

Network diversity, distance and economic impact in a cluster: visualising linkages and assessing network capital

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Abstract

Purpose – Effective policy to support business ecosystems should build on evidence-based analyses of firm-level activities and outcomes. This paper aims to contribute to this requirement and makes three contributions. The first contribution is to extend the application of the network capital concept to a variety of eight distinct linkage categories (e.g. suppliers, customers and business support agencies) that support networking and clustering, in both activity and impact terms. The second contribution is outlining a novel method of network visualisation (V-LINC) based on the collection of primary and qualitative data. The third contribution is in applying the method to one cluster, information and communications technologies.

Design/methodology/approach – Qualitative research on the nature and extent of organisational network linkages was undertaken. Structured interviews with a set of focal firms followed a tailored design approach. The concept of network capital was extended and applied to the cluster context by measuring network inputs and output (i.e. investments and impact). The approach was operationalised via a novel impact measurement approach, denoted as V-LINC, an acronym for visualising linkages in networks and clusters.

Findings – The authors develop a business impact framework exploiting novel linkage visualisations and qualitative data from firms in a cluster in one city region across eight linkage types to capture distinct network capital elements. Organisational inputs into network development, measured as investment and involvement indicators and organisational outcomes from those networks, measured as importance and intensity indicators, are used to assess network performance. A comprehensive, systematic and robust analysis of network elements and performance is possible. Distance is found to interact differently across linkage types. Targeted recommendations may be made from the analysis of local or regional business ecosystems in light of measured business impacts of linkages.

Research limitations/implications – Due to the resource-intensive nature of data collection, the current study engages a limited sample of firms and interviewees. Applications of this approach in other contexts will permit further research into its usefulness in evaluating business impacts generated through networking activities.

Originality/value – The method introduced here (V-LINC) offers a novel means to include both geography network theory into an understanding of knowledge relationships and networks within clusters. Accounting



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for both distance and linkage type reveals which categories of intra-regional and extra-regional linkages generate the greatest impact, given their frequency. The approach adds to available cluster visualisation and analysis approaches through identifying patterns of disaggregated knowledge flows and their impacts, with application to evaluation demands of policy.

Keywords Network capital, Visualisation, ICT cluster, Network impact

Paper type Research paper

1. Introduction

A range of research focusses on the role of inter-organisational collaboration with an explicit focus on knowledge exchange given its role in economic growth (Antonelli *et al.*, 2011; Grossman and Helpman, 1994). Both organisational and geographic processes have been identified as playing roles in the various creation, accumulation and transmission phases of knowledge development. Agglomeration and clustering processes suggest potential economies from firms' spatial locations (Marshall, 1921; Porter, 1990; Brosnan *et al.*, 2016), while differential capacities of firms in absorbing external knowledge point to the roles of firm-level willingness and ability to develop knowledge networks as also important (Cohen and Levinthal, 1990; Zahra and George, 2002). As Huggins and Thompson (2014) indicate, the geographic and spatial elements are related as absorptive capacity depends on locational and historical context – regions with high absorptive capacity exhibiting above-average proportions of organisations with advanced capacities.

The study of the impact of organisations' external ties within collaborative networks is central to this study. The focus on organisations includes firms and other relevant actors focussing on supporting flows of knowledge within and across regions, via networking, such as universities, chambers of commerce and support agencies targeted with business development.

Network research may be underpinned by network visualisations, where actors and ties or linkages are mapped a-spatially (Purchase *et al.*, 1997). However, social network analysis maps do not account for important features impinging on relational space such as physical distance between linkage nodes or the capacities of networks to translate networking activity into economically beneficial knowledge (Huggins *et al.*, 2012). Here, we demonstrate that network visualisations contribute to cluster analysis by improving how distinct elements of network linkages and their impacts may be both understood *and* estimated. Explaining variations in not only the quantity but also the quality (i.e. absorptive capacity) of network relations between participants aids explanation of how networks operate, also contributing evidence bases appropriate for business and public policy (Gatto, 2015).

We proceed by extending the concept of *network capital* to the cluster context. Network capital consists of investments in strategic and calculative relations to access knowledge to enhance expected economic returns (Huggins and Weir, 2007; Huggins and Thompson, 2015). We focus on sources of network capital that are developed across activities that serve a range of economic outcomes for organisations and regional development, revealed across a measured set of linkages. Aligning with Simonin (1999) our interests include not only technological or innovation networks but also those linkages involving market, industry and managerial knowledge, addressing an area that “has not yet received proper conceptual or empirical elaboration” (Sammarra and Biggiero, 2008, p. 801). The first contribution of the study is the development of a network-impact framework enabling assessment of both inputs into and outputs from a distinct set of functional networking activities, targeting a range of knowledge links.

The second contribution of the research is in applying network visualisation based on primary and qualitative data, a need highlighted in Bergman and Feser (1999). The selected research context is a knowledge-intensive cluster in information and communications

technologies (ICT) [1] in which our visualisation approach (denoted *V-LINC* i.e. visualisation of linkages in networks and clusters) permits recording, visualisation and analysis of linkages to explore the nature and impact of inter-organisational relations. Thus, we illustrate the web of network capital configured by both its spatial and functional dimensions, permitting comparison of networking inputs and their economic returns. The methods followed are open to application in other cluster and networking contexts across different spatial scales, to consider configurations of network capital and the benefits or costs, of network activities.

Our analysis also allows us to shed light on the role of geography (local to international) on the extent of linkage activity and linkage impacts for a set of networks. Knowledge-based concepts of clusters emphasise that geographic proximity *may* generate positive impacts from collaborative interactions (Arikan, 2009; Malmberg and Power, 2005; Boschma, 2005). Relational and functional aspects of Porter's cluster concept (outlined in Brosnan *et al.*, 2016) point to the contested role for geography on the economic impacts of linkages. We contribute to this debate by assessing network impacts in the context of geographical scales.

The questions addressed in the paper are:

- Q1. Which types of network-capital linkages do firms most frequently access and maintain?
- Q2. How does the role of the distance vary across different types of network linkage?
- Q3. How are geographic and functional linkage characteristics of knowledge networks associated with performance outcomes of network-capital linkages?

In Section 2, the conceptual underpinnings of our impact framework are set out in the context of challenges for estimating network impacts in economic terms. Our network-capital based framework for assessing network impact is presented. Section 3 presents our data collection and empirical strategy. Results are presented in Section 4 where visualisation from the *V-LINC* method of network analysis are introduced, as well as tabulated analysis and findings. Section 5 summarises and presents conclusions on implications for effective network-capital based development.

2. Theoretical background and conceptual framework

2.1 Agglomeration, clustering and networking

From theory, the spatial agglomeration of firms results from different types of external benefits (Marshall, 1921): a more extensive pool of labour may emerge, specialised inputs may be developed and local knowledge flows can be enabled, potentially generating benefits (Brosnan *et al.*, 2016). In practice, substantial variation in the impacts of such externalities on firms has been estimated (Beaudry and Schiffauerova, 2009; de Groot *et al.*, 2015). Prior research indicates the relative impact of inter-firm linkages seems largest for inputs (i.e. input-output or value-chain linkages), with labour linkages the next most important and knowledge spillovers the weakest (Ellison *et al.*, 2010). Notwithstanding the range of related research, Diodato *et al.* (2016, p. 2) argue that agglomeration impacts remain "poorly understood".

Knowledge spillovers are problematic as a concept as knowledge itself is so broad (Sammarra and Biggiero, 2008). Ambiguity over the impact of knowledge spillovers and their variation over the industry life cycle (Audretsch and Feldman, 1996) has the added complication that market imperfections also generate unintended spillovers (Scotchmer, 2004).

Attempting to separate out the variety of interacting factors affecting the performance of agglomerations and firms within them is challenging. One means to this end is through investigation of the place-based collaborative networks in which firms are engaged.

Specifying different types of collaboration is also an option, through distinct categorisation of technological, market, industry-specific and managerial knowledge (Simonin, 1999). Such inter-organisational knowledge exchanges are recognised as playing an important role in economic growth through endogenous effects (Antonelli *et al.*, 2011; Grossman and Helpman, 1994). The growth of cities, for example, has been explained in endogenous terms “stemming from a city’s capability to invest in a range of intangible assets, in particular human capital” (Huggins, 2016).

