic geography argued that during the early stages of a new high-technology industry there is a 'window of locational opportunity' that means serendipitous events or circumstances – e.g. where a key firm happens to be formed – can determine the locations in which new clusters emerge and possibly over time become established (Boschma and van der Knaap, 1999). However, informed by thinking about regional economic evolution outlined above, more recent approaches tend to emphasise that new clusters emerge in places where there is an enabling context of existing resources, technological capabilities, and knowledge inherited from a previous industrial strength or institutional environment. For instance, Isaksen (2016) views the process of new cluster emergence as an interplay of these 'pre-existing conditions' and 'triggering factors' related to the formation of new enterprises.

Within the evolutionary economic geography literature, the importance of new enterprises to the genesis of clusters is mainly reflected in a focus on patterns of repeated spin-off firm formation. As there is a high likelihood that spin-offs will be established in relative geographical proximity to a parent organisation, they are an important mechanism (in conjunction with labour mobility) through which a cluster of geographically located firms with similar routines and knowledge bases can form within a region (even when they are not directly linked through transactional relationships) (Boschma and Frenken, 2011). In science-based industries particularly, the key firms that help stimulate a cluster may be spin-outs from universities (or second-generation spin-offs from these firms) (e.g. Garnsey and Heffernan, 2005). More generally, however, empirical studies across a range of industries, following Klepper (2010), have demonstrated that this process occurs through patterns of spin-offs from other firms (Boschma and Frenken, 2011). When these firms are in established, technologically related industries this can be a mechanism of path branching.

For new firm formation more generally (not just spin-offs), the presence of a wider regional 'entrepreneurial ecosystem' that supports start-ups is a vital factor in cluster development (see Part 1). However, this entrepreneurial ecosystem will itself be subject to evolution over time. As Mack and Mayer (2016) argue, during the key formative stage of a cluster, components of a local entrepreneurial ecosystem oriented specifically towards start-ups in a new industry – such as market demand from established firms, an entrepreneurial culture underpinned by the ready availability of financial capital, or provision of educational courses dedicated to targeted entrepreneurial skills - may be underdeveloped. On the other hand, components relating to a support infrastructure for new enterprises – such as incubators, science parks, or formal network organisations – may be present as a focal point around which the ecosystem can begin to emerge.

Applying the principle

Understanding potential evolutionary paths provides important context for cluster evaluation. In short, we should expect different types and intensities of activity at different phases of evolution and over the longer-term clusters can either stabilise or shift technological trajectories. When assessing potential for growth, policymakers and their delivery agencies should note where the clusters are in terms of evolutionary path. However, they should also consider the next (likely) phase of evolution and, in particular, evaluate how effectively positioned the cluster is in terms of its strategic vision and current resources to move along the developmental pathway.

2.5. Absorptive Capacity of Firms and Cluster Growth

Finally, in evidencing the framework we were asked to address the topic of absorptive capacity and how that can be most effectively assessed. This review provides some background on the origins and significance of absorptive capacity and how it relates to cluster growth potential. We argue that while the concept has important theoretical implications, it is quite difficult to assess in practice, particularly at the regional scale. This is because it is a firm-level concept and understanding absorptive capacity in a particular region requires studying and aggregating the capacities of the firms in that place. However, because this capacity is related to knowledge creation and flows, understanding these can yield insights into how likely firms are to have access to, adopt, and adapt knowledge created within the cluster (and externally).

Absorptive capacity was introduced to the academic literature by Cohen and Levinthal (1990). This was based on the arguments that i) "the ability of a firm to recognise the value of new, external information, assimilate it, and apply it to commercial ends is critical to its innovative capabilities" and that ii) this absorptive capacity "is largely a function of the firm's level of prior related knowledge" (p.128). The popularisation of this concept has coincided with a growing recognition that innovation by firms is an 'open' process that is as dependent on accessing and utilising sources of novel knowledge from outside their boundaries as it is on the generation of new internal proprietary knowledge (Chesbrough, 2003). However, the need for absorptive capacity shows that this scope to acquire and assimilate external knowledge, and then also transform and exploit it for commercial ends, is determined by these existing internal knowledge capabilities (Zaha and George, 2002). This means that, for instance, investments in R&D inside

a firm can have a beneficial knock-on effect on its ability to absorb more advanced knowledge from organisations such as universities, public research institutes, and other R&D-intensive firms (Cohen and Levinthal, 1990). The emphasis on levels of 'prior related knowledge' in the definition of absorptive capacity also indicates that processes such as technological adoption within firms is strongly path dependent – i.e., it is easier for firms to build on and extend existing capabilities in an incremental process rather than introduce new technologies in domains in which the organisation does not have an existing capability (Lane and Lubatkin, 1998; Spanos and Voudouris, 2009).

Absorptive capacity therefore has been developed as a concept that refers to the properties of individual firms. The idea has, however, also been mobilised as an explanation for the presence of different innovation levels at a regional level. For instance, Oughton et al. (2002) identify that firms in regions with low innovation performance "often articulate little demand for R&D and other innovation inputs and tend to lack a tradition of cooperation and trust both amongst themselves or with regional innovation actors, such as universities" (p.102). A low demand for innovation inputs reflects a lack of absorptive capacity at the firm level. This in-turn reduces their ability to benefit from public sector support and leads to what Oughton et al. call the 'regional innovation paradox'. This refers to:

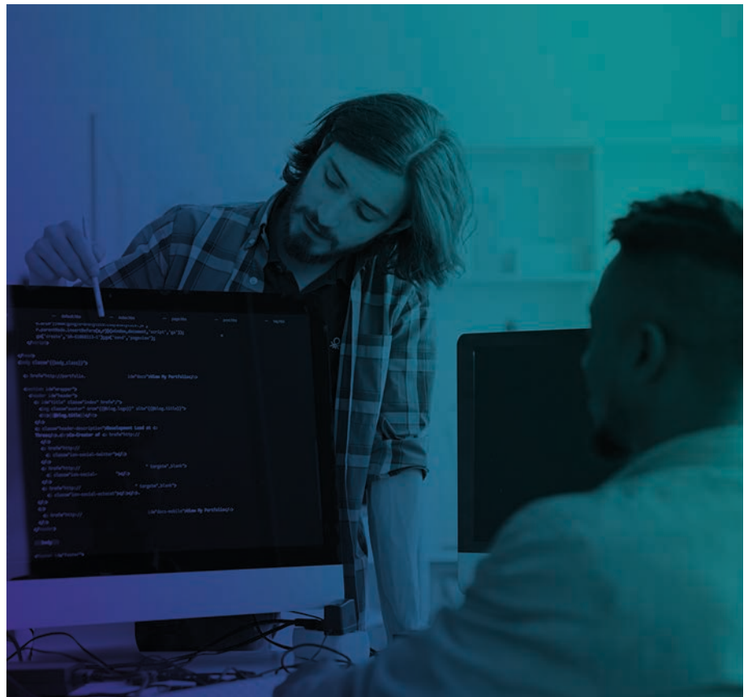
"the apparent contradiction between the comparatively greater need to spend on innovation in lagging regions and their relatively lower capacity to absorb public funds earmarked for the promotion of innovation and to invest in innovation related activities compared to more advanced regions" (Oughton et al. 2002, p.97).

In a key paper exploring the effect of absorptive capacity at a regional level, Giuliani (2005) also "attributes substantial explanatory power to firm-level knowledge bases as key elements of the capacity of clusters to grow" (p.284). These knowledge bases, it is argued, have an effect on both 'intra-cluster' flows of knowledge between firms within the region and 'extra-cluster' linkages with important sources of external knowledge from outside the region. The potential for firms to build these different forms of network, and therefore the absorptive capacity of the cluster as a whole, is therefore also dependent on processes such as the building of social capital amongst firms (for intra-cluster knowledge exchange) and the development of firm internationalisation strategies (for extra-cluster knowledge sourcing) (Valdaliso et al. 2011). Absorptive capacity also affects the potential for firms within a cluster to access knowledge from non-firm organisations such as universities or technology/innovation centres that can be an important part of the wider regional innovation/entrepreneurial ecosystem (Hervas-Oliver, 2012).

This concept has been applied beyond the firm to describe the absorptive potential of firms in the aggregate in any given place or scale – such as regions, cities, or other administrative divisions. However, it is important to note that the places themselves are not absorbing innovation but the regional (e.g.) absorptive capacity is a generalized characterization of firms in a place, within which there is (frequently) a lot of heterogeneity. Firms within a cluster will have differing levels of development in their knowledge bases and the heterogeneity that exists between firms will "lead them to play differing, sometimes asymmetric roles within the cluster knowledge system" (Giuliani, 2005, p.277). For instance, certain leading, technologically advanced firms may have a 'Gatekeeper' role in searching for new external knowledge and importing it into the cluster (also Morrison, 2008). The prospects for this knowledge to then diffuse more widely in the cluster is, however, dependent on the intra-cluster knowledge system, which will not function effectively if other firms do not have a related knowledge base to the Gatekeeper (Giuliani, 2005).

