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The Geography of Knowledge Creation

Technological Relatedness and Regional Smart Specialization Strategies[1]

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Abstract:
This chapter synthesises the literatures of evolutionary economic geography and the geography of innovation in order to demonstrate the path dependent and evolutionary logic inherent to knowledge creation and diffusion processes. Critically, this synthesis reaffirms the continued importance of geography as a palpable medium to organize economic activity. Making explicit use of the 'knowledge space' methodology developed by Kogler *et al.,* (2013) this chapter examines the technological evolution of Ireland (1981 – 2010) and provides new insights on how regional knowledge trajectories are shaped by path-dependent, recombinant, and co-evolutionary network dynamics. For Ireland, we show that its technological development can be understood as a branching phenomenon, whereby new technological trajectories branched out from previously existing or related pieces of knowledge. The chapter concludes by theorising how the knowledge space framework has an important bearing on the recently proposed Smart Specialisation thesis, which is envisioned to underpin knowledge-based regional economic development throughout Europe for the coming decade.

JEL: O31, O33, R11

Key Words:
Knowledge Space, Technological Relatedness, Patents, Regional Diversification, Knowledge Creation & Diffusion, Smart Specialization Strategies, Ireland.

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1 INTRODUCTION

The production of economically valuable knowledge has taken center stage as one of the most critical dimensions of regional development and economic growth, and is considered a significant determinant of the varying levels of prosperity that persist amongst territories (Schumpeter 1942; Asheim and Gertler 2005). Considering the recent economic crisis, there is a growing awareness among regional scientists and policy-makers that the fortunes of regions, and by extension the firms embedded within them, are intrinsically related to a set of localized capabilities and regionally embedded know-how (Maskell and Malmberg 1999). More broadly, these region-specific capabilities function as an economic roadmap guiding the future development of regions, as new products (Hidalgo et al. 2007), industries (Neffke et al. 2011) and technologies (Kogler et al. 2013) emerge from the existing knowledge base of the region (Boschma and Frenken 2012).

That regions/firms/industries diversify into activities related to their current specialization should come as no great surprise, and has broadly been confirmed by several recent studies (Boschma 2017). Despite this insight, what remains unclear are the complex geo-centric processes that lie at the heart of technological change and regional diversification (Kogler 2017). Thus, while considerable focus has been directed towards the processes of knowledge production in a spatial context, significantly less attention has been directed towards the actual types of knowledge produced within regions and how the properties of this knowledge impact future regional development. This is a significant research gap with far reaching policy implications given that most advanced economic development theories, as well as innovation policies, stress the importance of "local knowledge" as a source of jurisdictional competitive advantage.

The realization regarding the importance of knowledge production and diffusion processes for innovation and subsequent economic development and growth is certainly nothing new (Feldman 1994; Bathelt et al. 2011). However, it is only recently that the relevant literatures have started to consider the properties of local knowledge rather than mainly focusing on absolute measures in terms of output and quality. Building on older ideas in geography, for example, Tobler's first law of geography that states that "everything is related to everything else, but near things are more related than distant things" (Tobler, 1970, p. 236), and in economics, for example, input–output analysis (Simpson and Tsukui 1965), the concept of "technological relatedness" has risen to the forefront, constituting a framework with the potential to depict past and future regional technology trajectories.

Following the contribution of Hidalgo et al. (2007), economic geographers have begun redirecting their attention towards the role of knowledge creation and its impact on regional diversification. Here the concept of relatedness, how related two economic activities are to one another, has been particularly influential, as it moves beyond absolute values in terms of economic concentration and industrial composition to explain "distance" between technologies as a key factor of future regional development (Essletzbichler 2015). Indeed, the ability to accurately capture relatedness between economic activities opens up a platform for understanding future regional diversification as a branching process grounded in "geographical biases" (Penrose 1959; Boschma 2017; Rutten 2017). More precisely, this enables us to quantify the emergence of new industries from how related that new industry is to the existing technological portfolio of the region (Teece 1982; Engelsman and Van Raan 1991; Teece et al. 1994).

Armed with this rationale, the purpose of this chapter is to synthesize the literatures of evolutionary economic geography (Boschma and Martin 2007, 2010; Martin and Sunley 2007;

Kogler 2015) and the geography of innovation (Feldman and Florida 1994; Asheim and Gertler 2005; Feldman and Kogler 2010) to demonstrate the path-dependent and evolutionary logic inherent to knowledge creation. Critically, this synthesis reaffirms the importance of geography as a palpable medium to organize economic activity. Making explicit use of the "knowledge space" methodology developed by Kogler et al. (2013), Rigby (2015) and Boschma et al. (2015) this chapter provides detailed insights on how regional knowledge trajectories are shaped by path-dependent, recombinant, and co-evolutionary network dynamics. We do this by examining the knowledge space of regions in Ireland over the time period 1981–2010.

