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High Technology Clusters, Flagship MNE Subsidiaries, and Mothership Ecosystems: Specialisation, Adaptation and Connectivity in Staving off Cluster Malaise

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Abstract

This paper links the literatures from international business and economic geography to explore how an industrial cluster extends its life-cycle and overcomes the vulnerabilities of technological specialization. The role of the MNE subsidiary and ancillary cluster members in this process is examined in a longitudinal study of the birth, growth and extended maturity of an Irish technological cluster. The case reveals the significance of interplays between the MNE subsidiary, the cluster that the subsidiary is a member of (the subsidiary?s ?host? cluster) and the parent company that is often itself part of a cluster (the parent?s ?home? cluster) in developing varied technological activity. Just as subsidiaries can ?tap into? the local cluster to source knowledge, local technological entrepreneurs can reverse the flow and access knowledge from the MNE parent?s home cluster.

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ABSTRACT

This paper links the literatures from international business and economic geography to explore how an industrial cluster extends its life-cycle and overcomes the vulnerabilities of technological specialization. The role of the MNE subsidiary and ancillary cluster members in this process is examined in a longitudinal study of the birth, growth and extended maturity of an Irish technological cluster. The case reveals the significance of interplays between the MNE subsidiary, the cluster that the subsidiary is a member of (the subsidiary's 'host' cluster) and the parent company that is often itself part of a cluster (the parent's 'home' cluster) in developing varied technological activity. Just as subsidiaries can 'tap into' the local cluster to source knowledge, local technological entrepreneurs can reverse the flow and access knowledge from the MNE parent's home cluster.

INTRODUCTION

Technological clusters have their genesis in university science (Braunerhjelm and Helgesson 2006, Charles and Benneworth, 2001; Rosenberg, 2002), entrepreneurship (Feldman and Braunerhjelm 2006) or pioneering multinationals (Manning, 2008). Capabilities are created and developed in such clusters - indeed, technological capabilities are the main stream of cluster well-being (Best, 2001; 2005) and are manifest in a firm's ability to shape and integrate core competencies with external resources and complementary assets (Teece et al, 2000). Micro-level firms' capabilities aggregate into cluster capabilities that are locally distinctive and have evolved across its enterprises, both foreign and indigenous, over time. The cluster's internal capabilities are embedded in the products, processes and skills of the local milieu.

As a cluster evolves, it benefits from the learning associated with its increasing specialization. Spillovers, spinoffs, spinouts and increased foreign investment drive the technological cluster's vibrancy around its distinctive specialization, and as its success becomes more notable the cluster develops substantial reputational capital (Giblin and Ryan, 2010). MNEs establish subsidiaries in clusters to access specialised capabilities, and the cluster's position in an MNE's (Multinational Enterprise) global value chain is enhanced as its specialized technological capabilities become increasingly valued. At the same time, however, as their technological capabilities becomes more specialized, it is increasingly vulnerable to the phenomenon of technological lock in (Narula, 2002; Martin and Sunley, 2003), and thus to disruptive technology (Bower and Christensen, 1995), which could lead to its downgrading in the global value chain, the potential loss of its hard-earned reputational capital, and its consequent exhaustion or 'hollowing-out': or even more disastrously to its extinction through technological 'wipe-out'. To stave off such a possibility, technological clusters must continuously upgrade and intensify their knowledge-intensive capabilities

(Porter, 1990; Cantwell and Santagelo, 1999; Narula and Zanfei, 2005; Best, 2005).

Such technological clusters have life-cycles (Malmberg and Maskell, 2002; Feldman et al, 2005; Jenkins and Tallman, 2010) - they form, grow, mature and can become extinct (Saxenian, 1994; Brenner, 2004; Bathelt et al, 2004; Martin and Sunley, 2003). However, the role of MNEs in cluster life stages and in particular how the external connectivity offered by MNEs could impact the life stages of clusters is not well developed in the literature. How technological clusters can maintain their growth phases, extend their maturity phases and fight possible extinction is under-researched in a literature preoccupied with their genesis and growth.