Consequently, characteristics of a place's knowledge diffusion processes and mechanisms are important determinants of firm access to knowledge and its potential for adoption. Knowledge does not simply 'spillover' within clusters; instead its circulation in these environments is reliant on the presence of active mechanisms of transmission between firms and with non-firm organisations (Breschi and Lissoni, 2001; Fitjar and Rodríguez-Pose, 2017). Co-location between these actors can facilitate these mechanisms, but it is not alone a sufficient factor to ensure that relationships of knowledge transmission will exist. The economic geography literature now recognises that forms of 'relational' (rather than geographical) proximity, for instance, from informal social ties or formal organisational networks are essential conditions for knowledge sharing. Relational proximity may be enabled by geographical proximity, but it can also form between actors who are not co-located (see Boschma, 2005). This perspective also emphasises the importance of 'cognitive' proximity in these relationships – i.e., the closeness in knowledge base and interpretive frameworks between partners – that resonates strongly with the ideas underlying the absorptive capacity concept (see Nooteboom, 2000).

Notwithstanding the potential heterogeneity of firm-level knowledge bases, a central argument underpinning the literature on clusters and industrial districts in economic geography is that shared institutions (e.g., informal conventions) and cognitive frames do form between actors in the same or related industries that regularly interact within a region (e.g., Storper, 1995; Maskell, 2001). This makes it possible for hard-to-transfer 'tacit' forms of knowledge to circulate within these environments and gives members of cluster-based epistemic communities with access to this highly valued knowledge a competitive edge over those located elsewhere (Henry and Pinch, 2000; Håkanson, 2005). The formation of these shared institutional and cognitive frames is not likely to occur in the early stages of a cluster's development, so need to be understood as part of the evolutionary process discussed in the deep-dive review of 'dominant growth paths/trajectories of cluster development'.



Typically, the firm- and cluster-level perspectives covered in this review are addressed separately in the academic literature. A notable attempt to combine these perspectives by Pinch et al. (2003) draws on a distinction between 'component' and 'architectural' knowledge developed by Matusik and Hill (1998). Pinch et al. (2003) define component knowledge as referring to "those specific knowledge resources, skills, and technologies that relate to identifiable parts of an organizational system, rather than to the whole" (p.379; emphasis in original); and architectural knowledge as relating to "the organization of an entire system and the structures and routines for organizing its component knowledge for productive use" (p.380). Here, architectural knowledge at the firm level is specific to the organisation and associated with the capacity to absorb new knowledge (Cohen and Levinthal, 1990). Pinch et al. (2003) propose that architectural knowledge can also form at the cluster level as a "shared system for organizing component knowledge that is common to a set of proximate firms" (p.382). This occurs when local firms develop shared practices, routines, and 'ways of thinking' that, because they are socially embedded in that place-based context, do not easily spread beyond the geographical boundaries of the cluster. The intra-cluster knowledge diffusion system therefore performs a function that is analogous to organisational absorptive capacity:

> Common cluster-level architectural knowledge … increases the capacity of a cluster to absorb component knowledge from an individual firm in the cluster. It leads firms to seek similar component knowledge, incorporate it in similar ways, adapt it in ways that reflect common understandings and apply it in a similar fashion in the marketplace. This dissemination of cluster level component knowledge can give the agglomeration a relatively short-term competitive advantage before the knowledge is more generally diffused throughout the sector. Yet whilst the component knowledge may spread relatively quickly, the cluster-level architectural knowledge is, through its embedded character, much harder to spread and continues to give the cluster a competitive advantage (Pinch et al. 2003, p.383).

Applying the principle

Because we are not in a position to survey every firm in every cluster about their innovation and knowledge adoption practices, our framework has to rely on proxies and descriptions of knowledge diffusion patterns. We try to gauge this primarily on the basis of questions about qualities and ease of knowledge flows and accessibility. We also ask about innovation cultures, networks and, specifically, about how open firms are to sharing information and collaboration – both trademarks of regions with highly innovative firms.

3. CLUSTER GROWTH CASE STUDIES

The ultimate aim of this project was to provide a framework with which policymakers and their delivery agencies could understand clusters and develop an evidence base to inform decisions. This section presents three cluster case studies that both demonstrate potential outputs from applying the framework and contributes to that evolving evidence base.

We survey three clusters selected in consultation with Innovate UK – East Midlands medical technologies, Solent marine and maritime, and Belfast cyber security. The cases were intentionally selected to be at different evolutionary stages, based on very different technologies and industries, and are located in different part of the country. This enabled us to test and refine the framework across a diverse range of cases.

We preface the case studies by emphasising two important points. First, these clusters have different growth trajectories and strengths and weaknesses and, as such, readers should resist the urge to compare them to each other without first developing a rigorous rubric for evaluation. Indeed, we think that developing such a tool would be a logical next step. Until then, it is premature to conclude that one cluster is "better" or has greater growth potential than the others. Second, while we discourage normative comparison, reflecting on the differences and similarities between clusters is a useful exercise. For instance, in this cohort, skills and governance are themes that emerge across cases. Exploring these commonalities may provide insights to inform crosscutting programmes. In that case, the broader the evidence base the deeper insights are likely to be. Throughout the case studies we have tried to emphasise lessons significant to the local cluster but synthesising these would be another valuable next step.

3.1. East Midlands Medical Technologies Cluster (Case Study 1)

Cluster Overview

- **Characteristics and history:** The East Midlands is recognised as a centre of Medical Technologies (MedTech) activity. This forms a substantial part of the wider health and life sciences sector in the region. The cluster covers a range of activities (e.g., product development, contract manufacturing, contract research). It builds on the region's heritage in pharmaceuticals, particularly a legacy of R&D activities formerly conducted in the region by Boots (Nottingham) and AstraZeneca (Loughborough). The East Midlands also has a long history in manufacturing and engineering industries that are a source of skills and capabilities related to the MedTech cluster. Respondents described the strength of the cluster relating to capabilities in being able to bring new product ideas to market rather than relating to a specialisation in any specific therapeutic area.

- **Geography and size:** The best available survey of the size of the cluster is a 2019 report commissioned by MI Health and supported by Midlands Engine (this covers East and West Midlands). This found there were 459 Med Tech business sites in the East Midlands, employing 11,700 people, and with a turnover of £1.9bn. The employment location quotient for the East Midlands is 1.39 (third highest for UK regions) (Hatch Regeneris, 2019). MedTech activity is especially concentrated in Nottingham. Respondents also highlighted related activity in the neighbouring cities of Leicester and Derby. The University town of Loughborough, located in the middle of these three largest cities in the East Midlands, is also an important centre. By LEP area, D2N2 has 272 business sites (around 124 in Nottingham itself), 6,700 employment, and a location quotient of 1.75: Leicester/Leicestershire (including Loughborough) has 102 business sites, 3,600 employment, and a location quotient of 1.88. Respondents also mentioned some activity in the mainly rural parts of the rest of the East Midlands region (including the counties of Lincolnshire and Northamptonshire).

- **Areas of potential future growth:** MedTech is a still maturing, but not newly emergent cluster in the East Midlands. Between 2015 and 2017 MedTech employment grew by 11.6%, the highest rate of any UK region (Hatch Regeneris, 2019, p.34). Respondents expected a steady level of growth to continue and possibly accelerate in the coming years. A potential driver of this future growth is the closer integration of digital technologies into MedTech products. There are also opportunities related to the scaling up of existing MedTech businesses in the region.

MedTech may not be constituted as a formal cluster in the region but is supported at a collective level through the activities of sector organisations such as Medilink (see below). Despite this, some respondents felt that, while there is a critical mass of elements needed for a successful MedTech cluster in the East Midlands, the level of connectivity (or 'glue') between these elements needs to be strengthened.

Core Assets

- **Anchor firms:** A potential gap in the East Midlands MedTech sector is a lack of large 'anchor' firms. The most common exception to this mentioned by interviewees is 3M in Loughborough. Overall, however, the East Midlands cluster has many small and medium-sized companies. Across the East and West Midlands, 65% of MedTech businesses are micro (0-9 employees), 34% are SMEs (10-249 employees), and only 1.5% (a total of 14) are large (over 250 employees) (Hatch Regeneris, 2019, p.11).

- **Higher education and training institutions:** A range of universities in the East Midlands are actively engaged with the MedTech sector. This includes research-intensive institutions the University of Nottingham and University of Leicester that both have Medical Schools. Also important here, however, are universities with strong applied research strengths in areas such as design and engineering. In the East Midlands these universities include Loughborough, Nottingham Trent, De Montfort (in Leicester), and Derby.

    - The Medical Technologies Innovation Facility (part of Nottingham Trent University and part funded through the LEP) has recently been created to strengthen collaboration between industry, academia, and the NHS in the process of bringing MedTech products to market more quickly.

- The regional Academic Health Science Network for the East Midlands has, according to interviewees, become active in supporting MedTech in recent years.

- **Other research and anchor organisations:** Several associations, labs, and government investments exist in the region. These include:

  - Medilink is a Life Sciences Industry Association. It has been operating in the East Midlands since 2004 and has recently expanded to also cover the West Midlands. This is a key organisation in bringing together and supporting MedTech companies in the region. It works closely with other key stakeholders in the cluster.

  - Different types of local NHS Trust across the region are also important actors in the MedTech ecosystem. However, interviewees reported that many MedTech companies perceive it to be difficult to engage with NHS trusts.