2 THE GEOGRAPHY OF KNOWLEDGE CREATION

Innovation exhibits a particular geography (Feldman 1994). Although the past few decades have provided detailed accounts of the underlying process of knowledge production in a spatial context, the nexus between geography and innovation remains a bit of a mystery, whereby neither geographers nor economists have managed to fully open the "black box of innovation" (Rosenberg 1994). In attempting to deconstruct this black box several authors have postulated that different types of "space" produce different sources of knowledge as their competitive advantage (Bunnell and Coe 2001). Here, recent enquires have engaged in a debate whether it is specialized places, characterized by economies of scope and scale, or those that exhibit a more diverse sectoral structure, that facilitates the cross-fertilization of ideas between previously unconnected knowledge bases, that are more conductive to knowledge production and thus higher levels of innovation activities (Beaudry and Schiffauerova 2009).

Marshall (1920) already stressed the importance of concentrating related industries at a particular place to maximize comparative advantages in the market, but it was Jacobs (1969) who rightfully pointed out the role of diversity for innovation and economic growth, a process now commonly referred to as "development through diversification". For Jacobs, it is the addition of new work and the resulting division of labor that cause regions to expand and continually develop. Comparing the failures of Manchester with the successes of Birmingham, Jacobs remarks that it was the addition of many little industries with fragmented working patterns, some of which went on to form large organizations, that resulted in Birmingham becoming the center of industrial development within the United Kingdom at the time. By the same token, Manchester's over-specialization in the once dominant textiles industry resulted in it being ill-equipped to engage in other (related) sectors of the economy. Even today, it is possible to identify those regions that where once prosperous but have since declined. Detroit, the Rust Belt in general, or the Ruhr region are all examples of once thriving economies who have since stagnated. As Jacobs herself puts it, they are "economies that did not add new kinds of goods and services, but continued only to repeat old work" (Jacobs 1969, p. 49). In a geographic context, they are regions that became locked-in due to institutional insolvencies, outdated manufacturing techniques and an inability to look outwards (Grabher 1993; Hassink 2010; Martin and Sunley 2006).

In addition to its economic functions, Jacobs also claims that cities enact important social processes, not just by bringing many people together but also by bringing together a wide variety of ideas from which potentially new knowledge can be created. In this regard, Jacobs' conceptualization of the city as being the locus for innovation draws extensive parallels with Schumpeter's (1942) "creative destruction" thesis. As a foundation to this chapter the writings of Jacobs (1969) and Schumpeter (1912, 1942) provide two important insights into the underlying capabilities of regions and their capacity to generate new types of knowledge.

First and foremost, innovation is a fractured and complicated process whose effects are not evenly distributed throughout space (Rigby 2015). Ironically, innovations' only certainty is the uncertainty associated with trial-and-error (Essletzbichler 2015). Further, the majority of innovations in the past decades have occurred in cities. In their study of the US knowledge space, 90 percent of all patent applications are concentrated within 366 metropolitan statistical areas (Kogler et al. 2013). Large diversified cities embody a functioning urban network ecology, frequently well-developed political and institutional systems, research facilities as well as global knowledge linkages, all of which are conducive to knowledge creation (Gertler 2003; Bathelt et al. 2004). With regards to their creative potential, cities are places where the division of labor is greatest and where new work rapidly replaces older work.

Second, in an evolutionary context the creation of new knowledge is not a random or exogenous process as neo-classical interpretations would suggest. It is in fact, both highly stylized and path dependent. Once again, this line of argument draws inference from both Jacobs' (1969) theories of diversity and cross-fertilization of ideas, and from Schumpeter's (1912) "neue Kombinationen" thesis. Essentially, the creation of new knowledge is recognized as a fundamentally recombinant process whereby "old ideas are reconfigured in new ways to make new ideas" (Weitzman 1998, p. 333). Since this cross-fertilization of ideas is greatest in diversified cities, it is cities that hold the most potential for knowledge creation and regional diversification (Beaudry and Schiffauerova 2009).