Endogenous growth and increasing returns are evident in the agglomeration concept developed by Porter (1990) i.e. “cluster”. In fact, in Porter’s (1990, p. 131) initial formulation of the concept, while geographic proximity was identified as important, the focus was rather on the system of evolved linkages, relationships and processes connecting businesses i.e. “industries related by various links of various kinds”. The processes through which increasing returns might be generated include scale effects, network effects, learning effects and other interaction effects (Arthur, 1988). Within collaborative clusters all sources of increasing returns matter “with the potential for realising scale effects and learning effects magnified by the potential of interaction and networking effects” (Brosnan *et al.*, 2016, p. 508). Research into network contexts, therefore, contributes to understanding the nature, structure and impacts of knowledge flows in a variety of networks.

Across cluster-focussed research Speldekamp *et al.* (2020) note that while understanding of the contribution of clusters to economic performance has improved, the significant contradiction remains across empirical results with respect to *how* clusters generate economic growth or innovation (Wolman and Hincapie, 2014). Positive benefits of regional clusters has been reported (Hospers and Beugelsdijk, 2002; Delgado *et al.*, 2014), while ambiguity is evident with other findings of limited positive productivity effects and no strong innovation effects (Duranton, 2011).

In policy contexts, network-based policies that target regional development have been found to generate different results in different contexts (Martin *et al.*, 2011; Falck *et al.*, 2010). Acknowledging that poor networking sets limitations on knowledge flows (Breschi and Lissoni, 2001), there is widespread agreement that developing co-operative relationships across firms and other agents is an important policy goal (Schott and Wickstrom Jensen, 2016; Huggins, 2000). As argued by Graf and Broekel (2020, p. 12), it is necessary to consider “what type of network failures are actually present” to better understand how networks function or exhibit dysfunction and to target appropriate policies.

Over time market failure arguments in favour of traditional industrial policy have been supplemented by *network* failure rationales for regional cluster-type policies (McCann and Ortega-Argiles, 2013). Network failures have been studied alongside cluster life-cycles (Suire and Vicente, 2009; Brenner and Schlump, 2011) with such failures associated with economic decline. Where markets fail to produce sufficient productive knowledge, policy options target network expansion through innovation incentives, reducing risks in under-appropriation of knowledge, upgrading human capital and improving general knowledge infrastructures (Scotchmer, 2004; Vicente, 2017). Solutions to network failures include increasing network density through, e.g. clustering supports. A more detailed analysis of networking activities sheds light on where weaknesses lie.

2.2 Proximity and network capital

Geographic proximity has been found to offer no immutable guarantee of benefits from agglomeration or local interaction (Bathelt *et al.*, 2004; Tallman and Phene, 2007). Rather, many useful flows of knowledge have been identified through distant rather than local networks (Ceci and Iubatti, 2012; Fitjar and Rodriguez-Pose, 2011). More distant knowledge sources tend to

feature for innovation-based links (Davenport, 2005). When benefits from knowledge networks arise, they appear to depend on a range of institutional, cognitive, organisational and social proximities (Boschma, 2005; Tödting *et al.*, 2011; Fritsch and Kauffeld-Monz, 2010). Membership of knowledge-sharing networks, however, spatially configured, rather than proximity, represents a distinct dimension of network impact.

As envisaged here, network capital includes scope for greater spatial reach than in, for example, the related “social capital” concept, which tends to be built up and concentrated across communities in spatial terms and consists of assets such as goodwill, belonging and social intercourse (OECD, 2001). Where social capital is developed it results in trust and keeps people connected in ways where they can live and work productively together. As Huggins (2010) clarifies, social capital focusses on individual actors within inter-personal networks (following Putnam, 2000) and it may contribute to the creation of socially beneficial resources. However, it is essentially built up *without* expectation of the results generated from relational interactions. In contrast, network capital is a firm-centric concept, defined as investments in strategic and calculative relations to access knowledge to enhance expected economic returns (Huggins and Thompson, 2015). Investing deliberately or as Williamson (1993) terms it – calculative – involves an expectation of economic return (Belussi and Sedita, 2012).

In addition to the economies associated with agglomeration that generate different impacts for firms, organisations also differ in their ability to convert collaborative interactions into profitable outcomes. Firms’ absorptive capacity – their ability to exploit external knowledge – is complementary to external knowledge acquisition (Laursen and Salter, 2006; Cohen and Levinthal, 1990; Hansen and Birkinshaw, 2007) and considered to be multi-dimensional given the separate processes it encompasses (Volberda *et al.*, 2010; Ferreras-Mendez *et al.*, 2015). This implies that the underlying relational dynamics of firms engaging in collaboration, irrespective of other benefits, generates benefits from interactions and is worthy of investigation (Smith *et al.*, 2020). It also points to the potential in separating out resources used by firms in investing in the creation and maintenance of networks when assessing their benefits. In this way, whether the expectation of economic return from investments in network capital has been fulfilled may be examined.

2.3 Visualising networks: framing assessment of network capital

Visual representation of a network requires linkage types to be identified. Some research has acknowledged the important roles of Input and Output linkages (including e.g. Porter, 1990, 1998b; Sölvell and Protsiv, 2008; Sölvell *et al.*, 2009). In the examination of various “cooperative arrangements” for “knowledge and information sourcing” as the basis for network capital, Huggins and Weir (2007, p. 713) identify linkages to include those with other firms; suppliers; clients; competitors; consultants; R&D laboratories; and higher educational institutions. Porter (1998a, p. 78) highlights the importance of linkages for productivity improvement and identifies partners including “governmental and other institutions, such as universities, standard-setting agencies, think tanks, training providers, and trade associations, who provide specialised training, education, information, research and technical support”. Value chain or transactional approaches can also be considered with linkage categories derived from related literature (Marshall, 1921; Porter, 1998a; Contractor and Lorange, 2002; Leydesdorff, 2012).

Within each linkage, category lies potential interaction that may be organised around activities, actors and/or resources. In short, no standard mapping or visualisation techniques have emerged with some scholars calling for mapping conventions to be used [e.g. Gardner and Cooper (2003) for supply-chain research]. For this research a functional approach was

selected, based on the literature. The selected list of linkages, provided below, illustrates that firms may choose to engage in networks with a range of partners, in the business realm and beyond, into governmental and support institutions:

- *Government agency linkages (GA)*: all forms of linkages to government departments and agencies including state support for enterprise; e.g. regional authorities and local gov. agencies.
- *Industry association linkages (IA)*: all memberships and relationships with organisations for collaboration; e.g. IA groups, chambers of commerce, cluster organisations.
- *Industry peer linkages (IP)*: formal and informal relationships with companies in similar or related industries, e.g. related via shared technologies or targeting complementary markets.
- *Input linkages (IN)*: links with suppliers of raw materials, goods and services with a critical impact on the end product or service of the surveyed firm.
- *Output linkages (OU)*: customers and channel sellers – both goods and services. Outputs may be with individual customers or assigned to customer segments and regions.
- *Research and development linkages (R&D)*: include R&D relationships between companies and with academic and research institutes.
- *Specialist service linkages (SS)*: relationships with vendors supplying essential services unavailable in-house (outside of inputs) e.g. services specific to an industry, distribution, IT, consultancy, marketing, financial and legal services.
- *Training linkages (TN)*: including third parties providing specific TN/learning for employees, e.g. relationships with academic institutes addressing skills needs now/for the future.

Establishing networks of linkages – whatever their classification or typology – requires effort and, therefore, investment and indeed maintaining linkages over time similarly has resource implications. It is useful to use the concept of network capital, defined as investments in strategic and calculative relations to access knowledge to enhance expected economic returns (Huggins and Thompson, 2015). In the context of a range of possible business-relevant linkages, they can be identified as a set of separate investments in network capital or disparate types of network capital. This approach permits the identification of such investments by linkage category offering a route to evaluate their business impact by linkage-type and a firm-specific perspective that may be applied in the context of networks and clusters. To date research on the network capital has not adopted such disaggregated approaches focussing on a span of different linkages.