- **Support structures:** Biocity is the life sciences incubator established on the former Boots R&D site in Nottingham. It opened in 2003, founded by the two universities, and has grown to encompass several sites across the UK since. It has recently been acquired, is now owned by an independent group (previously by the two universities), who have another incubator facility – MediCity – within the Boots headquarters in Nottingham. It offers a combination of accelerator programmes, physical space/facilities, and investment funds that attracts start-ups from within and outside the region and the new owners have stated ambitious plans for growth.

- **Finance:** Financing for companies was identified as a main issue holding back the growth of the cluster. Funding from the public sector is available and well signposted, although newer, innovative companies may struggle to access these grants. Private sector funding (e.g. venture capital) that would allow companies to grow more quickly (rather than just survive from grant to grant) is however less readily available for MedTech companies in the East Midlands. BioCity does however have its own investment fund and is starting to build a network of angel investors.

UNDERSTANDING CLUSTER GROWTH POTENTIAL

The historical legacy in pharmaceuticals and manufacturing has laid a potentially strong foundation for MedTech in the region, however the sector is clearly still evolving. Initiatives to link industry and academia as well as to incubate startups in this space point to a recognition of the potential for this sector as well as a willingness to invest in its development. While the pool of assets is not particularly deep in this area yet, there appears to be potential for strengthening local capacity, improving access to shared assets, and multiplying cluster development initiatives.

Skills

- **Talent pool:** There is a skilled workforce in the region that is in-part made up of former employees of organisations like Boots and AstraZeneca. Interviewees noted, however, that this experienced component of the workforce is now ageing and approaching retirement. There is therefore an ongoing need for new skilled workers to replace them.

- **Local skills provision:** Interviewees were generally positive about the contribution of regional universities to meeting this demand for future skilled employees. This reflects the diverse strengths of these different institutions. Some, such as Nottingham Trent, were beginning to develop courses that were specifically targeted at supplying graduates to the MedTech industry. Alongside university medical schools in contributing to MedTech, Loughborough's synergy of design engineering and sports science is also a contributor. There is a potential concern about low levels of graduate retention in the East Midlands, but this was not perceived to be a significant challenge by all interviewees.

There are specific issues around highly-specialist skills that will be needed in the MedTech industry that relate to, for instance, new regulatory requirements or the increasing importance of technical fields such as informatics. These are industry-wide challenges that interviewees thought the East Midlands was reasonably well equipped to address. The small MedTech companies may however find it harder to effectively identify and respond to future skill needs.

Knowledge Exchange

- **Firm research and development practices:** The small size of most MedTech companies means that they generally will have only limited internal R&D capacity. Exceptions to this will exist in the form of research-led MedTech companies that are university spin-outs or based in incubators such as Biocity.

- **Knowledge sharing and flows:** Some interviewees thought that a culture of openness and collaboration between companies and other organisations was a strength of the MedTech cluster in the East Midlands. This was attributed in-part to the necessity that smaller firms have to access knowledge, support or resources from outside. A contrasting view, however, was that new MedTech companies were often slower to engage with the wider cluster than other types of life science companies. They, for instance, may not need to access laboratory facilities until later on in their product development process, and prefer to keep a low profile to protect their intellectual property until they have a prototype in place. Hence, engaging with new MedTech start-ups in the region can be more challenging for organisations such as Medilink or Biocity. Some interviewees were aware of instances when MedTech companies in the region had interacted with organisations such as universities outside the East Midlands. This showed a willingness to access knowledge or expertise wherever it is. The small size of firms may, however, limit their absorptive capacity and limit the number of 'gatekeeper' companies there will be in the cluster. Others noted a lack of individuals in the East Midlands with international networks related to, for instance, finance.

- **Knowledge access and cultures:** In addition to the strong culture of openness, interviewees also identified a strong entrepreneurial spirit as a driver for the cluster. The sources of new start-ups in the cluster are varied, including companies started by people from other parts of the healthcare industry or former employees of Boots or AstraZeneca, a small number of university spin-outs, and companies from outside the region attracted to locate in the BioCity incubator. A challenge identified by interviewees is supporting more of these start-ups to scale-up into larger growth businesses. A high proportion (78%) of micro businesses in the Midlands MedTech sector are 10 years or older, compared to 69% in the UK as a whole (Hatch Regeneris, 2019, p.11).

- **Firm network relationships:** Supply chain relationships between MedTech companies are also common in the region. Interviewees thought that a strength of the region was that it had a good representation of companies in every part of MedTech supply chains (e.g., R&D/design, testing, manufacturing). Also important to the cluster are a wider range of supporting companies in related industries such as transport, logistics, professional services. Strong informal networks and more formal networks supported by organisations such as Medilink were also felt to be important. These stakeholder organisations, for instance, encourage companies to interact with universities. Medilink have also been active in hosting online events to bring people from the cluster together throughout the Covid-19 pandemic.

This analysis identified strengths and weaknesses in knowledge exchange in the region. Cultures of openness and collaboration provide a strong foundation for innovative exchange, but these practices were not evenly shared across firms in the region and networks are as likely to be used to access external resources as to connect with more proximate firms. As a result, there are potential opportunities for strengthening connections and facilitating interactions between larger organisations and more established firms and smaller, emerging players.

Governance Networks

- The MedTech sector in the East Midlands has been recognised as an important part of the regional economy in the strategies of the former East Midlands Regional Development Agency and current local enterprise partnerships for Nottinghamshire/Derbyshire and Leicestershire. Some actors have also received support from, for example, Nottingham City Council.
    - The key stakeholder organisations for the cluster (e.g. Medilink, Biocity, Medical Technologies Innovation Facility, etc.) have good relationships and work together effectively to help support and promote the sector. Despite this coordinated leadership, at least one interviewee thought that a stronger overarching vision for the cluster could help its development.
    - A relatively new actor of note in this space is the Midlands Engine Health board that covers both East and West Midlands. This has coincided with Medilink expanding to also cover the West Midlands. There is therefore an opportunity to facilitate collaboration across this wider region. The level of current awareness of the Midlands Engine amongst companies was however questioned. It was felt that this was not yet as strong a brand as the Northern Powerhouse.

In general, it was felt that the East Midlands could be more effective in raising the profile of its MedTech sector at a national level. Leicester and Leicestershire were announced as a Department for International Trade (DIT) High Potential Opportunity (HPO) zone for rehabilitation medicine in 2020.

Discussion: Innovation opportunities and needed support

- **Evolution and market opportunities:** MedTech is an established strength in the East Midlands economy, with potential for accelerated growth in the future as the MedTech sector as a whole continues to evolve. A major area of market opportunities relates to bringing medical and digital technologies more closely together.

- **Resilience:** The MedTech sector in the East Midlands has proved to be resilient over time with strong institutional and infrastructural assets (e.g. Medilink, Biocity) having developed to support the cluster. An important feature of the cluster that has been a constraint on its growth is that not many firms have scaled up to become anchors. Encouraging these firms to scale-up will (alongside supporting new start-up formation) be a key challenge in the future evolution of the cluster along a dynamic pathway.

- Areas of potential support and intervention: Improving the capability of MedTech firms to access finance from private sector investors will be a key step in unlocking their potential to scale-up. Stakeholders also have an important role in continuing to strengthen connectivity between organisations both within and outside the regional cluster. It will also be beneficial to raise the profile of the East Midlands Medtech sector on a national stage.

3.2. Marine and Maritime Cluster in the Solent (Case Study 2)

Cluster Overview

- **Characteristics and history:** The marine and maritime cluster in the Solent region is centred on Southampton and Portsmouth and its ports. The area has been a centre of major maritime and trade activity dating back to Roman times. The Royal Navy has had a presence in the area since 1194. The cluster includes different sectors freight and logistics; naval defense; leisure craft and luxury vessel design, construction, and outfitting; cruise and marine hospitality; ferries and marine transportation; maritime engineering; marine ecology and biotechnology; and maritime law and regulation. However, it could also include firms involved in satellite and communications technologies; advanced manufacturing; materials and composites; fuel and energy development and transport; robotics and AI systems; alternative energy technologies; as well as firms that rely on the port and its logistics networks.

- **Geography and size:** The cluster, which stretches between Poole and Chichester along the coast, is physically large and decentralised. Its marine activities benefit from a double tide due to the position of the Isle of Wight and proximity to European trade routes. As a result, much activity is concentrated around the two largest cities of Southampton and Portsmouth and the deepwater port.

- **Areas of potential future growth:** There is a strong consensus emerging that cluster priorities and innovation are converging on technologies and processes to enable the transition to (1) net zero emissions in shipping and marine activity and (2) the development of autonomous vessels. This evolution has important implications for the cluster as well as to the industries that comprise it. Shipping is notoriously dirty and many of the industries that rely on access to the port and have long contributed to growth - such as manufacturing and petroleum refining - are incredibly carbon intensive. Alternative energy and automation, however, are technologies that intersect with and are impacting most of the diverse sectors and subsectors in the area. The most obvious impacts are on cruise liners and ferry companies seeking economical solutions to respond to demand for cleaner travel and increasingly strict environmental impact regulations (and defense firms seeking similar technology for next generation navy vessels) and firms developing autonomous solutions for crew transfer and navigation. While there are currently few firms in the area dedicated to the specific goals of net zero and maritime autonomy, the fact that they will rely on intersectional technologies may create greater opportunities to establish and define clear areas of excellence, as well as increase opportunities for collaboration and synergies.