Notwithstanding, the aforementioned studies have recently been criticized on a number of theoretical and methodological grounds, given their tendency to ignore the evolutionary paradigm inherent to firms and regions. Inspired by the methodology developed by Hidalgo et al. (2007) a growing body of empirical literature has begun analyzing the branching capabilities of regions, industries and technologies, as a process grounded in local capabilities. It has become common to refer to this division of the literature as the "relatedness literature". The point of departure is where the geography of innovation primarily asks "where does innovation take place"? The relatedness literature asks, "why does a particular innovation take place here and not elsewhere?" Accordingly, this perspective shifts from a static to a dynamic understanding of regional diversification and technological change, with a concise appreciation of the role history plays in shaping regional development (Kogler 2015). However, while the recent evolutionary resurgence in economic geography has brought with it its own theories and methods, the role of history in explaining economic growth vis-à-vis path dependence is again not entirely new. In this vein Dosi (1997, p. 1531) states that any historical perspective or explanation of "why something exists intimately rests on how it became what it is" – a point that will be revisited below.

3 RELATED VARIETY AND TECHNOLOGICAL RELATEDNESS

Moving beyond the categorical (dichotomy) classification of places and activities into Marshallian specialization or Jacobian diversification externalities (Beaudry and Schiffauerova 2009) recent insights point to the necessity to develop a more nuanced and continuous way of describing the relationships between different knowledge and technology domains. Essentially, both patterns of specialization as well as the cross-fertilization of ideas between sectors, are important aspects that shape regional economic development patterns (Caragliu et al. 2016). Following this line of argument, recent advances in the relevant literature, in particular in the field of Evolutionary Economic Geography, have begun to focus on the role of relatedness in driving regional development (Boschma and Frenken 2012).

Here, in addition to the spatial proximity, it is increasingly also cognitive proximity that is considered necessary to facilitate knowledge absorption and learning processes that result in the creation of new and economically valuable products and processes, that is, innovations (Cohen and Levinthal 1990). The insight is that co-location alone does not automatically result in knowledge recombination or creation processes, but that it also needs a common framework of understanding among the agents and sectors that engage in knowledge exchange processes. This assumption does not necessarily undermine the importance of geography in mediating knowledge flows as cognitive proximity has always been a consideration, if not direct but implicit, in the methodologies applied in earlier relevant studies concerning knowledge flows and spillovers (Jaffe et al. 1993; Audretsch and Feldman 2004; Paci et al. 2014). One could even argue that the concept of relatedness foremost demonstrates how geography facilitates knowledge exchange and learning processes, but also indicates how in turn spatial proximity enforces other relevant dimensions of proximity, that is, social, organizational, institutional, as well as cognitive (Nooteboom 2000; Boschma 2005). Fornahl et al. (2011) define cognitive distance as knowledge that is neither identical (hence it can be usefully exchanged) nor too distant (therefore it can still be effectively absorbed). Related variety achieves this delicate combination by balancing similarity with dissimilarity (Frenken et al. 2007).

But what is technological relatedness? How would one measure it? What does it measure, and why would one want to measure it to begin with? For the past decade or so economic geographers have been grappling with these types questions to better understand the branching patterns of industries, technologies, regions and even countries (Penrose 1959; Hidalgo et al. 2007; Neffke et al. 2011; Kogler et al. 2013). The logic underpinning the relatedness framework is that future diversification is grounded in a series of path-dependent processes, whereby new knowledge branches out from existing or related pieces of knowledge. As described by Neffke (2009, p. 125), “regional economies have coherent portfolios of industries that expand into related industries and contract by getting rid of unrelated industries”. These ideas parallel both the resource based view (RBV) of the firm (Penrose 1959) and the evolutionary theory of the firm (Nelson and Winter 1982). Thus, the relatedness literature reinforces the evolutionary processes of selection, variety and retention, and demonstrates that the accumulation and production of knowledge is embedded in region-specific patterns which have been developed slowly over time (Frenken and Boschma 2007).

Evolutionary analogies within economic geography are uniquely positioned to address these questions, given that over the past two decades or so a vast and flourishing literature has emerged stressing that the foundations for long term sustainable economic growth rested on the ability of regions to produce knowledge that is both spatially sticky and non-ubiquitous (Gertler 2003; Hidalgo and Hausmann 2009). In their writings on “localized capabilities” Maskell and Malmberg (1999) explain that the resources available to the firm are both tangible (machinery and technologies) and intangible (organizational practices, skills and cultural norms) but since they have been developed slowly over time are not easily reproducible by others. Conversely, this firm-specific knowledge is largely tacit in nature, hence continuing to infer an advantage onto those firms that produced it in the first place (Balland and Rigby 2017). Overtime, this type of knowledge, often embedded in individuals (skills) and in firms (routines) transcends the boundaries of the individual firm and, thereafter, becomes embedded in the economic ecology of a region. These processes result in the production (accumulation) of knowledge being a path dependent phenomenon, whereby regions (firms) leverage their place specific assets to recognize and thereafter exploit new economic paths. From an evolutionary standpoint, it makes sense that regions (firms) employ practices that have proven successful in the past as it reduces the opportunistic risk and trial and error characteristics associated with technological change (Schumpeter 1942; Nelson and Winter, 1982; Romer, 1990). For regions, the gradual layering of “successful” knowledge contributes to both the place specific and path dependent processes of knowledge creation and diffusion. Ultimately, this layering ensures that imitation by non-local actors is highly unlikely because geographical distance, among other things, forms a barrier to knowledge transfer and learning processes.