Assessing investment in network capital is complex and may be proxied using the time (Burnham *et al.*, 2003) to account for the time-input required to create and maintain relations, as well as the frequency of such commitments. Active network management may be needed in some cases more than others and competence in managing external relationships has been identified as the basis for a dynamic capability with consequences for performance (Kale and Singh, 2007). Strong and weak linkages may be measured in terms of time input. Further insight is revealed via the dimension of linkage breadth that includes information on whether the linkage involves more than one contact or by the organisational position/status of the contact. This is useful to establish how a consequential interest might be generated from effective network investment. Such measures of input arguably account for activity, however, rather than impact or

outcome. Features that impact on the effect of external knowledge on performance outcomes have included the breadth of linkages established and their depth or intensity (Nieto and Santamaria, 2010; Chen *et al.*, 2013).

Further research is required to better understand those linkages that generate the highest returns, according to Love *et al.* (2014) who focus on the relationship between the number of a firm's linkages in the context of decisions to innovate and without consideration of the impact of that innovation. On a related note, Lichtenthaler (2005) also argues that the development of measures of success of external knowledge exploitation are needed that take into consideration the strategies, processes and structures through which firms translate it into commercial propositions.

We propose a network impact framework, in Table 1, as a comprehensive means for understanding the performance that organisations achieve from their networking and external knowledge exploitation efforts, that crucially serves to measure economic success or failure. While social capital is associated with individuals' capacity to mobilise their individual networks, network capital features organisation-centricity. Social capital can "lubricate" flows of knowledge (Vorley *et al.*, 2012) but it does not determine flows of *economically* useful knowledge (Huber, 2012). In contrast, network capital development is targeted at an economic advantage as an intentional effort in knowledge interactions is considered important for creating superior knowledge through collective processes (Antonelli, 2008). It is important that impact indicators differentiate between linkages generating benefits in terms of e.g. current mission criticality and future-oriented development. Identification of impact across linkage types (following linkage categories) reveals the extent to which targeted investment generates differentiated economic returns, on the basis of linkage-type.

The business impact is separated into two elements of inputs by and outcomes from deliberate networking. Organisational input (OI) encompasses investment and involvement indicators. Organisational investment is measured through both time commitment and the frequency of contacts required to maintain the linkage. Organisational involvement accounts for two additional indicators; the breadth of contacts in the target organisation and contacts' proximity to decision-making. In this way, we expand on the basic elements relating to network investment outlined in Grabher and Ibert (2006), Huggins and Weir (2007) and Huggins and Thompson (2015), addressing the nature of the underpinning relationships.

To compare OIs to outcomes, importance and intensity indicators are identified. Identifying separate dimensions of network outcomes is necessary to appreciate the network input-output (or investment-impact) relationship. Importance addresses the criticality of the linkage for the organisation's operations – capturing linkages that might not be mission-critical but still generate benefit. Finally, intensity measures linkage strength and the expectation of future continuity. If the commitment to current organisational activities is

Elements	Indicators	
Organisational input	<i>Investment</i> <ul style="list-style-type: none"> ● Frequency ● Time commitment 	<i>Involvement</i> <ul style="list-style-type: none"> ● Breadth of organisational contacts ● Hierarchical position of contacts
Organisational outcome	<i>Importance</i> <ul style="list-style-type: none"> ● Current benefit ● Mission criticality 	<i>Intensity</i> <ul style="list-style-type: none"> ● Linkage strength for firm ● Prospective durability

Table 1.
Business impact:
elements and
indicators

compromised by diverting resources into network investment, network impact may be diminished rather than augmented by over-investing in linkages (Lindner and Strulik, 2014).

3. Data and empirical strategy

Qualitative research on the nature and extent of organisational linkages was undertaken. Structured interviews with a set of focal firms followed a tailored design approach (Wolfe, 2009; Dillman *et al.*, 2014) based on eight linkage categories and four dimensions: namely, Investment, Involvement, Importance and Intensity [1]. Firms in the cluster region were identified and a sample invited for an interview. In selecting practitioners, a purposive, convenience sampling approach was used as interviewees with experience were required to glean the information requested (Lavrakas, 2008). Assistance in identifying firms was provided through engagement with IT@Cork, a not-for-profit, independent cluster organisation representing the interests of local ICT businesses [2]. A range of personnel in each organisation with knowledge of linkages was targeted with interviews arranged at the firm's premises or the cluster organisation.

A sample of 16 firms was selected for an interview, including 12 small and medium-sized enterprises and 4 large firms: 10 of the 16 were indigenous businesses. This sampling approach was necessary due to the resource-intensity of face-to-face interviews. A total of 47 face-to-face interviews took place across four months and interviews typically took 2 hours.

For each linkage identified by interviewees, they were requested to provide a score along four dimensions of investment, involvement, importance and intensity (developing measures in Hobbs, 2010). In the absence of *a priori* reasoning, we applied an equal weighting of input and outcome elements in measuring network capital impact. Each of the eight sub-indicators was organised with Likert scale responses from 1–10 (10 measurements maximum strength): a maximum possible score for each linkage type for each focal firm was 40. The value of each dimension includes two sub-indicators, weighted equally. Scores for each linkage were arranged into one of four bands: high (>30 to 40); medium (>20 to 29); low (>10 to 19); and tenuous (1 to 9).

Interviewees were requested to indicate the spatial reach of linkages across four potential geographies. Linkages outside the cluster region but within the country were denoted “national”; linkages outside national boundaries but within Europe were denoted “European” with remaining linkages “international”. All remaining linkages were “local”. Local geographic scope and cluster boundaries were defined as County Cork [3], within which there were 889 ICT enterprises using 5,485 people (CSO, 2016) [4]. The ICT sector includes a number of embedded multinational companies (amongst which, Apple and Dell-EMC).

To address the research questions, we examined the data across linkage type and geography using a series of Wilcoxon signed-rank statistical tests. These are appropriate for small samples and make no assumptions regarding the underlying distribution of the data collected (Harris and Hardin, 2013). The non-parametric tests allow for the examination of whether any statistically different patterns are evident for specific linkage measures, across different linkage types (linkage categories) and by linkage-geography categories.

4. Results

4.1 From linkage type to impacts: information and communications technologies cluster considerations

Results of V-LINC analysis are presented in tables and visualisations for 571 linkages identified. The observations yielded by the data generation approach and its ordinal nature was suited to non-parametric tests of differences (Wilcoxon rank-sum tests) that permit

measurement of differences between linkage types and across geographies. Across cluster firms, we identify the nature of network capital across linkages and geographies considering impact in terms of both input and outcome.

4.2 Linkage identification: type and geography

Figure 1 and Table 2 present network capital by linkage category across geographies. Figure 1 displays the geographic pattern of linkages with locational markers (highlighted pins) in each panel representing the respondent firm sample. Local linkages are focussed on the Cork area with evidence of a linkage highway to Ireland’s capital, Dublin. A range of linkages is evident across European and other international destinations.