This cluster is both mature and evolving. It has a substantial critical mass of firms operating in marine and maritime industries but these industries are incredibly diverse. This breadth of activities is arguably the region's greatest asset and the most significant challenge to cluster development. One observer commented that many firms that engage with maritime activities would not define themselves as marine or maritime firms. Instead, many identify as engineering, manufacturing, system development, or communications firms that may participate in marine supply chains as well as those for other industries. Similarly, because of the variety of clearly marine focused firms - from world-class racing boat designers to cruise ship provisioners to defense contractors - it is very hard to develop a clear narrative about what the cluster specialises in. Many of the industries in the cluster are likely to be impacted by and move into developing solutions for a net zero economy and increasing automation. These are new areas for growth and the cluster has significant growth potential, and could potentially consolidate, along a new evolutionary path.

Core Assets

- **Anchor firms:** The Solent region has a deep ecosystem of anchor firms and organisations in marine and maritime and related industries.
  - The largest firms are in defence (also referred to as the defence primes, e.g., BAE Systems, Thales, Babcock International, Kinetic, QinetiQ, Airbus)
  - Other transport-related firms include Carnival UK (cruise), Red Funnel (ferries), ABP/DWP (ports), and Lloyds Register.
  - There are also some notable and highly innovative smaller firms such as Ocean Infinity, Griffon Hoverworks, Sunseeker, L3 Technologies, Saab SeaEye.
  - Boat builders also represent a significant segment of the cluster and include Oyster Yachts, Cheetah Marine, Meercat Boats, Discovery Yachts and Fairline Yachts.

- **Higher education and training institutions:** The region has strong higher education and research institutions, with three universities (Southampton, Portsmouth, and Solent) as well as several further education colleges. While very few of these provide specialised training in marine and maritime outside of oceanography programmes, they do have considerable strengths in research and scholarship in related areas.
  - The University of Southampton hosts the Southampton Marine and Maritime Institute (SMMI), an internationally recognised centre of excellence for research, innovation and education, with work spanning both the natural ocean environment (marine) and human use of the sea (maritime). It is also home to the Wolfson Unit, which engages in ship model testing, sailing yacht performance and ship design software.
  - The University of Portsmouth hosts the Centre for Blue Governance, which researches aquatic ecosystem and biodiversity management, marine security issues, blue energies, and transportation. The Future Technology Centre, also at the University of Portsmouth, is a space for engineering students to engage with new and emerging technologies, some of which have marine applications and fuel related innovation. The university's Centre for Creative and Immersive Extended Reality (CCIXR) more generally focuses on immersive technologies aimed at the creative industries, but has also been used for marine and maritime simulation and training.
  - The Warsach Maritime School at Solent University is one of the only institutions that offers specialised training in marine and maritime fields, with courses for crew, officers, and captains, as well as marine engineering and electro-technical disciplines.
- **Other research and anchor organisations:** These include the National Oceanography Centre (NOC), which focuses on science and technology development; provides large research facilities and access to data and samples for the benefit of UK science; and generates value and public benefit by supporting public policy development, hazard assessment, ocean governance and regulation, and sustainable development. The Maritime and Coastguard Agency (MCA) is based in Southampton and produces legislation and guidance as well as certification to ships and seafarers. The Royal National Lifeboat Institute (RNLI) in Poole is also considered part of the broader cluster. The South Coast Centre for Excellence in Satellite Applications - part of the Catapult network - is involved in research using satellites for ecosystem monitoring, maritime communications, and autonomous systems.
- **Support structures:** TechSolent, a sector association for firms engaged in technology development, also includes marine and maritime firms among its membership. Barclay's Eagle Lab may provide acceleration and incubation services to marine and maritime startups.
- **Finance:** Firms did not appear to require specialised finance to engage in innovation. Some firms have been eligible for government funding and grants, but uptake is thought to be relatively low.

- **Infrastructure:** Many of the firms in the cluster rely on infrastructure such as the port facilities and access to the marine environment through public and private marinas. Other specialised infrastructure include simulation facilities at CCIXR, hull and vessel testing pools funded by Lloyds Register, sewage barns at a University of Portsmouth facility, and materials testing facilities in various university centres. A partnership between NOC, the Royal Navy, built CEA-Ops a tech park for marine robotics, testing and trialling, and future skills. There is currently a project underway to install 5G communications networks, including on buoys offshore, which will be critical to many businesses and for vessel communications.

While many we interviewed agreed that the region is gifted with a rich array of assets to support research and innovation, there was less consensus about how well coordinated these entities are or how accessible (or utilised) they are by firms in the area. While this may be due to the weakness of cluster governance and coordination mentioned above, it is likely more related to a constellation of other factors, including the fragmented nature of the subsectors in the cluster creating barriers to information sharing, the inherent difficulties that firms face in collaborating with universities and public sector labs, and because firms in the region do not necessarily require or see the value of research collaboration to their businesses. One of the actors we interviewed from a university conceded that where universities are concerned the fault also may lie with the fact that they lack a specific marine and maritime strategy linking the different departments and offerings that could contribute to this space. Another interesting observation is that while the actors we interviewed could confidently list these strong research assets, training programmes, support structures, and infrastructure, few of them were able to articulate how these contribute directly to innovation and growth within the region. While it was clear that there is world-class capacity in the area, it appears that there are opportunities to capture and commercialise this more effectively locally.

UNDERSTANDING CLUSTER GROWTH POTENTIAL

Skills

- **Talent pool:** The Solent region has a strong foundation of skills to support cluster industries. Skills required range from maritime engineering, to crew skills to pilot and maintain vessels, logistics expertise, and skilled building crafts to build and outfit boats. Increasingly, demanded skills include electrical engineering, system design and maintenance, information management and analysis, robotics, among others. In short, the industry is collectively evolving from relying primarily on manual and mechanical skills to requiring more expertise in digital and advanced technologies. A recent Skills Advisory Panel found that out of 240,200 projected net job openings in the Solent LEP area over the next decade at least 39% of all jobs will likely require a level 4+ or higher skills. Level 3 and level 2 skills are projected to account for around 19% and 20% respectively.

- **Local skills provision:** Universities in the area admitted that they did not have many specialised training programmes geared towards the marine and maritime sector, although they do have offerings in marine science, marine law, and engineering. Colleges have responded to employer demands by tailoring programmes to fill local needs. One example is the Centre of Excellence in Manufacturing and Advanced Skills Training (CEMAST) at Fareham College, a state-of-the-art training facility for a range of engineering disciplines. The centre hosts the Civil Engineering Training Centre (CETC) campus, a collaboration of 16 employers who partner with the college in the area of civil engineering to provide a completely different training delivery model for these businesses. The facility provides a fully operational, realistic groundworks and civil engineering training environment that enables students and employers access to machinery, tools, materials and resources to develop work-ready skills and credentials.

The areas where the cluster hopes to expand, such as pioneering alternative fuels and leading innovation in robotics and automation require skills that are in high demand nationally and for which marine and maritime industries must compete with other sectors such as aerospace and automotive. To the extent that shortages in engineering and digital skills are a national phenomenon, collaboration will be required between governments at all levels to enhance training programmes, increase graduates, and support upskilling. Addressing industry-specific gaps would benefit from coordination between firms and regional leadership to engage in a process similar to that undertaken to map skills gaps and propose solutions.

Knowledge Exchange

- **Firm research and development practices:** Many firms were viewed as research active and involved in developing cutting edge technology and design. The large defense primes and more agile smaller firms (e.g., Ocean Infinity, Griffon Hoverworks, Sunseeker, L3 Technologies, Saab SeaEye) were most frequently cited as innovators that invest significantly in R&D. Beyond this, little is known about the practices of smaller firms.

- **Knowledge sharing and flows:** Despite the critical mass of firms in the industry and generally high levels of innovation, networks of knowledge exchange appear to be relatively weak. The most innovative firms that we interviewed reported that they have engaged in strategic partnerships, have worked together in collaborative bids, and have supply chain relationships with other firms in the area. However, they also reported that these relationships did not occur very frequently or by design.

- **Knowledge access and cultures**: While no one cited specific resistance to knowledge exchange it was clear that the region was also not characterised by a culture of openness and collaboration. Some firms reported challenges with working with smaller firms and consortia to capture grants. While universities were often mentioned by actors involved in the governance side of the cluster, firms also found those partnerships only infrequently successful. Here they cited different priorities and timelines and blue sky type research objectives as barriers.

- **Firm network relationships:** There is a perception that most supply chain relationships are with firms outside of the cluster. Interfirm partnerships were either rare or not widely publicised (and so unknown to respondents). Universities reported numerous relationships with firms but admitted that it was not always easy to bridge the divide between academia and industry and that firms had very different capabilities to engage.