Region-specific capabilities, or the knowledge space of a region, contain a multitude of information on both the opportunities for the *likely* future diversification, but also a *realistic* expectation on the innovative capacity of that region. This is because, at least in the short run, the industrial composition of regions can be considered relativity stable as technologies or routines do not change rapidly.[1] Hidalgo et al. (2007) tested these claims utilizing export data, and demonstrated how a countries current industrial structure significantly affects its potential for future diversification possibilities. In doing so, the authors developed the product space framework and argue that two products are considered related if two countries have a comparative advantage in both products. Similarly, Hausmann and Klinger (2007) also found that those countries that populate denser sections of the product space, that is, countries with a comparative advantage in multiple products, have a greater opportunity to diversify into new products. Intuitively this makes sense as more developed countries have increased opportunities (capabilities) to expand their industrial portfolios, while less developed countries would struggle to meet these demands. Kogler et al. (2013) adapt the same general principles in their portrayal of the US knowledge space. Employing information on the co-occurrence of technology classes listed on patent documents, these authors discern the distance (relatedness) between individual inventions by calculating how related each patent technology class is to each other, and more importantly how this changes over several decades of technology evolution. Furthermore, by analysing levels of relatedness between products, technologies and industries it is possible – albeit imperfectly – to predict what areas of the knowledge space a region is most likely to diversify into relative to its current position.

Notwithstanding the significant theoretical advances in the study of the geography of knowledge, innovation and technical change that have been made recently, empirics have significantly lagged behind theorizing mainly due to the lack of available micro-level data required for detailed investigations. This shortcoming resulted in a series of rather top level descriptive statistics, but significantly less empirical validation, especially across countries/regions. Fortunately, many of these concerns are now being addressed as previously underutilized information in several databases is exploited. In terms of investigating the evolutionary patterns of regional technological change it is most notably the United States Patent and Trademark Office (USPTO) and the European Patent Office (EPO) who provide valuable data inputs to empirically validate some of the theoretical advances that have been made in the past decade.

Patent data provide a wealth of information pertaining to the creation and diffusion of technical knowledge in regions (Usai 2011). Contained within a patent document is information regarding inventors’ names, addresses, dates, external affiliations, technological classification codes and patent as well as scientific literature citations. This level of detail gives researchers the tools needed to trace the technological development of regions, industries and knowledge typologies over space and time. Most importantly for the current chapter are the technological classification codes listed on patent documents. Mapping the co-occurrence of these classification codes generates the “knowledge space”, a topic to which we will turn now.

4 THE KNOWLEDGE SPACE

The concept of the product space (Hidalgo et al. 2007) provided the initial idea for the knowledge space developed by Kogler et al. (2013). Essentially, the product space is a network-based representation that captures the levels of cognitive proximity (relatedness) based on how often two specific products are co-exported by each country (Hidalgo et al. 2007). In this network, the individual nodes are product categories and the links between them indicate the degree of relatedness. Making use of international trade data this approached aimed to analyze whether a country would develop a comparative advantage in a specific product category on the condition that this new product was related to the countries existing export portfolio (Hidalgo et al. 2007; Hausmann and Hidalgo 2010).

Moving down the geographical scale, Kogler et al. (2013) develop a knowledge space to analyze the technological evolution of US cities. The key distinction is that instead of focusing on the co-production of exports, the knowledge space is created using information on the co-occurrence of classification codes listed on patent documents. In this study, the authors establish a link between technological relatedness and the pace of invention in US cities. They also found that some cities maintain their technological coherence, while the technological trajectories of others fracture and dissipate, yet in other cities new technologies develop. In a follow up study, Rigby (2015), found that technologies that where related to the regions pre-existing knowledge base had a higher probability to enter that particular region than technologies that were unrelated. Boschma et al. (2015) have also demonstrated that the probability of gaining a new technology class in a metropolitan area increases by 30 percent if the level of relatedness with existing technologies in the city increases by 10 percent, while the exit probability of an existing technology in a city decreases by 8 percent.