Table 2 indicates that across the 571 measured linkages, the most frequent were OU (157 linkages), over 50% higher than the next most frequent category, SSs (97). Within the categories of OU, SSs, IN and IAs (ranked 1 to 4 in Table 2, col. 6), 70% of all linkages constituting this cluster’s network capital are represented. Table 2 distinguishes geographic

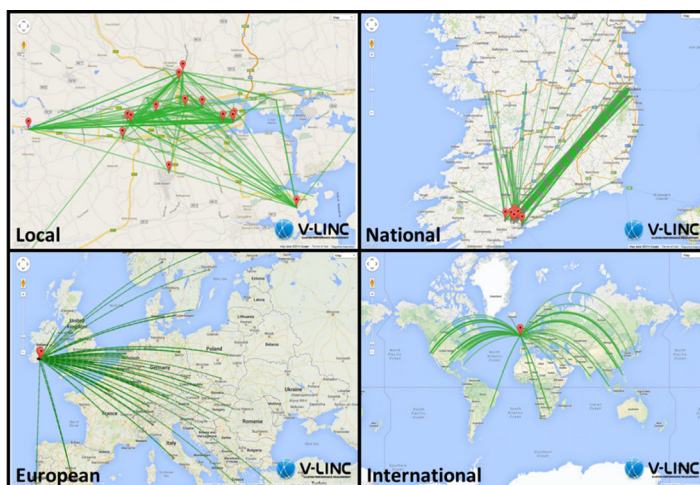


Figure 1. Cork ICT linkages by geographic scope

Geographic scope → Linkage category ↓	Local	National	European	Other international	Total linkages and rank [x]	Category as % of total linkages
OU	14%	16%	43%	27%	157 [1]	28%
SSs	39%	31%	13%	17%	97 [2]	17%
IN	27%	27%	17%	28%	81 [3]	14%
IAs	49%	31%	12%	8%	65 [4]	11%
TN	55%	34%	4%	6%	47 [5]	8%
IPs	47%	16%	14%	23%	43 [6]	8%
R&D	37%	24%	20%	19%	41 [7]	7%
GA	38%	60%	3%	0%	40 [8]	7%
<i>Avg Share geo. scope</i>	<i>38%</i>	<i>30%</i>	<i>16%</i>	<i>16%</i>		
Total (linkages)	190	155	119	107	571	
Share (%) of total	33%	27%	21%	19%	100%	100%

Table 2. Distribution of network capital linkages by category and geographic scope: Cork ICT cluster

patterns. Across the sample, 33% of linkages are local (190/571) with 27% national. The remaining 40% are evenly dispersed between European and other international locations.

Local plus national linkages dominate several categories especially GA (98% of linkages), IAs (80%), IPs (63%), SSs (70%) and TN (89%) and R&D (61%). The largest international shares, European plus international linkages, are observed for OU (70%), IN (45%), R&D (39%) and IPs (37%). In one linkage category only did international linkages account for more than 50% i.e. in the highest-frequency category, OU. Local plus national linkages represent the majority in this sample with local linkages dominating national in categories of IAs, IPs, R&D, SSs and TN.

A balance favouring local linkages may indicate potential to benefit from knowledge spill-overs *if* (as often assumed) proximity reduces search and co-ordination costs [encompassed in investment and involvement (IN) indicators]. We examine the extent to which firms in the cluster generate strong outcomes from the most local linkages (Jaffe *et al.*, 1993; Hasan and Koning, 2017). As widely acknowledged both local and global linkages simultaneously feature in international production and consumption webs and especially for innovation-driven growth it is emphasised that international links and international knowledge sourcing are required (Davenport, 2005; Drejer and Vinding, 2007).

To consider the role of distance in explaining frequency/share of linkages, a series of Wilcoxon signed-rank tests was conducted between the shares of aggregate network linkages for each geography. A statistically significant difference is evident between the shares of *local-plus-national* compared to *European-plus-other international* network capital. Estimates (significant at the 1% level) indicate the relative importance of the local-plus-national share, using network density or frequency data, suggesting potential for local spillovers. This was supported by statistically significant differences estimated for each comparison of local-to-European (1% significance), local-to-other International (5% significance), national-to-European (5% significance) and national-to-European (5% significance) linkages, respectively. In contrast, the comparison of local to national linkages suggested that the local/national distance discrepancy does *not* explain the relative frequencies of these aspects of network capital. Evidence of the importance of local and national collaborations are also favoured in the North of England, Greece and Turkey, in related work on network capital (Huggins *et al.*, 2012). Distance and linkage density appear inversely related to aggregate linkages.

4.3 Geographical differences in network capital

Linkage impacts are presented in Table 3 for each category, for all geographies combined and separately. Measures are organised into two impact bands: High plus Medium linkages (H + M) and Low plus Tenuous linkages (L + T).

Approximately 68% of linkages fall into the higher band (H + M) with a range of 41% for R&D to 92% for OU. The top three linkages of highest frequency (i.e. OU, SSs and IN) also rank highest for impact. While less than one third (32%) of linkages are low or tenuous, substantial shares of are reported in this band for R&D (59%), IN (58%), TN (51%) and IAs (51%).

For geography, more balance across bands is evident for local and national linkages. For local linkages, 58% are in the H + M band with 56% of national linkages. For both international measures, higher shares are evident of 84% and 86%, respectively. Aggregate shares by geography provide no evidence that impact declines with distance.

Focussing on the 190 local linkages, 58% are in the higher impact band. The largest shares of linkages here are outputs (89%), IN (86%) and SSs (67%). Local shares are 39% of SS linkages, 27% of IN and 14% of OU. IP linkages are recorded with the lowest impact in

Network diversity

Impact	Tot (n)	Tot%	Network capital linkage category							
			GA	IA	IP	IN	OU	RD	SS	TN
All linkages	571	100	40	65	43	81	157	41	97	47
H + M	390	68	63%	49%	42%	85%	92%	41%	63%	49%
L + T	181	32	38%	51%	58%	15%	8%	59%	37%	51%
Linkage share			7%	11%	8%	14%	27%	7%	17%	8%
Rank of share			7	4	5	3	1	7	2	5
<i>Local</i>	190		15	32	20	22	22	15	38	26
H + M	111	58	60%	49%	10%	86%	89%	38%	67%	54%
L + T	79	42	40%	52%	90%	14%	11%	63%	33%	46%
% Local links			8%	17%	11%	12%	12%	8%	20%	14%
% Agg. links			4%	3%	6%	4%	4%	4%	3%	7%
<i>National</i>	155		24	20	7	22	26	10	30	16
H + M	87	56	67%	20%	14%	82%	85%	20%	57%	44%
L + T	68	44	33%	80%	86%	18%	15%	80%	43%	56%
% Nat. links			15%	13%	5%	14%	17%	6%	19%	10%
% Agg. links			4%	4%	1%	4%	5%	2%	5%	3%
<i>International</i>	226		1	13	16	37	109	16	29	5
H + M	192	85	0%	92%	94%	87%	93%	56%	65%	40%
L + T	34	15	100%	8%	6%	13%	7%	44%	35%	60%
% Int. links			0%	6%	7%	16%	48%	7%	13%	2%
% Agg. links			0%	2%	3%	6%	19%	3%	5%	1%
<i>European</i>	119		1	8	6	14	67	8	13	2
H + M	102	86	0%	88%	83%	86%	97%	50%	62%	50%
L + T	17	14	100%	12%	17%	14%	3%	50%	38%	50%
% Euro. links			1%	7%	5%	12%	56%	7%	11%	2%
% Agg. links			0%	2%	3%	6%	19%	3%	5%	1%
<i>Other Int</i>	107		0	5	10	23	42	8	16	3
H + M	90	84	~	100%	100%	87%	90%	62%	69%	33%
L + T	17	16	~	0	0	13%	10%	38%	31%	67%
% Oth. links			~	5%	9%	21%	39%	7%	15%	3%
% Agg. links			~	1%	2%	4%	7%	1%	3%	<1%

Table 3. Network capital impact: linkage category and geography

90% of cases. High proportions of lower impact are observed for local R&D (62%) and IA (52%) linkages.

Of the 155 national linkages, 56% are in the higher impact band, including shares of 85% for OU, 82% for IN and 67% for GA linkages. However, 80% or more of the national IA, IP and R&D linkages exhibited a lower impact.

The 119 European linkages reveal 86% in the higher band. Four linkage types exhibit over 80% of linkages in this band: OU (97%), IA (88%), IN (86%) and IPs (83%). Half of R&D and TN linkages fall into the low impact category. The one linkage of GA was low impact.

Of the 107 international (non-European) linkages, 84% are high impact. All four linkage types featuring above 80% high-impact linkages for Europe demonstrate similar performance here – and all linkages for IA and IPs display higher impact (100%). Over two-thirds of TN linkages are lower impact for this geography.

If distance holds explanatory power for linkages of impact, an inverse relationship would be evident (and statistically significant) between density/frequency and distance for high and medium linkages (390 in Table 3). Wilcoxon signed-rank tests of differences in linkage frequency between geographies were conducted. Tests for comparisons with local linkage frequencies indicated significant differences in linkage frequency for the comparison of

local-to-national linkages only (at 5% significance) and local collaborations revealed an average higher frequency of 8% points. Neither local-to-European nor local-to-other international linkages exhibited significance. Therefore, the impact was associated with local rather than national linkages.