There is a clear opportunity here to develop more insight into firm R&D practices, particularly as they vary by subsector, and to find ways to improve knowledge circulation. The specific challenges surrounding knowledge exchange, diffusion, and adoption will likely vary by marine and maritime subsector. As such, efforts to increase and share understanding about innovation in the sector and building out business networks, as well as how best to support the relationships that are developing organically (between local firms or those outside the area) may be helpful to increase the success rate of these activities.

Governance Networks

- **Cluster development networks:** There is no single leading cluster organisation but several. So far, neither of these relatively new initiatives has succeeded in generating decisive buy-in from the cluster community or overcoming the fragmentation and lack of narrative that characterise the marine and maritime sector in the region.
    - Maritime UK Solent, led by the Solent LEP, is quite nascent but has large ambitions to bring together marine and maritime actors in the area using the LEP's already established expertise in innovation and regional development to stimulate synergies.
    - Solent Maritime Enterprise Zone (MEZ) was established in December 2019 as an umbrella organisation comprising a consortium of the Royal Navy, industry (including small and medium sized enterprises), government and academia working collaboratively to establish a centre of excellence for maritime research, innovation, education, skills and training. It, too, has ambitions to build and consolidate networks, facilitate information exchange, and to tackle collective challenges and opportunities.
    - Recently, Maritime UK Solent, the MEZ, and the Connected Places Catapult launched a collaboration called the Maritime Innovation Gateway (MIG) but too early to tell whether that will be an effective rallying point for business in the cluster.

There is clearly a potential role for a cluster convenor to lead the process of defining the cluster and establishing a common narrative to underpin future growth. Opinions about the success and potential of the existing organisations vary widely. Some actors were pessimistic about any sort

of cluster initiative. Others defined the cluster purely in terms of the boundaries, membership, and objectives of one or the other. Some saw a role for both initiatives while others expressed disappointment in the progress of one while favoring the prospects of the other. This pronounced lack of consensus demonstrates that despite strong industrial foundations the emergence of cluster governance is neither uncontested nor inevitable. It is likely that over time a division of labour will emerge between the two presumptive cluster organisations. It is also possible that the evolution of FreePort negotiations and implementation will accelerate and create opportunities for a consolidation of leadership. Under these conditions, it is probably unwise to "pick winners" and support one organisation over the other. However, where possible, policy should encourage collaboration and seek to avoid duplication and risks of "networking fatigue" that could work against both initiatives.

Discussion: Innovation opportunities and needed support

- **Evolution and market opportunities:** Respondents were quite unanimous in their assessment that the twin issues of net zero and autonomy/AI were both great opportunities and challenges that firms will have to adapt to in order to remain competitive, particularly as environmental and labour regulations evolve. One factor that could also play a transformative role in cluster evolution is the proposed Solent FreePort. Freeports are designated special economic zones around ports and airports where goods arriving from abroad are exempt from taxation. The sites of eight new FreePorts, including in the Solent, were announced in the May 2021 budget. These are intended to consolidate hubs of trade and investment in the post-Brexit economy, promote regeneration and job creation, and create hotbeds of innovation. While it is currently very early days in the proposal process and actors involved are not yet clear on how it will impact cluster development, the FreePort initiative appears to be a catalyst in bringing together diverse actors in the area to construct a vision for regional development in which marine and maritime, logistics, and emerging technologies are likely to play a central role.

- **Resilience:** Failure to adapt to shifting technological regimes thought to be the most important threat to the region. The area had already (long ago) lost its shipbuilding industry but actors believe that they have many strengths in the marine and maritime cluster and that they will be able to leverage the FreePort and government resources to navigate the transition.

- **Areas of potential support and intervention:** While there are lots of areas that could be improved, the two most significant appear to be plugging skills gaps and increasing the scale and effectiveness of local networks. Industries will not be able to transition to emerging areas, or remain competitive in existing niches, without a reliable pipeline of talent, particularly with engineering and digital skills. Respondents also suggested that networks within the region could be strengthened to better circulate information about innovation activities and potentially build synergies and partnerships. There is also opportunity to connect with other marine and maritime clusters around the country. Such interventions may also help to coalesce a shared identity of what the marine and maritime cluster in the Solent is and what its unique offerings are to raise its profile nationally and beyond.

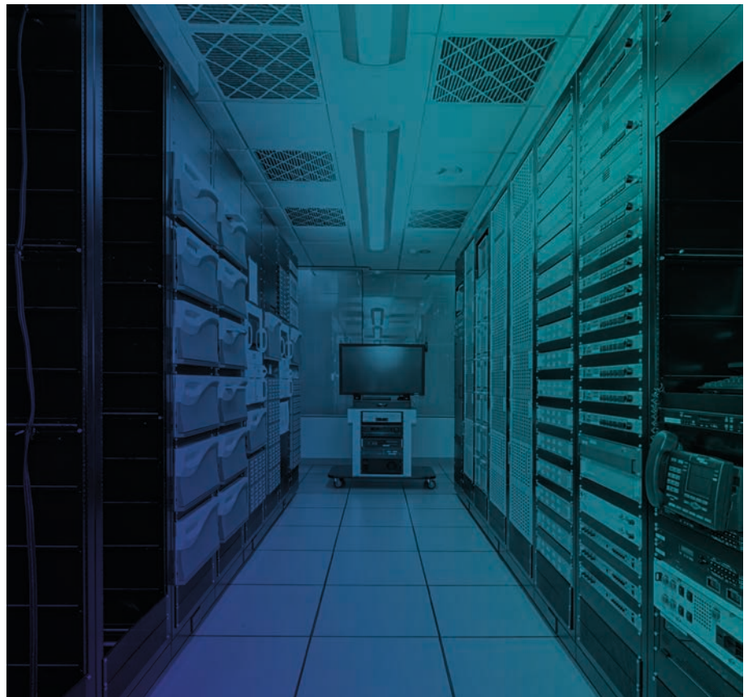
3.3 Belfast Cyber Cluster (Case Study 3)

Cluster Overview

- **Characteristics and history:** Belfast is recognised as a UK cyber hub, providing products, services, and R&D for the cyber security sector. Respondents highlighted the strong international interest and FDI flows, particularly from the US, as important in the growth of the local sector to date. The Centre for Secure Information Technologies (CSIT), located at Queen's University Belfast and founded in 2009, provided an important R&D catalyst regionally and promoted knowledge exchange and research commercialisation both with local industry engagement focus, and through relationships with other international cybersecurity hubs. Related technology specialisms locally also include fintech and insurance industries, both of which have a strong interest in cybersecurity applications. The sector is acknowledged as strategically important to the Northern Ireland (NI) economy, and ambitious growth targets have been set through the NI Executive, the NI Department for the Economy and Invest NI.

- **Geography and size:** Centred on around 100 firms. The majority of firms are located in relatively close proximity within the Belfast city area, however there is some related activity in the sector across Northern Ireland. The NI sector in total employs around 2,300 (FTE) cyber security professionals and currently generates £161 million per annum in Gross Value Added (salaries) to the NI economy (NI Cyber Security Snapshot, 2021).

- **Areas of potential future growth:** Respondents felt that the cybersecurity sector was still in an early stage of development and that it was still experiencing a phase of rapid growth. However, they also saw growth potential in more sophisticated applications of machine learning and artificial intelligence.



UNDERSTANDING CLUSTER GROWTH POTENTIAL

Over the last decade Belfast has become a clear cyber security hotspot, both within the UK and, as signified by FDI flows, globally. Despite its impressive growth, respondents felt that Belfast was still a relatively small place. That government, industry, and academia are well-connected and the pool of individuals in each is small was seen as an advantage to networking and knowledge exchange. Maintaining that sense of connectedness and community will be important as the sector evolves. Respondents pointed to significant growth potential, given growing global interest in the sector's products and services, and the local strength in R&D capabilities. Locally ambitious job growth targets have been set. Sustaining the talent pipeline was highlighted across interviews as key to maintaining both growth and not jeopardising the strong culture of collaboration and knowledge sharing within the region.

Core Assets

- **Anchor firms:** Firms include global cyber security firms who have operations in the region (such as IBM Security, Proofpoint and Rapid 7), firms who have sited their cyber security services operations in NI (such as Allstate and Citi), and locally grown firms (such as B-Secur and Metacompliance) (Invest NI, 2021). FDI is an important shaping factor and US headquartered firms account for 62% of all cyber security employment in the region. Large foreign insurance and fintech companies, such as Allstate, Liberty, Citi, and Aflac, are also important anchors to the cluster because they have significant cyber divisions. Larger tech firms like Microsoft, Nvidia, and Paypal also have teams in Belfast. There are also a number of locally grown NI firms accounting for 21% of cyber security employment (NI Cyber Security Snapshot, 2021).

- **Higher education and training institutions:** There is a strong local talent base, underpinned by NI's strong performance in STEM education, its Universities and growing private sector skills providers. Respondents reported an attractive local workforce as a factor in the hub's development. Educational providers include Queens University and Ulster University (offering dedicated Cyber Security courses at PhD, MSc and Higher Apprenticeship Level), a bespoke programme offered by Belfast Metropolitan College and several private sector initiatives such as the Microsoft Skills Academy (NI Cyber Security Snapshot, 2021).