Complementary to the above, are the contributions of Neffke (2009), Boschma et al. (2013) and Essletzbichler (2015) who found that it was the regional structure, opposed to the national structure, that mattered most for regional diversification and knowledge creation. These finding give primacy to the claim that certain resources are less mobile than others, suggesting that capabilities need be developed at a regional level to enable the development of new specialisation patters (Maskell and Malmberg 1999). Throughout the geography of innovation literature the significance of regions as drivers of technological change are well documented (Feldman and Kogler 2010), and well-known regional success stories include, ICT in Silicon Valley (Saxenian 1994), fuel cell technology in the Baden-Wuerttemberg region (Tanner 2014, 2016), speciality wine in Piedmont (Morrison and Rabellotti 2009), or the media cluster in Leipzig (Bathelt 2005). Following the methodology outlined in Hidalgo et al. (2007), the knowledge space is operationalized in the following manner:

$$\varphi_{i,j,t} = \min\{P(RTAx_{i,t}|RTAx_{j,t}), \{P(RTAx_{j,t}|RTAx_{i,t})\}\} \quad (1)$$

where technological relatedness $\varphi_{i,j,t}$ between technologies i and j is computed as the minimum pair-wise conditional probability of citing technology i while also patenting in technology that j at time t. As has become commonplace, we only focus on those regions that are a substantial producer of a given technology, whereby we restrict our sample to include only those regions with a regional technological advantage, $RTA_{r,t}(i) = 1$ if:

$$\frac{patents_{r,t}\ (i)/\Sigma_i\ patents_{r,t}\ (i)}{\Sigma_c\ patents_{r,t}\ (i)/\Sigma_c\ \Sigma_i\ patents_{r,t}\ (i)} > 1 \quad (2)$$