Significant differences were also identified for comparisons of national-to-European (at 10% significance) and national-to-other international linkages (at 5% significance). However, results indicated that the impact was associated with a *higher* frequency of linkages with European and other international locations. On average linkages with European collaborators were 16 percentage points higher and for other international partners, the figure was 19 points. The distance was no hindrance to the impact generated in these linkages.

4.4 Network capital: composition and value-adding impact

Our data allow for differentiating between bonding and bridging network capital [following Putnam (2000) for social capital]. Bonding capital is typified by dense networks with many member ties evident, whereas sparser links characterise bridging capital where new knowledge may refresh available stocks [as with weak ties (Granovetter, 1973)]. The network structure in the ICT cluster reveals bonding network capital for those relatively higher densities evident across four of the eight linkage types examined (OU, SSs, IN and IAs: see Table 3).

Density, as outlined by Vicente (2017) provides limited insight into impact. Density *may* indicate cohesion within a network but benefits from collaboration may also generate negative lock-in and hinder efforts to attract new members (Crespo et al., 2014). If bridging network capital dominates (in the lower-density linkages e.g. TN, IPs, R&D and GA) such weaker associations may indicate potentially rich opportunities for *future* brokerage opportunities.

Drilling into linkage quality, we focus on high plus medium linkages (consisting of 68% of all linkages: Table 3) and consider evidence of impact differences across geographies and linkage types. Where firms successfully engage in generating returns from network capital, outcome effects are greater than inputs so net returns are positive. Our measure of network capital allows us to discriminate between those linkages where outcome impact is greater than input, across both geography and by linkage type. Table 4 indicates the outcome and input measures of impact for the eight linkage categories.

In aggregate across the eight linkage categories, outcome dimensions of impact are generally greater than for input, as indicated by shares of impacts scored as higher and medium (73% > 62% from Table 4). This pattern is evident in six categories with only IP linkages demonstrating a greater share of high-and-medium linkages for inputs (58%) than the outcome (51%); for IA links the shares are similar at 55%. There is close alignment

Table 4. Network capital: linkage category with outcome and input impact dimensions

Output and input impact	Total		Network capital linkage category							
	linkages	Tot%	GA	IA	IP	IN	OU	RD	SS	TN
H + M	417	73	68%	55%	51%	92%	88%	54%	70%	60%
H + M RANK			4	6	8	1	2	7	3	5
L + T	154	27	32%	45%	49%	8%	12%	46%	30%	40%
IN										
H + M	355	62	48%	55%	58%	64%	85%	39%	58%	36%
H + M RANK			6	5	3	2	1	7	4	8
L + T	216	38	52%	45%	42%	36%	15%	61%	42%	64%
H + M Outcome-H + M Input	62	11	20%	0	-8%	28%	3%	15%	12%	24%

between the impacts of inputs into and outcomes from network capital in the case of the most frequent linkage observed, OU, with high shares of linkages at H + M levels (85% and 88%). Substantial misalignment is observed for linkages of IN, TN, GA, R&D and SSs (ranging from differences of 28% to 12%) indicating strong returns to network inputs. Misalignments for the four most frequent linkages (in italics in Table 4) indicate that returns to network capital inputs are amongst the weakest for the most frequent categories (OU, SSs and IAs). Hence, the density or frequency of linkages, does not align simply with impact.

For a spatial perspective, a set of estimations of differences between outcome and input dimensions for each linkage, for each firm, was performed with comparisons across geographies (Wilcoxon signed-rank tests were used). Table 5 presents the results.

Across the four linkage types with the highest frequencies (italicised in Table 5: OU, SSs, IN and IAs) European linkages displayed a statistically significant positive difference between outcome and input dimensions. European linkages vary in their frequency (Table 2) across OU (43%), SSs (13%), IN (17%) and IAs (12%). However, for these linkage types, the impacts on outcome are *greater* than input impacts.

Even where firms use these linkage types relatively infrequently, the impact of input investments on outcome remains positive. A positive impact is also evident for the IAs linkage. Linkages of OU and IN also exhibit positive returns at the national level. Local linkages with positive returns are identified for SSs and IN. Other international linkages with positive returns are estimated for IAs.

For the less frequent linkages listed in the lower rows of Table 5, more limited evidence is provided in support of positive returns. At both national and local levels, the returns to network capital inputs were positive for TN and GA. In addition, positive returns are observed for IPs from non-European international linkages. The R&D linkage stands uniquely in the absence of positive returns to investment across all geographies.

5. Discussion

This paper examined differences in network capital linkages used by the set of firms within an ICT cluster context. It focussed on differences across eight types of linkage according to the spatial level of linkages and estimated economic inputs to and outputs from linkages. The study is limited in its findings given the number of observations considered, however, it is possible to identify general conclusions relevant to the development of network capital as

Outcomes > Input?	Intern.	Eur.	National	Local
<i>OU</i>	<i>N</i>	<i>Y**</i>	<i>Y*</i>	<i>N</i>
<i>SSs</i>	<i>N</i>	<i>Y**</i>	<i>N</i>	<i>Y+</i>
<i>IN</i>	<i>N</i>	<i>Y*</i>	<i>Y**</i>	<i>Y**</i>
<i>IAs</i>	<i>Y^**</i>	<i>Y^**</i>	<i>N</i>	<i>N</i>
TN	na	na	<i>Y**</i>	<i>Y**</i>
IPs	<i>Y*</i>	na	<i>N</i>	na
R&D	<i>N^</i>	<i>N^</i>	<i>N^</i>	<i>N^</i>
GA	Na	na	<i>Y**</i>	<i>Y*</i>

Notes: **Denotes statistical significance at 1%, *Denotes statistical significance at 5%, + Denotes statistical significance at 10%, na denotes insufficient observations for statistical testing, ^ Separate geographies were summed (e.g. both National and Local or International and European) to generate sufficient observations for statistical testing

Table 5.
Network capital
impacts: high and
moderate linkages

conceptualised, visualised and operationalised here. Limitations arise also given the specific cluster context, however, as an example of how the conceptualised framework may be applied, it is informative. We see connections with research focussed on absorptive capacity and its distinct organisational (Cohen and Levinthal, 1990) and regional (Miguelez and Moreno, 2015) manifestations, that offer explanations for differential knowledge-flow impacts.

To date, visualisations of clusters have consisted of maps of organisational links, such as for the Boston Biopharmaceutical Cluster Maps (US Cluster Mapping, 2015) or the Danish Food Cluster Ecosystem (Napier and Bjerregaard, 2013) or a-spatial network maps (Giuliani, 2013). V-LINC maps introduce a novel element, i.e. geography, incorporating network theory into the understanding of knowledge relationships and networks within clusters. V-LINC maps reveal which types of intra-regional and extra-regional linkages generate the greatest *impact*, given their frequency. The approach adds to available cluster visualisation and analysis approaches through identifying patterns of disaggregated knowledge flows and impacts.

The ability to visualise a cluster's spatial connections contributes to understanding clustering as a process of knowledge seeking and sharing, regionally and globally. Given the structure of the Irish economy and its international linkages, this element is important for considering the capacity to exploit specific knowledge-by-geography flows for economic impact. A greater understanding of types of linkage within particular geographic scopes offers foundations for the evaluation of linkages from both policy and strategic business perspectives beyond the cluster and location specified here.

For a policy perspective, the development of cluster support programmes can benefit from the inclusion of geographic scales and the finding that distance plays distinct roles across different network capital linkages. Our granular evidence on the role of distance for different linkage types supports arguments from network research that analysis should underpin programmes and efforts based on *assumed* network failures i.e. sub-optimal density of networks. The relative density of four linkage types (TN, IP, R&D and GA) appear low pointing to a role for targeted supports for further collaborations. Density may generate negative network impacts, such as lock-in, inertia and status-quo preferences within clusters. Taken as a group, these four linkage types here generate impacts greater than their inputs and so any programme of intervention must be more distinctive in its targets.