- **Support structures:** There is a supportive ecosystem attracting large international firms, facilitated through bodies such as Invest NI and the externally facing activity of NI Cyber.
  - NI Cyber is a membership body for organisations operating in the cyber sector within Northern Ireland and facilitates communication, collaboration and providing representation for the sector externally.
  - CSIT provides research and development capability and a focus on engaging with industry, providing a draw for additional collaborative R&D to the region.
  - Invest NI is Northern Ireland's regional economic development agency, which provides general business support and targeted industry promotion.

- **Finance:** The development of the cyber cluster has been supported by investment by the UK and Northern Ireland governments. CSIT has secured funding from Innovate UK, the EPSRC, and Invest NI. These partnerships have supported research and commercialisation and programming to support cyber firms in the cluster. Both Invest NI and Innovate UK offer R&D support for firms. The sector has also attracted VC and private capital funding. While the cluster is generally well-resourced, there are gaps in early-stage funding and in funding to support activities other than R&D.

- **Infrastructure:** Catalyst (formerly Northern Ireland Science Park) is a science park located in the Titanic Quarter, which bills itself as the epicentre of the Northern Ireland technology sector and hosts CSIT and many cybersecurity firms. This campus enables access to facilities and state of the art telecommunications infrastructure. Catalyst as an organisation is also active in promoting the tech industry in general and supporting entrepreneurs.

Despite the relative youth of the sector, it has a deep pool of supportive assets - from higher education to robust cluster networks. However, there is a sense that while there is a wealth of support, not everyone knows what is available and is able to access it. One respondent characterised the area as having strong pillars but lacking an effective convenor coordinating the different aspects of the ecosystem. The challenge is finding funding to support and sustain that role and while they acknowledged that industry could contribute, this support would probably most effectively and reliably be provided by the government.

Skills

- **Talent pool:** Respondents pointed to a strong base of local talent with free movement between firms offering excellent opportunities for learning and progression. A number of innovative and responsive new training initiatives were seen as making progress in sustaining the talent pipeline although this remains a challenge.

- **Local skills provision:** The Northern Ireland Executive has set an ambitious growth target of 5,000 cybersecurity jobs by 2030, more than doubling current levels. Respondents pointed to the need for greater recruitment into NI in addition to continued efforts to bolster training initiatives and awareness of cyber as a profession within NI.
    - CSIT provides a Masters programme in cybersecurity as well as a PhD programme.
    - The Assured Skills Programme is a short, demand-led, pre-employment training programme, which is fully funded by the Department for the Economy, to upskill individuals to give them the training required to compete for planned job vacancies in new foreign direct investment (FDI) companies and expanding businesses.

Sustaining the skills pipeline was raised across respondents and was seen as a critical factor to continued growth. The high level of FDI has had contradictory effects on talent supply. On one hand, foreign firms have invested a lot in skills and training, which has raised the quality of the talent pool. On the other hand, there is now more competition for talent and labour and training costs are rising. This has raised questions about how the industry can work with education to ensure that there is a sustainable skills pipeline responsive to evolving technical needs. Programmes like Assured Skills are one response as are other forms of educational outreach. However, there is potentially more to be done to ensure that skills do not act as a cap on cluster growth. Alongside current innovation to meet skills gaps, respondents mentioned the potential for greater diversification in other digital technology specialisms to bolster the strength of the region.

Knowledge Exchange

- **Knowledge access and cultures:** Respondents reported that the hub was small enough to be well connected, with networks underpinned by a strong culture of collaboration. They described an environment of coopetition where business rivals interact frequently and share information even if they do not have formal partnerships. Significantly, even foreign firms report these kinds of relationships which speaks to their embeddedness and engagement within the cluster. NI Cyber plays a role in facilitating these connections through events and other activity, however there was a feeling that additional dedicated leadership/ facilitation capacity would be beneficial for growth.

- **Knowledge sharing and flows:** Given its historical origins in CSIT, the cluster began as a highly academic network that gradually spun out and expanded to include private sector firms. There is a relatively robust tradition of university-industry interaction where academics benefit from having access to a pool of industry experts that they can call upon to join or validate research. However, there are opportunities to deepen these kinds of interactions as the cluster grows. It is significant that firms that do not currently have strong relationships with higher education are aware of their research and role in the cluster and would consider partnerships if and when opportunities arise. Respondents reported that the workforce was relatively mobile, but tended to stay within the region, creating a beneficial sharing of knowledge and skills.

The Belfast cybersecurity cluster hosts a community of firms that are informally well-connected, although the extent of their formal business relationships is unclear. Foreign firms appear to be highly engaged in the cluster and both rely on and contribute to the flow of talent between firms in the area. Several respondents commented on the strength of the local knowledge pool but noted that the cluster would benefit from stronger connections with other cybersecurity ecosystems to drive innovation.

Governance Networks

- **Cluster development networks:** There are a number of cluster convenors which succeed in getting the engagement of the cyber security community within NI, including NI Cyber and OWASP Belfast. The hub is also well connected globally through NI Cyber's and CSIT's international engagement activities (notably through Global EPIC).

- The NI Executive and The Department for the Economy (DfE) recognise the importance of the sector and provide a strategic vision, such as in the DfE's '10X Economy' economic vision for innovation in NI over the next decade.

Cluster networks in Belfast cyber are useful from both a knowledge exchange and business promotion perspective. Respondents noted that NI Cyber is important for growing the international reputation of the cluster and facilitating international business connections. Similarly, NI Cyber and CSIT also offer connections to accelerators and resources based in London and the broader UK cyber ecosystem. Others acknowledge the benefit that cluster initiatives provide but note that they still have a local industry association feel to them. There is a sense that networks are strong foundations, that they're working hard, but that there is still a lot of potential for them to help grow the cluster. For instance, there might be potential for extending its capacity to facilitate trade deals and to function as a vehicle for joint ventures. Governance networks could be more effective at interfacing with Innovate UK to promote opportunities for firms to access funding and participate in programmes. Finally, while respondents recognise the functions that NI Cyber plays there is also some acknowledgement that there is often no formal role within the organisation to do, for instance, business mentoring or promotion and that it is currently more of a voluntary organisation. This means that it relies on engaged individuals who may not be able to sustain that kind of involvement over the longer term. Continuing with this less formal model may challenge the resilience of the organisation, its offering, and its ability to support the cluster.

Discussion: Innovation opportunities and needed support

- **Evolution and market opportunities:** As the UK's Cyber Security Sectoral Analysis (2021) highlights, cyber security is a growing and diversifying sector and a "jewel in the UK's economic crown" (UK Cyber Security Sectoral Analysis 2021,p.6). Respondents highlighted both growing domestic and international demand for products and services and sectoral analysis shows a doubling of investment in the sector year on year (UK Cyber Security Sectoral Analysis 2021,p.6). Respondents pointed to diversification opportunities in a variety of other technology specialisms such as fintech, machine learning and AI.

- **Resilience:** Respondents were unanimous that maintaining a sustainable talent and skills pipeline was crucial to meeting ambitious growth targets. The lack of consistent funding for NI Cyber is also seen as a potential threat as the organisation relies heavily on volunteers and engaged individuals to run core initiatives. Brexit was also identified as a potential threat, and opportunity, as uncertainty creates business risk that may influence investment decisions. This is particularly relevant as the sector relies heavily on FDI that may be sensitive to unknowns associated with Northern Ireland's unique position.

- **Areas of potential support and intervention:** There is a focus on building critical mass of firms connected within the ecosystem and developing the capacity of cluster organisations to promote the industry both domestically and abroad. Increasing support and resourcing to cluster organisations could help this objective as well as consolidate and formalise structures

4. CLUSTER GROWTH POTENTIAL FRAMEWORK

The literature surveyed in section 2 situate key concepts and informed the framework that we developed to explore cluster growth potential in regions across the UK. We envision this process could be led by policymakers and their delivery agencies, in partnership with cluster associations or leaders where possible and appropriate.

There are a variety of indicators that can be used to gauge cluster success and maturity. While these can be useful, we are cognisant that for some clusters data can be difficult to access, whether because the boundaries of the cluster do not conform to geographies at which data is collected or because the cluster contains industries and activities for which finding appropriate Standard Industrial Classification (SIC) codes is difficult. Furthermore, care must be taken in interpreting the significance of indicators, particularly in comparing clusters to one another, as data is not always measured the same way across cases. For these reasons, while we incorporate indicators into the interpretive framework, we recommend that they be used to assess internal cluster evolution by looking at change over time wherever possible rather than as a comparative device.

The most significant insights about cluster growth potential will come from interviews with leaders and principal actors within each cluster (using the provided topic guide), the findings of which will be synthesised by policymakers and their delivery agencies drawing on their experience with a variety of related clusters and with the aid of the interpretive framework. Cluster leaders from local networks should also contribute to the evidence base. These might include the directors of any cluster or industry associations, key players in anchor organisations such as public research organisations, higher education, government agencies, or science/technology parks.

In this section, we present a topic guide to help structure interviews. The sections explore the characteristics and past development of the cluster, its current resource base and knowledge exchange practices, and its potential for future development. The questions themselves roughly map to the themes explored in the deep dive. The topic guide is followed by an interpretive framework, which provides guidance on how to structure cluster case studies using results from the interviews and integrate key metrics.