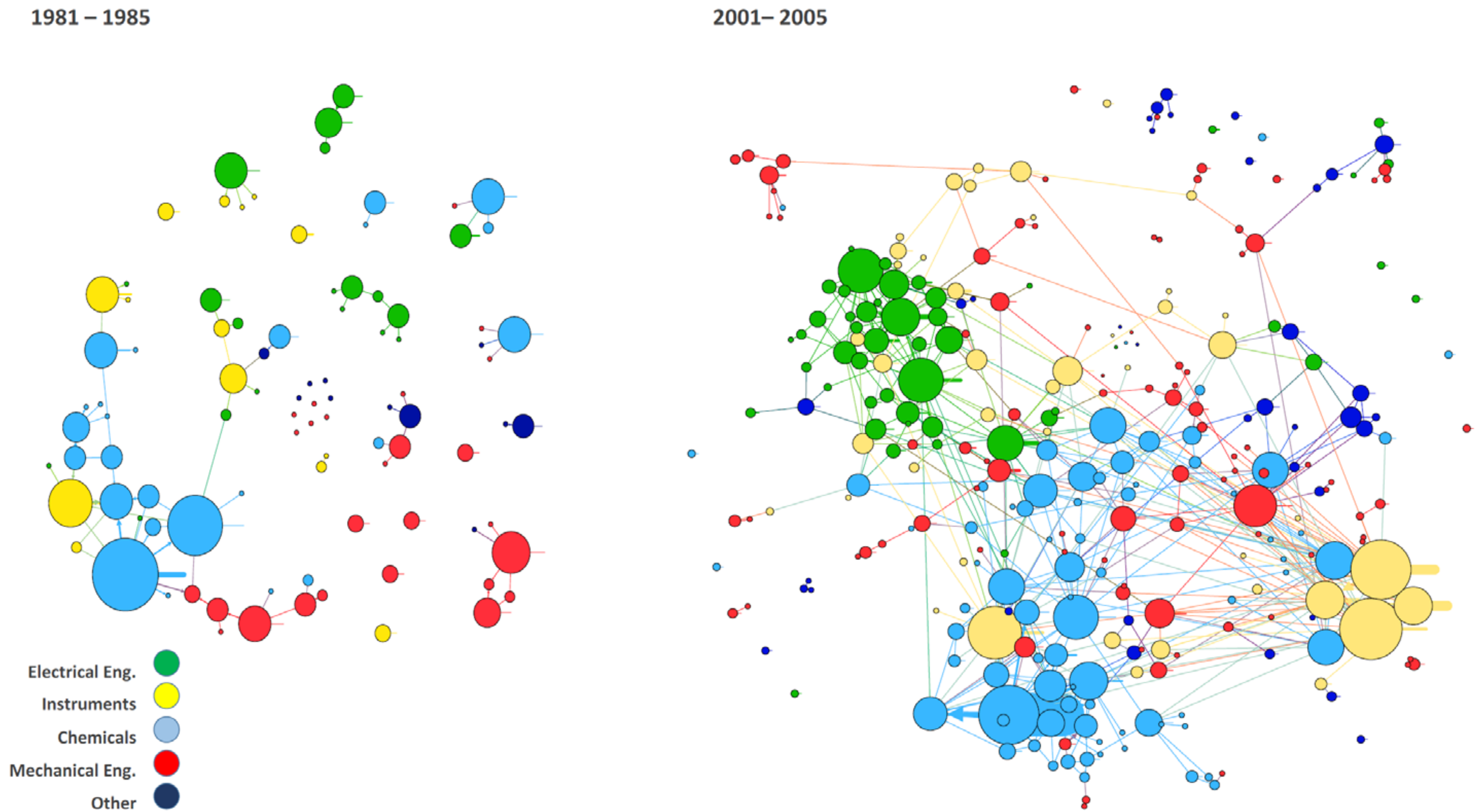

Figure 1: Dublin Knowledge Space

With these specifications in mind, Figure 13.1 shows the knowledge space for Dublin for the years 1981–85 and 2001–05. The knowledge space is an intuitive way to model the process of technological specialization/diversification in a regional economy. More specifically, it shows the growth (entry) and decline (exit) of certain technological domains and the relationships between them. In doing so, it corroborates the key principles in the relatedness literature and demonstrates that the geography of knowledge production is not a random phenomenon, but is both highly stylized and path dependent. Critically, it demonstrates that technology and associated industry sectors do not simply diversify into any direction, but rather branch out into related technologies (Kogler et al. 2017).
Following Schmoch (2008), the knowledge space has been aggregated into the five main technology classes; Chemistry, Instruments, Electrical Engineering, Mechanical Engineering and Other. The assumption is that nodes that appear in the same broad technology class also share a similar knowledge base, or that the competencies used in the production of one technology class can be easily reconfigured to develop another related one. The nodes in the networks in Figure 13.1 correspond to one of the 629 international patent classification codes listed in patent documents published by the European Patent Office (EPO), and the size of the node illustrates the number of patents in a particular technology class. In terms of descriptive statistics, instrument based patents have shown the greatest increase in applications increasing from 14 percent in the period 1981–85 to 31 percent by the end of 2010. Similarly, Electrical Engineering has increased from 13 percent to 26 percent over the same period.

Since the early to mid-1980s Dublin's knowledge space has evolved in ways that we might have anticipated. There have been clear signs of clustering of patents associated with Chemistry and Electrical Engineering indicating a high degree of relatedness between those classes. Following an evolutionary logic that new knowledge branches out from related and previously existing types of knowledge, it is worthwhile noticing that the development of the Instrument sector (optical instruments, medical technologies, measurement instruments) lies between the areas of Electrical Engineering and Chemistry. Boschma and Frenken (2012, p. 5) have previously pointed out that, "we understand the emergence of a new industry in a region from the level of technological relatedness between the new industry and the existing industries in a region". Similarly, Hausmann and Klinger (2007, p. 6) have demonstrated that these networks are extremely heterogeneous whereby if technologies "require highly similar inputs and endowments, then they are 'closer' together, but if they require totally different capabilities, they are 'farther' apart".

Next, we need to discern how relatedness between technologies shapes technological change at a regional level. To do this we generate a relatedness density index which captures how close a potentially new technology (specialization) is to the knowledge base of the region. Augmenting the density index outlined in Hidalgo et al. (2007) and accounting for the differences in data and technical specifications, relatedness density is operationalized as follows.

The density for a specific technology i in region r at time t is calculated using the corresponding relatedness index of technology i to the technologies in region r that have an RCA in time t, divided by the sum of technological relatedness of technology i to all the other technologies in Ireland in the t:

$$RelDen_{i,r,t} = \frac{\sum_{j \in r, j \neq i} \varphi_{ij}}{\sum_{j \neq i} \varphi_{ij}} \times 100 \quad (3)$$

By design, relatedness density takes a value between 0 percent and 100 percent. A density value equal to 0 percent would indicate that there is no technology related to technology i in region r at
time t. As such, is it unlikely that this technology would be adopted in the region because it cannot build on related expertise. Conversely, a value of 100 percent would indicate that all the technologies related to i are present in the region r knowledge space. With this in mind, Table 13.1 provides information on the relatedness density values of Irish NUTS3 regions for the time period 1981–85.

Table 1: Relatedness density for Irish NUTS 3 regions, 1981–85

Region	Technology Class				
	Electrical Engineering	Instruments	Chemistry	Mechanical Engineering	Other
Border	68	36	36	1	64
Dublin	67	82	89	44	60
Mid-East	19	55	21	86	18
Mid-West	19	55	21	86	18
Midlands	42	27	64	14	55
Southeast	2	18	11	57	1
Southwest	13	27	54	71	18
West	87	73	46	29	82

To further illustrate this point, the density value around “Chemistry” in Dublin was equal to 89 percent during the period 1981–85. Similar to Figure 13.1, you can see that Dublin’s specialization in chemistry enabled it to successfully build on related technologies. In the following period (2001–05), Chemistry became the most dominant patented technology sector in the Dublin knowledge space. A similar trend is also observed for Dublin’s other specializations in “Electrical Engineering” and “Instruments”, which had relatedness density values of 67 percent and 82 percent respectively, and which later became key technologies in Dublin’s knowledge space.