Input and outcome indicators assist understanding of network capital relevant for policymakers but also cluster members engaged in networking activities. Data on OI (investment and involvement indicators) provide measures of *business* choices, i.e. strategic organisational decisions and their corresponding operational plans including investments projected to generate positive outcomes. Data on outcomes provide direct measures of those projections and investments in terms of the extent to which organisational absorptive capacity plus acquired knowledge have jointly generated a positive impact.

Impact measures support the view that superior knowledge originates from beyond the home region as 85% of linkages outside Ireland fall into the high and medium category. Supports for developing additional non-national linkages appear appropriate in this context. As an exception, however, linkages with IPs generate positive returns *only* from international linkages: similar positive returns from this geography are evident in the denser category of IA.

Proximity may reduce search and co-ordination costs and our data point to some nuanced considerations. Input impact indicators are highest for linkages with the lowest shares of local linkages (e.g. OU, IN). Returns to network capital inputs are amongst the weakest for the most frequent linkages, where non-local and non-national links vary

between 20% and 70%. Hence, density or frequency of linkages does not align simply with proximity or impact and intensification of density is blunt if the goal is to increase impact.

The singular lack of positive impact across any geography for R&D stands out, a finding evident only from our differentiation of impact. A low-density linkage, R&D is amongst the lowest-ranked (Table 4) in terms of *both* outcomes and input impacts. Our finding does not indicate that benefits are not generated from R&D linkages, only that outcomes align with (i.e. are not greater than) inputs. Perhaps the breadth of knowledge links is a less useful measure of an impact than further insight into depth measures might indicate. For instance, exploitative learning has been associated with transferring deep, fine-grained knowledge in science-technology-innovation mode industries that may characterise ICT. As outlined in Ferreras-Mendez *et al.* (2015), deep relations with external partners is an appropriate means for sharing such knowledge (Yli-Renko *et al.*, 2001). Alternative exploratory learning offers a flexible means to identify appropriable knowledge from collaborations. Explorative capabilities currently demonstrated in cluster firms indicate their commitment to engagement and may be sufficient for their performance, without necessarily generating R&D benefits. It is also possible that through more effective network management, the strategic and intentional investment in network capital could permit the generation of greater outcomes or reduction in input resources or both.

In terms of the specific policy context of the cluster examined, the Irish Government devoted limited resources to cluster policies since the 1990s (Culliton, 1992; Cooke, 1996; NES, 1997, 1998). Interest has been recently revived with programmes announced (Enterprise Ireland, 2012, 2016), however, its focus and investments are removed from what is internationally classified as “national cluster policy” (Van Egeraat and Doyle, 2018; O’Connor *et al.*, 2017). Various cluster initiatives have been supported at the regional level in an *ad hoc* fashion. Through an analysis based on empirical V-LINC analysis, there is scope to address how specific clusters or clustering more generally, might be developed more strategically.

Our refinement of linkage types (supported in Huggins *et al.*, 2012) based on resource-intensive qualitative research points to the need for further research to inform policy development, to include not only improving connectedness or density but also, crucially, impact.

Notes

1. The study was facilitated through an EU-funded FP7-REGIONS project, Grant agreement ID: 319907, *Be Wiser* (Building Enterprises – Wireless and Internet Security in European Regions) granted to authors Byrne and Hobbs: see <http://be-wiser.eu/>
2. IT@Cork is an industry led cluster initiative and achieved the Bronze label for cluster management excellence from the European Secretariat for Cluster Analysis. Established in 1997 the organisation has 200 ICT-related companies using over 11,500 (INNO, 2014a). Its membership include firms providing services to the cluster, such as accounting, legal, financial, hospitality and recruitment. The majority (94%) of IT@Cork’s income is achieved through private subscriptions, sponsorship and event ticket-sales, with the remainder from public funding.
3. Cork county is part of the South-West, NUTS level 3, region (including counties Cork and Kerry) with a population of 542,868 (2016 data: Central Statistics Office, 2016). The GDP of the South-West region in 2015 was €32bn, approximately 18% of Ireland’s total – due to confidentiality concerns no regional data for the South-West was provided as (Central Statistics Office, 2018).
4. Employment and number of enterprises in each region relate to NACE section J (divisions 58–63) encompassing ICT services, software publishing and programming and telecommunications activities.

References

- Antonelli, C. (2008), *Localized Technological Change: Towards the Economics of Complexity*, Routledge, London.
- Antonelli, C., Patrucco, P.P. and Quatraro, F. (2011), "Productivity growth and pecuniary knowledge externalities: an empirical analysis of agglomeration economies in European regions", *Economic Geography*, Vol. 87 No. 1, pp. 23-50.
- Arikan, A.T. (2009), "Interfirm knowledge exchanges and knowledge creation capability of clusters", *Academy of Management Review*, Vol. 34 No. 4, pp. 658-676.
- Arthur, W.B. (1988), "Self-reinforcing mechanisms in economics", in Anderson, P.W., Arrow, K.J. and Pines, D. (Eds), *The Economy as an Evolving Complex System*, Addison-Wesley Publishing Company, Redwood City, CA, pp. 9-31.
- Audretsch, D.B. and Feldman, M.P. (1996), "R&D spillovers and the geography of innovation and production", *American Economic Review*, Vol. 86 No. 4, pp. 253-273.
- Bathelt, H., Malmberg, A. and Maskell, P. (2004), "Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation", *Progress in Human Geography*, Vol. 28 No. 1, pp. 31-56.
- Beaudry, C. and Schifauerova, A. (2009), "Who's right, Marshall or Jacobs? The localization versus urbanization debate", *Research Policy*, Vol. 38 No. 2, pp. 318-337.
- Belussi, F. and Sedita, S.R. (2012), "Industrial districts as open learning systems: combining emergent and deliberate knowledge structures", *Regional Studies*, Vol. 46 No. 2, pp. 165-184.
- Bergman, E.M. and Feser, E.J. (1999), *Industrial and Regional Clusters: Concepts and Comparative Applications*, The Web Book of Regional Science: WV University, available at: www.rii.wvu.edu (accessed 24 February 2021).
- Boschma, R. (2005), "Proximity and innovation: a critical assessment", *Regional Studies*, Vol. 39 No. 1, pp. 61-74.
- Brenner, T. and Schlump, C. (2011), "Policy measures and their effects in the different phases of the cluster life cycle", *Regional Studies*, Vol. 45 No. 10, pp. 1363-1386.
- Breschi, S. and Lissoni, F. (2001), "Knowledge spillovers and local innovation systems: a critical review", *Industrial and Corporate Change*, Vol. 10 No. 4, pp. 975-1005.
- Brosnan, S., Doyle, E. and O'Connor, S. (2016), "From Marshall's triad to porter's diamond: added value?", *Competitiveness Review*, Vol. 26 No. 5, pp. 500-516.
- Burnham, T.A., Freis, J.K. and Mahajan, V. (2003), "Consumer switching costs: a typology, antecedents and consequences", *Journal of the Academy of Marketing Science*, Vol. 31 No. 2, pp. 109-127.
- Ceci, F. and Iubatti, D. (2012), "Personal relationships and innovation diffusion in SME networks: a content analysis approach", *Research Policy*, Vol. 41 No. 3, pp. 565-579.
- Chen, C.W., Chang, M.L., Tseng, C.P., Chen, B.C. and Chang, Y.Y.C. (2013), "Critical human factor evaluation of knowledge sharing intention in Taiwanese enterprises", *Human Factors and Ergonomics in Manufacturing and Service Industries*, Vol. 23 No. 2, pp. 95-106.
- Cohen, W.M. and Levinthal, D.A. (1990), "Absorptive capacity: a new perspective on learning and innovation", *Administrative Science Quarterly*, Vol. 35 No. 1, pp. 128-152.
- Contractor, F.J. and Lorange, P. (2002), *Cooperative Strategies and Alliances*, Elsevier Science, Amsterdam.
- Cooke, P. (1996), "Networking for competitive advantage", Technical report, National Economic and Social Council Report No. 100, Dublin.
- Crespo, J., Suire, R. and Vicente, J. (2014), "Lock-in or lock-out? How structural properties of knowledge networks affect regional resilience", *Journal of Economic Geography*, Vol. 14 No. 1, pp. 199-219.
- Central Statistics Office (2016), Population by County 2016. Retrieved from CSO website: available at: www.cso.ie/en/releasesandpublications/ep/p-rsdgi/regionalsdgsireland2017/nt/#indicatorTitle_175170