4.1. Topic Guide

We envision this as a guide to facilitate discussion and so have included prompts and additional questions to give interviewers the option to ask subjects to elaborate on their answers and to give more detail about the kinds of information we might elicit from these sessions. Not all prompts/questions will be relevant or need to be answered to yield useful insights. Time constraints and the area of expertise of the respondent should be taken into consideration. Often, respondents will signpost existing research - e.g., reports or evaluation exercises - that are useful for providing background information, data, or more detail than they have time to elaborate in the allotted time. Where possible, relevant findings from these sources should be incorporated into the synthesis and can be used to provide more detailed prompts in future interviews.

Part 1 - The foundations and defining features of the cluster

In this section, we aim to understand the history and main features of the cluster

QUESTIONS	PROMPTS / SUPPLEMENTARY QUESTIONS

Q1 – Cluster characteristics
How would you characterise what this cluster is and does?
	• What kinds of activities is this cluster engaged with?
	• What does it make/sell/provide? For whom?
	• Is there a specialist market(s) that this cluster has a competitive advantage in? Please elaborate.
	• What role does this cluster occupy in national/global production and supply chains? Does it provide goods/services to end users, intermediary goods/services, does it rely on inputs from elsewhere?
	• What technologies (if any) form the basis of the cluster's competitive advantage?
	• Would you consider this cluster:
	  • emerging?
	  • developing?
	  • mature?

Q2 – Cluster history How has this cluster evolved?	• Why is the cluster there? Is it possible to identify any key catalysts or drivers in its emergence? • (How) does this cluster represent a change in path from previous industrial structures in the region? • Describe any key moments/events (if any) that catalysed cluster growth or evolution. This might be changes to the industry, knowledge base, technologies, regulations, or changes in the market that created opportunities for local firms; or it could be the arrival of a new firm/ lab/support organisation; or any other notable event.
Q3 – Geography & Size How would you define the cluster in terms of where it is physically located/concentrated and its size?	• How would you define the geography of this cluster? • In your own words explain how you would describe the area that it occupies (this might be with reference to specific administrative units or something more vague such as "the area around X" – the description does not have to be precise but specific reference points are useful). • In your view, has the cluster reached a critical mass? How so? • Approximately how many firms are currently active locally in the industries you consider to be part of the cluster? Note that this does not have to be precise, and an estimate will do (i.e. tens, a hundred, closer to a thousand?) • If that is difficult, would you characterise the cluster as large? Small? On what basis are you making this assessment?
Q4 – Priority firms and people What firms, or people, are the key actors in the cluster?	• List any 'anchor' firms or key individuals that you consider to be foundational to the emergence and growth of the cluster" – they may be large, customer firms; large employers who train their people well; or important movers and shakers in the market. • What makes those firms and people the most important? • Are there many second-generation firms of the same entrepreneurs
Q5 – Market potential and innovation opportunities What are and where are opportunities for growth and innovation?	We explore this question in more detail later in the interview but at this stage it is useful to get general impressions of cluster growth potential: • What broad opportunities are there for cluster growth? • Are there triggering factors to be alert to

Part 2 – Current capabilities related to innovation opportunities

This section explores different aspects of the current cluster to explore advantages and understand potential gaps.

QUESTIONS	PROMPTS / SUPPLEMENTARY QUESTIONS
Q6 – Firm sizes and characteristics Can you characterise the mix of firms that currently populate the cluster in terms of size, age, etc.?	• Are firms that have entered the cluster as it has grown mainly: a. small or start-up companies; b. spin-out companies from universities; c. spin-off companies from other companies; d. companies that started in other industries but have diversified into this industry; e. companies that have relocated from other regions; f. branches of companies headquartered in other regions g. other? • What are the synergies within the business community that make it possible to work together as a cluster?
Q7 – Firms (or businesspeople) contributing knowledge Which firms (or businesspeople) are most active in contributing to the development and dissemination of knowledge in the cluster?	• How innovative are they? Are they active in R&D? • How have they generated the new knowledge? How have they shared it? • Do the leaders in the cluster have a culture of 'openness'? How so?
Q8 – Non-firm institutions contributing knowledge What role do local universities or colleges play in developing and disseminating knowledge in the cluster?	• Specifically which universities and colleges, and which departments, institutions or leaders? • What kinds of knowledge are they involved in creating? • How has this influenced cluster development and innovation.
Q9 – Knowledge sources Are firms actively seeking out local or external sources of knowledge for their innovation processes?	• Are there any significant sources of external knowledge that are core to the cluster's success? Think of key strategic partnerships, universities/colleges/labs in other places. • If the answer to the previous question is that the strengths of the local HEI knowledge base are not that relevant to the local business cluster, explore whether there are other sources being drawn on, e.g. consultancies, professional advisors, a cluster management network, or whether non-firm sources of knowledge are not as important for this cluster's development
Q10 – Knowledge flows How is knowledge disseminated and transmitted in the cluster?	• How accessible is the knowledge to firms in the area? Do actors share knowledge frequently or easily? • Is knowledge shared through any cluster wide activities? Is it 'managed'? • Are there actors that are left out of or have difficulty accessing knowledge exchange networks? Who, and why?
Q11 – Firm network relations Would you say that a culture of collaboration and/or knowledge exchange between companies and with other organisations (e.g., universities, etc.) has developed within the cluster	How do actors typically interact with one another? a. supply chain linkages with other local companies inside the cluster b. supply chain linkages with companies outside the cluster c. informal networks between companies inside the cluster d. formal networks/associations e. collaborations with local universities or research centres f. collaborations with universities or research centres in other regions g. other?

QUESTIONS	PROMPTS / SUPPLEMENTARY QUESTIONS
Q12 – Cluster development networks Are there key people or networks (formal or informal) related to cluster development, management, strategy, best practices?	• Who leads those networks/initiatives? • Do any events/initiatives stand out as important for cluster development? Please describe them and how they influenced cluster growth.
Q13 – Skills (Talent pool) Does the cluster have a competitive advantage in specific skill sets?	• What skills are most important to innovation in the cluster? • How easily are these positions filled? • What labour force skills do the businesses require and are there common skills shortages issue that the cluster can strategise on?
Q14 – Skills (Sources) To what extent are skills locally developed versus sourced externally?	• What local education or training programmes are most important for skills development (if any)? • If skills are sourced externally, where from?
Q15 – Support structures What are the key supporting organisations and their roles in the innovation process?	Name the most significant actors and classify them, if possible/applicable, by the following categories: a. incubators/accelerators (public or private) b. cluster development organisations c. economic development agencies/departments d. industry/professional associations e. charitable and civic organisations f. other?
Q16 – External finance for growth or innovation What have been the most important sources of financing for the growth of the businesses?	• What finance sources (public or private sector) have been most important? • To what extent are these sources local? If they are not, how easily can firms in the cluster to these sources, for instance, via well-connected individuals? • How accessible are these for firms in the cluster?
Q17 – Infrastructure Is any specific or specialised (public or private) infrastructure a significant source of competitive advantage?	Probe for the relevance of: a. specialised lab equipment b. testing facilities c. transportation infrastructure d. communication networks e. other?

UNDERSTANDING CLUSTER GROWTH POTENTIAL

Part 3 – Innovation opportunities

Looking forward, what opportunities are there for future cluster growth and how well is it positioned to capitalise on these?

QUESTIONS	PROMPTS / SUPPLEMENTARY QUESTIONS
Q18 – Evolution How do you think the cluster will evolve in the medium- to long-term?	If not mentioned probe in relation to: a. size and composition; b. technological focus; c. markets (including downstream applications)
Q19 – Market opportunities How do you imagine that the market opportunities for this cluster will evolve over the medium- to long-term?	What domains of activity might become more/less important and how well positioned is the cluster to capitalize on these?
Q20 – Support Will the cluster achieve the vision by itself or might it need some support?	If not mentioned probe in relation to: 1. research and development capabilities (public or private); 2. supply of labour with relevant skills and provision of relevant training; 3. sources of funding for new or existing companies; 4. other support from national or local government/economic development agencies; 5. access to new customers or suppliers (local, national, or international); 6. local leadership or strategic vision. 7. Importance of the infrastructure?
Q21 – Resilience What contexts, if any, threaten cluster evolution along the lines described above?	Focus on pinch points, bottlenecks, vulnerabilities (if any).
Q22 – Leadership Does the cluster have strong leadership and a strategic vision for its development over the medium- to long-term?	To what extent are leading actors thinking collectively about opportunities?

WE HAVE COME TO THE END OF THE INTERVIEW, DO YOU HAVE ANYTHING YOU WOULD LIKE TO ADD REGARDING THE CLUSTER, ITS DEVELOPMENT AND OR FUTURE PROSPECTS WHICH HAVEN'T BEEN COVERED?

---------- END ----------

4.2. Interpretive Framework

This chapter situates the questions from the topic guide in a framework to write up case studies. For each bullet point, summarize findings that emerged from the questions indicated.