The above studies demonstrate the potential of the relatedness framework to anticipate future regional technology trajectories. Indeed, the relatedness literature stresses that the production of new knowledge exhibits a strong path dependency whereby new knowledge branches out from an existing piece of knowledge (Boschma 2017; Kogler 2017). These are without a doubt serious claims that have important bearings on both the capacity of regions to create new knowledge, but also for policy-makers who aim to enhance investment strategies for future regional development pathways. Therefore, it is not by coincidence that the literature on relatedness and regional diversification is increasingly used as a point of reference in many policy initiatives, including European Union's cohesion policy framework (McCann and Ortega-Argilés 2013, 2015), or more recently in the Smart Specialisation thesis which aims to provide a regional development framework for Europe for the coming decade (Foray et al. 2009; Morgan 2015; Foray 2015).

5 SMART SPECIALIZATION STRATEGIES

Very few development strategies have gained as much political traction as the Smart Specialisation Strategy thesis (Morgan 2015). Popularized by Dominique Foray and colleagues in 2009, the concepts' immediate popularity came at a time when the industrial composition of regions ranked high on almost every political agenda. Although not a direct outcome of the crisis itself,[2] the concept has had, and will continue to have, a significant impact on the economic re-structuring of regions in the future.

At its core, smart specialisation strategies are the European Union's innovation policy for the coming decade, and admittedly its approach is relatively straightforward (McCann and Ortega-Argilés 2015). The strategy aims to enhance regional competitiveness by identifying and enabling those regions that have particular 'strengths' in certain industries (technologies). Accordingly, the strategy has two goals. First, by focusing on their relative strengths, it is envisioned that regions will be able to identity future development avenues through which they can thereafter build a relative competitive advantage against other jurisdictions. This process underpins the entrepreneurial discovery part of the strategy, which is expected to result in structural change. Second, it is envisioned that these regional specialisation patterns will also prevent the duplication of efforts and exhaustion of resources in the common market. Adhering to the Research and Innovation Strategy for Smart Specialization is currently a prerequisite by the EU Commission for regions to receive further funding from the European Regional Development Fund (ERDF).

Intuitively this approach seems perfectly logical and in line with the theories concerned with regional economic development, which is a compounding factor contributing to the Smart Specialization Strategies concept's success. However, as rightfully pointed out by Foray et al. (2011, p. 1) this has resulted in the concept itself becoming a "policy running ahead of theory". The closing segments of this chapter seek to demonstrate how the relatedness literature in general, but the knowledge space framework more specifically, has the capacity to address a number of these key concerns.

One could argue, the greatest strength of the Smart Specialization Strategy is its reversal in protocol, and more specifically in its empowerment of individual regions as champions of the own destiny. From a geographic standpoint is it easy to see how the relatedness literature has increasingly been linked up with the Smart Specialization Strategy. Returning to the theory outlined above, regions are repertoires of history, reflecting the path dependent (Martin and Sunley 2006) and place dependent (Hassink 2010) characteristics of knowledge production, often referred to as local capabilities (Maskell and Malmberg 1999). From this perspective, the assemblage of knowledge in a region provides certain opportunities in terms of future diversification, but it also functions as an indicator of potential limitations to the future innovative capacity that can be developed assuming that regional, industrial, and technical configurations remain relatively constant in the immediate term. Similarly, Markkula (2015, p. 50), states that "smart specialisation and societal innovation can only work if choices are based on real knowledge of local potential and if the right actors are involved". This reorientation from a traditionally top-down to a more bottom-up policy approach indicates that regions no longer must prescribe to some predefined example of innovative excellence, frequently referred to as the "Silicon Valley Model" (Saxenian 1991). Instead, the entrepreneurial backbone of the entire Smart Specialization thesis should be geared towards the relative strengths and capabilities present in a given region. This would deter spurious investments in the "fashionable fields" of biotechnology and nanotechnology, among others, as most regions do not have the capacity nor knowledge infrastructure to diversify into these industry sectors.