-
- Central Statistics Office (2018), Statistical Release, County Incomes and Regional GDP. Retrieved from CSO website: available at: www.cso.ie/en/releasesandpublications/er/cirgdp/countyincomesandregionalgdp2018/
- Culliton, J. (1992), "A time for change: Industrial policy for the 1990's", Technical report, Report by the Industry Policy Review Group, Stationary Office, Dublin.
- Davenport, S. (2005), "Exploring the role of proximity in SME knowledge-acquisition", *Research Policy*, Vol. 34 No. 5, pp. 683-701.
- de Groot, H.L.F., Poot, J. and Smit, M.J. (2015), "Which agglomeration externalities matter most and why", *Journal of Economic Surveys*, Vol. 30 No. 4, pp. 756-782.
- Delgado, M., Porter, M.E. and Stern, S. (2014), "Clusters, convergence, and economic performance", *Research Policy*, Vol. 43 No. 10, pp. 1785-1799.
- Dillman, D., Smyth, J. and Leah-Melani, C. (2014), *Internet, Phone, Mail and Mixed-Mode Surveys: The Tailored Design Method*, 4th ed., John Wiley: Hoboken, NJ.
- Diodato, D., Neffke, F. and O'Clery, N. (2016), "Agglomeration economies: the heterogeneous contribution of human capital and value chains", Center for International Development at Harvard University Working Paper No. 76.
- Drejer, I. and Vinding, A.L. (2007), "Searching near and far: determinants of innovative firms' propensity to collaborate across geographical distance", *Industry and Innovation*, Vol. 14 No. 3, pp. 259-275.
- Duranton, G. (2011), "'California dreaming': the feeble case for cluster policies", *Review of Economic Analysis, Digital Initiatives at the University of Waterloo Library*, Vol. 3 No. 1, pp. 3-45.
- Ellison, G., Glaeser, E.L. and Kerr, W. (2010), "What causes industry agglomeration? Evidence from coagglomeration patterns", *American Economic Review*, Vol. 100 No. 3, pp. 1195-1213.
- Enterprise Ireland (2012), "New €2million clustering programme to promote cooperation between businesses and create more jobs", [Press Release], Release retrieved from EI website available at: www.enterprise-ireland.com/en/News/PressReleases/2012-Press-Releases/New-%E2%82%AC2million-clustering-programme-to-promote-cooperation-between-businesses-and-create-more-jobs-%E2%80%9393-Minister-Bruton.html
- Enterprise Ireland (2016), "Call for pilot clustering programme 2016", Press release retrieved from EI website, available at: www.enterprise-ireland.com/en/management/access-strategic-advice-and-expertise/clustering-programme.html
- Falck, O., Heblich, S. and Kipar, S. (2010), "Industrial innovation: direct evidence from a cluster-oriented policy", *Regional Science and Urban Economics*, Vol. 40 No. 6, pp. 574-582.
- Ferreras-Mendez, J.L., Newell, S., Fernandez-Mesa, A. and Alegre, J. (2015), "Depth and breadth of external knowledge search and performance: the mediating role of absorptive capacity", *Industrial Marketing Management*, Vol. 47, pp. 86-97.
- Fitjar, R.D. and Rodríguez-Pose, A. (2011), "Innovating in the periphery: firms, values and innovation in southwest Norway", *European Planning Studies*, Vol. 19 No. 4, pp. 555-574.
- Fritsch, M. and Kauffeld-Monz, M. (2010), "The impact of network structure on knowledge transfer: an application of social network analysis in the context of regional innovation networks", *The Annals of Regional Science*, Vol. 44 No. 1, pp. 21-38.
- Gardner, J.T. and Cooper, M.C. (2003), "Strategic supply chain mapping approaches", *Journal of Business Logistics*, Vol. 24 No. 2, pp. 37-64.
- Gatto, M. (2015), *Making Research Useful: Current Challenges and Good Practices in Data Visualisation*, Reuters Institute for the Study of Journalism.
- Giuliani, E. (2013), "Network dynamics in regional clusters: evidence from Chile", *Research Policy*, Vol. 42 No. 8, pp. 1406-1419.
- Grabher, G. and Ibert, O. (2006), "Bad company? The ambiguity of personal knowledge networks", *Journal of Economic Geography*, Vol. 6 No. 3, pp. 251-271.

-
- Graf, H. and Broekel, T. (2020), "A shot in the dark? Policy influence on cluster networks", *Research Policy*, Vol. 49 No. 3.
- Granovetter, M. (1973), "The strength of weak ties", *American Journal of Sociology*, Vol. 78 No. 6, pp. 1360-1380.
- Grossman, G.M. and Helpman, E. (1994), "Endogenous innovation in the theory of growth", *Journal of Economic Perspectives*, Vol. 8 No. 1, pp. 23-44.
- Hansen, M.T. and Birkinshaw, J. (2007), "The innovation value chain", *Harvard Business Review*, Vol. 85 No. 6, pp. 121-130.
- Harris, T. and Hardin, J.W. (2013), "Exact Wilcoxon signed-rank and Wilcoxon Mann-Whitney rank-sum tests", *The Stata Journal: Promoting Communications on Statistics and Stata*, Vol. 13 No. 2, pp. 337-343.
- Hasan, S. and Koning, R. (2017), "When proximity may not be destiny: the role of existing relationships", Working Paper, SSRN, accessed February, 2021.
- Hobbs, J. (2010), "A framework for analysis of spatial specialisations of industry", Unpublished PhD thesis, Cork Institute of Technology, Cork.
- Hospers, G. and Beugelsdijk, S. (2002), "Regional cluster policies: learning by comparing?", *Kyklos*, Vol. 55 No. 3, pp. 381-402.
- Huber, F. (2012), "Do clusters really matter for innovation practices in information technology? Questioning the significance of technological knowledge spillovers", *Journal of Economic Geography*, Vol. 12 No. 1, pp. 107-126.
- Huggins, R. (2000), *The Business of Networks: Inter-Firm Interaction, Institutional Policy and the TEC Experiment*, Routledge, Abingdon.
- Huggins, R. (2010), "Forms of network resource: knowledge access and the role of inter-firm networks", *International Journal of Management Reviews*, Vol. 12 No. 3, pp. 335-352.
- Huggins, R. (2016), "Capital, institutions and urban growth systems", *Cambridge Journal of Regions, Economy and Society*, Vol. 9 No. 2, pp. 443-643.
- Huggins, R. and Thompson, P. (2014), "A network-based view of regional growth", *Journal of Economic Geography*, Vol. 14 No. 3, pp. 511-545.
- Huggins, R. and Thompson, P. (2015), "Entrepreneurship, innovation and regional growth: a network theory", *Small Business Economics*, Vol. 45 No. 1, pp. 103-128.
- Huggins, R. and Weir, M. (2007), "Intellectual assets and public policy", *Journal of Intellectual Capital*, Vol. 8 No. 4, pp. 708-720.
- Huggins, R., Thompson, P. and Johnston, A. (2012), "Network capital, social capital, and knowledge flow: how the nature of inter-organisational networks impacts on innovation", *Industry and Innovation*, Vol. 19 No. 3, pp. 203-232.
- Jaffe, A., Trajtenberg, M. and Henderson, R. (1993), "Geographic localization of knowledge spillovers as evidenced by patent citations", *The Quarterly Journal of Economics*, Vol. 108 No. 3, pp. 577-598.
- Kale, P. and Singh, H. (2007), "Building firm capabilities through learning: the role of the alliance learning process in alliance capability and firm-level alliance success", *Strategic Management Journal*, Vol. 28 No. 10, pp. 981-1000.
- Laurson, K. and Salter, A. (2006), "Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms", *Strategic Management Journal*, Vol. 27 No. 2, pp. 131-150.
- Lavrakas, P. (2008), *Encyclopedia of Survey Research Methods*, Sage, CA.
- Leydesdorff, L. (2012), "The triple helix, quadruple helix, . . . , and an n-tuple of helices: explanatory models for analyzing the knowledge-based economy?", *Journal of the Knowledge Economy*, Vol. 3 No. 1, pp. 25-35.
- Lichtenthaler, U. (2005), "External commercialization of knowledge: review and research agenda", *International Journal of Management Reviews*, Vol. 7 No. 4, pp. 231-255.