The sections in the suggested framework are:

- Cluster overview;
- Core assets;
- Skills;
- Knowledge exchange;
- Governance networks; and
- Discussion: Innovation opportunities and needed support

Some notes on applying the framework:

- As interview qualities and case contexts will differ, not all questions will be relevant in each case. Similarly, information relevant to the topic heading may have been discussed in response to questions not listed. Please consider this a set of guidelines and not a rigid framework.

- Note that data from secondary sources mentioned in the interviews should be included where appropriate to add detail and should be cited.

- Also note that some findings will be repeated across bullets. Skills, for example, tend to come up in several places. This is to be expected and should be considered indicative of significant themes - where a consensus has emerged about either core strengths or areas that might benefit from intervention or support.

- In each section, we have included some metrics that might be useful for situating the cluster. This data can be collected for the ecosystem more generally or, where feasible, for the cluster/relevant sectors. Where possible, comparisons should be made over time (rather than with other clusters) to establish rate of change and growth potential. We recommend that all data be interpreted in the context of the qualitative findings. Slowing growth on some metrics could indicate that the cluster is changing technological trajectories because it is highly innovative and that measures need to be adapted or expanded.

- Each section concludes with a “self-assessment” section where investigators can synthesize their observations using the guidance provided.

Cluster overview

Overview metrics

The most useful metrics here will establish basics about the business base of the cluster these can include:

- Number of firms in industries related to the cluster, and growth over time;
- Data on entrepreneurship and startup rates;
- Data on average ages of firms, firm lifespans, and churn;
- Total employment in the cluster and changes over time;
- Where relevant, these metrics can be disaggregated by industry or sector to demonstrate emerging areas of growth.

- Characteristics and history: Q1 (How would you characterise what this cluster is and does?) and Q2 (How has this cluster evolved?).

- Geography and size: Q3 (How would you define the cluster in terms of where it is physically located/concentrated and its size?) and Q6 (Can you characterise the mix of firms that currently populate the cluster in terms of size, age, etc.?).

- Areas of potential future growth: Q5 (What are and where are opportunities for growth and innovation?)

- **Self-assessment:** Reflect on the extent to which this is a cluster based on the findings presented in this section. Does the level of activity in this area seem significant? How established is the cluster? Does it have growth potential? Is there a coherent shared vision for the future of the cluster - if yes, describe.

Core assets

Core assets metrics

Metrics in this category will capture fundamentals about cluster assets. Note that some of these categories do not lend themselves well to quantification (e.g., infrastructure does not have an easy or generic metric).

- Additional data on the business base, such as firm sizes, prevalence of foreign owned firms;
- Research funding to universities and colleges (e.g., HERD, total funding from government, etc.);
- Number of firms in relevant incubator or accelerator programmes;
- Data on firms participating in government R&I funding programmes;
- Data on VC deals or private equity rounds, where appropriate.

- Anchor firms: Q7 (Which firms (or businesspeople) are most active in contributing to the development and dissemination of knowledge in the cluster?) and Q4 (What firms, or people, are the key actors in the cluster?).
  - [Use sub-bullets to list different key actors and roles]
- Higher education and training institutions: Q8 (What role do local universities or colleges play in developing and disseminating knowledge in the cluster? Specifically which universities and colleges, and which departments, institutions or leaders?).
  - [Use sub-bullets to list different key actors and roles]
- Other research and anchor organisations: Q8 (Are there any significant government labs and research organisations? Government actors?).
  - [Use sub-bullets to list different key actors and roles]
- Support structures: Q15 (What are the key supporting organisations and their roles in the innovation process?)
  - [Use sub-bullets to list different key actors and roles]
- Finance: Q16 (What have been the most important sources of financing for the growth of the businesses?)
- Infrastructure: Q17 (Is any specific or specialised (public or private) infrastructure a significant source of competitive advantage?)
- **Self-assessment:** Reflect on the extent to which the assets listed are suitable for the direction of evolution and to deliver on the development vision for the cluster. What are the main gaps and opportunities? Which actors could or should be supported or involved in co-designing initiatives to address these gaps?

Skills

Skills metrics

These measures focus on the quality and composition of the talent pool.

- Educational attainment and qualifications profile (this is usually available at the regional scale but may be difficult to disaggregate by relevant sectors);
- Occupational profiles;
- Labour demand statistics and job projections;
- Graduate retention rates;
- Average job tenure;
- Graduation rates from relevant/specialised degrees or training programmes;
- Job creation targets.

- Talent pool: Q13 (Does the cluster have a competitive advantage in specific skill sets?)

- Local skills provision: Q14 (To what extent are skills locally developed versus sourced externally? What local education or training programmes are most important for skills development (if any)? If skills are sourced externally, where from?)
- [Use sub-bullets to highlight specific programmes or initiatives]
- **Self-assessment:** Reflect on the skills status quo and on existing and emerging gaps. Consider which types of programmes should be emphasised (e.g., specialist skills training for the cluster, general skills that could be developed, leadership or management skills training, etc.) and which institutions are best suited to delivering these. Also note differences in timelines in terms of programme implementation and workforce impacts. What interventions are needed in the short term, and what options exist or could be created, and how do these differ from longer term needs?

Knowledge exchange

Knowledge exchange metrics

Knowledge flows and networks are very difficult to measure in clusters and so qualitative methods will generally provide more targeted insights. Because not all forms of knowledge exchange are reported or available by sectors or at relevant geographies, measures may not capture the vigour or vibrancy of knowledge flows and diffusion in a region. Where geographies align, the UK Innovation Survey and Innovate UK have data on:

- Business collaboration practices;
- Collaborative research;
- Sources of innovation

- Firm research and development practices: Q7 (Which firms (or businesspeople) are most active in contributing to the development and dissemination of knowledge in the cluster? How innovative are they? Are they active in R&D?) and Q9 (Are firms actively seeking out local or external sources of knowledge for their innovation processes?)
- Knowledge sharing and flows: Q10 (How is knowledge disseminated and transmitted in the cluster?)
- Knowledge access and cultures: Q10 (How accessible is the knowledge to firms in the area? Do actors share knowledge frequently or easily? Is knowledge shared through any cluster wide activities? Is it ‘managed’?) and Q7 (Do the leaders in the cluster have a culture of ‘openness’? How so?) and Q11 (Would you say that a culture of collaboration and/or knowledge exchange between companies and with other organisations (e.g., universities, etc.) has developed within the cluster?)
- Firm network relationships: Q11 (How do firms typically interact with one another?)

- **Self-assessment:** Reflect on the practices of knowledge production and exchange as well as cultures associated with sharing knowledge. Are there any gaps, challenges, or bottlenecks? Particularly explore whether there are barriers to knowledge exchange specific to certain segments of the economy (e.g., between higher education and firms, between firms of different sizes, between firms in different sectors, etc.).

Governance networks

Network metrics

As with knowledge exchange, networking practices are difficult to measure and are more effectively assessed using qualitative methods. Some potential indicators may be insightful, if available:

- Existence of relevant local networking groups and highly connected individuals;
- Number of members in cluster associations;
- Attendance at networking events;
- Number of related networking events.

- Cluster development networks: Q12 (Are there key people or networks (formal or informal) related to cluster development, management, strategy, best practices? What are their roles?) and Q22 (To what extent are leading actors thinking collectively about opportunities?)
  - [Use sub-bullets to highlight key networks/actors, if more than one]

- **Self-assessment:** Reflect on the state of evolution of cluster development networks and leadership. Are the networks that presently constitute the cluster suitable for the direction of evolution? Note any gaps but also the nature of the relationship between cluster organizations and leaders, if more than one is currently active. Do cluster leaders and their networks have a coherent vision for cluster evolution and are they able to articulate coherent goals? What is the primary focus of their development efforts and their ambitions - is it localised, enabling cluster growth, or externally oriented seeking connections to national or global networks? Do the existing networks have the capacity to enact their visions?

Discussion: Innovation opportunities and needed support

Metrics

Relevant metrics are comparable to those typically sought by Innovate UK for assessing the scale and growth rate of innovation opportunities, the market access through innovation, and the additionality of public support.

- Size and growth rate of the domestic and global markets that the cluster aligns to;
- Evidence of the suitability of the cluster's innovation capabilities to the needs of the future market;
- Data points showing firms have skin in the game and could go further, faster with public support

Conclude by assessing the future potential of the cluster.

- Evolution and market opportunities: Q18 (How do you think the cluster will evolve in the short- to medium-term?) and Q19 (How do you imagine that the market opportunities for this cluster will evolve over the medium- to long-term?)

- Resilience: Q21 (What contexts, if any, undermine cluster evolution along the lines described above?)

- Areas of potential support and intervention: Q20 (Will the cluster achieve the vision by itself or might it need some support?) Is there a clear case for intervention?
  - ○ [Use sub-bullets to list multiple areas]

Concluding self-assessment:

Given the findings of the preceding sections, how well equipped is the cluster (in terms of assets, skills, knowledge base and knowledge exchange, and governance networks) to leverage and evolve to seize future market opportunities and manage challenges?

If you have insight into national growth priorities and policies, please comment on how well cluster ambitions and assets align with these.

Reflect on priority areas for support and what might be needed in terms of programming or resources to enable, or steer, cluster activities. Which actors will be central to those efforts, either from within the cluster or through partnerships across Government departments?

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