Operationalizing an approach capable of capturing regional development pathways throughout the entire European Union has proven to be a difficult task. Until recently, the lack of evidence was due to the shortage of appropriate data required for such large-scale detailed investigations. Fortunately, the increased digitalization of many datasets, as well as the merging of existing ones, along with more advanced methodological toolsets, have equipped researchers with the necessary means to tackle this task. The knowledge space methodology and the analysis of regional knowledge spaces provide unique insights into the branching capacities of regions through the process of related diversification. The ultimate objective is to provide regions with clear directions regarding where they should invest today in order to maximize their local knowledge base in the future, which is really the key question we still lack an answer for in the widely discussed Smart Specialization framework.

Boschma and Frenken (2012) and Kogler (2015), put forward the idea that the sectoral evolution of regions can be predicted, albeit imperfectly, through understanding the processes of technological relatedness underlying structural change. Since then a number of follow-up studies have confirmed that regions/firms/technologies diversify into activities that are technologically proximate to their current specialization (Hidalgo et al. 2007; Neffke et al. 2011, Kogler et al. 2013, 2017; Rigby 2015; Boschma et al. 2015; Essletzbichler 2015). Based on the relatedness-index between technologies, recent attempts to map the knowledge space of US cities have shown that some cities maintain their current specialization, while others develop entirely new technological regimes (Rigby 2015). In a more European context, Kogler et al. (2017), extend their original methodology to account for the impact of entry and exit on patterns of regional specialization. Initial efforts in this direction indicate that by analysing the evolution of knowledge cores of regions it is possible to predict the most likely diversification pathways of specific regional economies. Furthermore, it also indicates that it is possible to show where regions are lacking specialization and should withdraw engagement, and finally, where it would be possible to bridge the gap between two distinct technologies to generate new technology trajectories through the recombination of existing ones.

Based on the evolutionary logic that the production of new technological capabilities exhibits a strong path dependency whereby new knowledge branches out from existing piece of knowledge, it indicates that regions cannot rapidly switch between economic activities and that radical technological jumps are an exception. All of this demonstrates that regional strategies that do not adequately take into consideration the knowledge base of the region are destined to fail, and warns of the dangers of a "one size fits all" policy.

6 CONCLUDING REMARKS AND FUTURE RESEARCH DIRECTIONS

Much has been written about the localized dimension of knowledge production and its impact on regional diversification (Boschma 2017; Kogler 2017). Such discussions have increasingly pointed towards the evolution of regions' economic structure in terms of their underlying knowledge base and specifically the path- and place-dependent characteristics guiding their evolution (Kogler 2016). Throughout this chapter, we adopted an evolutionary discourse of technological change to reaffirm the continued importance of geography as a palpable medium to organize economic activity. Following a series of studies (Kogler et al. 2013, 2017) concerning the technological relatedness at a given place the principle assumption is that technological advances build on, and derive from, existing pieces of knowledge expertise present at a place.

To further investigate and map local evolutionary technology trajectories, we introduced the knowledge space framework, which is a network based representation that captures the underlying technological structure of regional economies (Kogler et al. 2013). More precisely, we examined the technological evolution of Ireland's capital city Dublin and provided new insights on how regional knowledge trajectories are shaped by path-dependent, recombinant, and co-evolutionary network dynamics. Critically, we demonstrated how Dublin's knowledge space provided certain opportunities for its future diversification. To further illustrate this point, we introduced a relatedness density index to quantify how close an emerging technology is to the existing knowledge base of the region. Essentially, we established how the density of technologies located around Dublin's knowledge space provided a series of likely diversification options, which then became key sectors for Dublin's economy at a later point in time.

Looking ahead, and in terms of future research directions, this chapter briefly concluded by theorizing how the proposed knowledge space methodology has important bearings for the recently proposed Smart Specialization Strategies framework. By taking an evolutionary look at regions in terms of their underlying knowledge structure the expectation is that it is possible to direct investments into realistic development pathways, while also providing advice on where to retract engagement due to the lack or regional specialization competencies. Further, the knowledge space methodology also holds the potential to provide insights into the areas of regional knowledge spaces where it is most likely possible to bridge the gap between two distinct technologies that have previously been unconnected by means of recombination activities. (Feldman et al. 2015). These are undoubtedly serious claims with far reaching implications for academics, practitioners, and policy-makers alike, and should serve as a blueprint for future research directions in this field of inquiry and policy-making.

NOTES

[1] Following Neffke et al. (2011), Kogler et al. (2013, 2017) demonstrate that over longer periods of time, that is, decades, the level of relatedness between technologies can – and does – change. With this in mind, an important question then is, how can we understand the emergence of a new industry (technology) in a region from how related that new industry (technology) is to the existing composition of the region.
[2] The Smart Specialization Strategy was developed because of recommendations put forward by the Knowledge for Growth Expert Group in 2005; see here for further information: http://ec.europa.eu/invest-in-research/monitoring/knowledge_en.htm.

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