-
- Lindner, I. and Strulik, H. (2014), "From tradition to modernity economic growth in a small world", *Journal of Development Economics*, Vol. 109 No. 1, pp. 17-29.
- Love, J.H., Roper, S. and Vahter, P. (2014), "Learning from openness: the dynamics of breadth in external innovation linkages", *Strategic Management Journal*, Vol. 35 No. 11, pp. 1703-1716.
- McCann, P. and Ortega-Argiles, R. (2013), "Modern regional innovation policy", *Cambridge Journal of Regions, Economy and Society*, Vol. 6 No. 2, pp. 187-216.
- Malmberg, A. and Power, D. (2005), "(How) do (firms in) clusters create knowledge", *Industry and Innovation*, Vol. 12 No. 4, pp. 409-431.
- Marshall, A. (1921), *Principles of Economics*, Macmillan, London.
- Martin, R., Mayer, T. and Mayneris, F. (2011), "Public support to clusters: a firm level study of French 'local productive systems'", *Regional Science and Urban Economics*, Vol. 41 No. 2, pp. 108-123.
- Miguelez, E. and Moreno, R. (2015), "Knowledge flows and the absorptive capacity of regions", *Research Policy*, Vol. 44 No. 4, pp. 833-848.
- Napier, G. and Bjerregaard, H. (2013), "Towards an international food cluster in Denmark", The Danish Cluster Academy, available at: <https://www.rm.dk/siteassets/regional-udvikling/ru/publikationer/fodevarer/towards-an-international-food-cluster-in-denmark.pdf> (accessed February 2021).
- NESC (1997), "Clusters in Ireland", Technical report, National Economic and Social Council (Research Series Nos. 1-3), Dublin.
- NESC (1998), "Sustaining competitive advantage: Proceedings of NESC seminar", Technical report, National Economic and Social Council, Dublin.
- Nieto, M.J. and Santamaria, L. (2010), "Technological collaboration: bridging the innovation gap between small and large firms", *Journal of Small Business Management*, Vol. 48 No. 1, pp. 44-69.
- O'Connor, S., Doyle, E. and Brosnan, S. (2017), "Clustering in Ireland: development cycle considerations", *Regional Studies, Regional Science*, Vol. 4 No. 1, pp. 263-283.
- OECD (2001), *The Well-Being of Nations: The Role of Human and Social Capital*, OECD, Paris.
- Porter, M.E. (1990), *The Competitive Advantage of Nations*, Free Press, New York, NY.
- Porter, M.E. (1998a), "Clusters and the new economics of competition", *Harvard Business Review*, Vol. 76 No. 6, pp. 77-90.
- Porter, M.E. (1998b), *On Competition*, Harvard Business School Press, Boston, MA.
- Purchase, H.C., Cohen, R.F. and James, M. (1997), "An experimental study of the basis for graph drawing algorithms", *ACM Journal of Experimental Algorithmics*, Vol. 2 No. 4, pp. 1-17.
- Putnam, R. (2000), *Bowling Alone: The Collapse and Revival of American Community*, Simon and Schuster, New York, NY.
- Sammarrà, A. and Biggiero, L. (2008), "Heterogeneity and specificity of inter-firm knowledge flows in innovation networks", *Journal of Management Studies*, Vol. 45 No. 4, pp. 800-829.
- Schott, T. and Wickstrom Jensen, K. (2016), "Firms' innovation benefiting from networking and institutional support: a global analysis of national and firm effects", *Research Policy*, Vol. 45 No. 6, pp. 1233-1246.
- Scotchmer, S. (2004), *Innovation and Incentives*, Harvard University Press, Cambridge, MA.
- Simonin, B.L. (1999), "Transfer of marketing know how in international strategic alliances: an empirical investigation of the role and antecedents of knowledge ambiguity", *Journal of International Business Studies*, Vol. 30 No. 3, pp. 463-490.
- Smith, M., Wilson, J.R. and Wise, E. (2020), "Evaluating clusters: where theory collides with practice", *Regional Science Policy and Practice*, Vol. 12 No. 3, pp. 413-430.
- Sölvell, Ö., Ketels, C. and Lindqvist, G. (2009), *The European Cluster Observatory: EU Cluster Mapping and Strengthening Clusters in Europe*, Center for Strategy and Competitiveness (CSC), Stockholm.
-

-
- Sölvell, Ö. and Protsiv, S. (2008), *Cluster Strengths and Regional Innovation*, Stockholm School of Economics, Stockholm.
- Speldekamp, D., Saka-Helmhout, A. and Knobens, J. (2020), "Reconciling perspectives on clusters: an integrative review and research agenda", *International Journal of Management Reviews*, Vol. 22 No. 1, pp. 75-98.
- Suire, R. and Vicente, J. (2009), "Why do some places succeed when others decline? A social interaction model of cluster viability", *Journal of Economic Geography*, Vol. 9 No. 3, pp. 381-404.
- Suire, R. and Vicente, J. (2014), "Clusters for life or life cycles of clusters: in search of the critical factors of clusters' resilience", *Entrepreneurship and Regional Development*, Vol. 26 Nos 1/2, pp. 142-164.
- Tallman, S. and Phene, A. (2007), "Leveraging knowledge across geographic boundaries", *Organization Science*, Vol. 18 No. 2, pp. 252-260.
- Tödtling, F., Lengauer, L. and Höglinger, C. (2011), "Knowledge sourcing and innovation in 'thick' and 'thin' regional innovation systems: comparing ICT firms in two Austrian regions", *European Planning Studies*, Vol. 19 No. 7, pp. 1245-1276.
- US Cluster Mapping (2015), "U.S. Cluster mapping project, institute for strategy and competitiveness, Harvard business school", available at: <http://clustermapping.us/cluster/biopharmaceuticals> (accessed February 2021).
- Van Egeraat, C. and Doyle, E. (2018), "Rethinking Irish cluster policy", *Administration*, Vol. 66 No. 1, pp. 107-128.
- Vicente, J. (2017), "Network failures and policy challenges along the life cycle of cluster", in Fornahl, D. and Hassink, R. (Eds), *The Life Cycle of Clusters: A Policy Perspective*, Edward Elgar, Cheltenham, pp. 56-75.
- Volberda, H.W., Foss, N.J. and Lyles, M.A. (2010), "Absorbing the concept of absorptive capacity: how to realize its potential in the organization field", *Organization Science*, Vol. 21 No. 4, pp. 931-951.
- Vorley, T., Mould, O. and Courtney, R. (2012), "My networking is not working! Conceptualizing the latent and dysfunctional dimensions of the network paradigm", *Economic Geography*, Vol. 88 No. 1, pp. 77-96.
- Williamson, O. (1993), "Calculativeness, trust, and economic organization", *The Journal of Law and Economics*, Vol. 36 No. 1, Part 2, pp. 453-486.
- Wolfe, D. (2009), "Introduction: embedded clusters in the global economy", *European Planning Studies*, Vol. 17 No. 2, pp. 179-187.
- Wolman, H. and Hincapie, D. (2014), "Clusters and cluster-based development policy", *Economic Development Quarterly*, Vol. 29 No. 2, pp. 135-149.
- Yli-Renko, H., Autio, E. and Sapienza, H.J. (2001), "Social Capital, knowledge acquisition, and knowledge exploitation in young technology-based firms", *Strategic Management Journal*, Vol. 22 Nos 6-7, pp. 587-613.
- Zahra, S. and George, G. (2002), "Absorptive capacity: a review, reconceptualization, and extension", *The Academy of Management Review*, Vol. 27 No. 2, pp. 185-203.

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