MNEs are the architects of global knowledge systems, and MNE subsidiaries are often the conduits of knowledge flows within and between clusters (Andersson et al, 2002, 2007; Carlson and Mudambi, 2003; Lundvall, 2007; Mudambi and Swift, 2012). Knowledge transfer is a social process whereby valuable knowledge flows through social networks (Guiliani, 2007), thus social relationships are critical to knowledge flows between clusters (Agrawal et al. 2003. Mudambi and Navarra (2004) describe three types of knowledge flows; first, from the MNE subsidiary to the parent, second from the subsidiary to the subsidiary's host cluster and third from the subsidiary's host cluster to the subsidiary itself, and much work has been done on how these knowledge flows enhance the cluster's technological capabilities (Mudambi and Swift, 2012) and can even serve to bring it into existence (Cooke, 2004; Manning, 2008; Giblin and Ryan, 2010). The MNE subsidiary becomes a 'flagship' firm - a coordinator and advocate for the cluster (Rugman and D'Cruz, 2000) - that both taps into and shapes, directs and determines the technological trajectory of the cluster. However, over time, that technological trajectory can become highly vulnerable to technological lock-in (Hassink, et al, 2005; Bergman, 2008) and institutional inertia (Narula, 2002).

While MNE subsidiaries may shape the technology that impacts the cluster in which they are member of (that is, the subsidiary's host cluster), it can often take a long time for the subsidiary's host cluster to develop a full-range, first-tier ecosystem. The parent company may itself belong to a technology cluster (the parent's home cluster) that is commonly a technology creator, with a world-class research university and flourishing technological entrepreneurship, and it is likely to have institutional thickness to venture capitalists, enterprise agencies, legal experts, patent authorities, etc. Therefore, there is an interplay between the subsidiary, the subsidiary's host cluster and the parent's home cluster.

We address this interplay in this paper, which reports on a revelatory longitudinal case study of a technological cluster as it expands, specializes, matures and endeavors to evade exhaustion and extinction, with a particular focus on the roles of MNE subsidiaries and ancillary cluster members. Our primary objective is to explore the processes by which a cluster overcomes the vulnerabilities of over-dependence on a technological specialization and thus potential obsolescence. We report on how a mature cluster can extend its life span through adaptation and variation, initially in related technology and product categories, and subsequently in less related arenas of more original technologies and products

More specifically, the paper examines how an MNE subsidiary's product development mandate evolves and expands as it exhibits enhanced capabilities, often gained by tapping into the local cluster's knowledge base; how the interaction between industry and academia occurs in creative thinking spaces in which the partners feel more liberated to develop new technological trajectories; how academic entrepreneurs introduce new products in new categories; how MNE subsidiaries act as incubators of soft managerial skills and entrepreneurial know-how that lead to new firm spinouts in both related and unrelated technologies, and how they grease the spokes of global networks and provide valuable access to their parent's home cluster ecosystem to host cluster members.

The MNE's home technology cluster is commonly a technology creator, with a world-class research university and flourishing technological entrepreneurship, and it is likely to have institutional thickness to venture capitalists, enterprise agencies, legal experts, patent authorities, etc.. This paper describes how such social capital is afforded to, acquired and utilized by ancillary members of a host cluster. It reveals how second-tier technological clusters fit into the global hierarchy of technology clusters, and identifies the gatekeepers and brokers of knowledge in these uncorked social networks and the strength or weakness of their extant bridging and binding ties.

MNES IN INDUSTRIAL CLUSTERS

While there is general consensus on the symbiotic value between MNE subsidiaries and technology clusters, there is less agreement as to their role in cluster formation. Cluster formation has been seen to be driven by entrepreneurs (Birkinshaw et al, 2011; Wolfe and Gertler, 2006; Feldman et al. 2005; Feldman and Braunerhjelm, 2006) and research universities (Braunerhjelm and Helgesson 2006, Charles and Benneworth, 2001; Rosenberg, 2002): studies of how MNE subsidiaries instigate the formation of a local cluster as their arrival and presence trigger activities that develop into a cluster (Jacobson and Mottiar, 1999; Cooke, 2004; O'Gorman and Kautonen, 2004; Manning, 2008; Giblin and Ryan, 2010) are less common (although some exist). Some studies have questioned the sustainability of such clusters due to concerns over embeddedness, the extent of spillover, the substance of linkages with local suppliers, and the capability and stickiness of the MNE subsidiary (Birkinshaw and Hood, 2000; De Propris and Driffield, 2006; Phelps, 2008).

Manning (2008), however, illustrates how what he terms 'pioneer MNEs' customize local institutions and business practices, and so promote the initial development and sustainability of the technological cluster, often to shape their sourcing needs in secondary or unexplored locations. Enterprise agencies and academic institutions respond to arrival of their subsidiaries - commonly in search of lower cost resources in unexplored or second-tier locations - by providing relevant specialized resources, skills and technological capabilities (Giblin and Ryan, 2010). Such locations are unlikely initially to possess the specialized skills and capabilities of dominant first-tier technology clusters, but local policy makers, enterprise associations, institutions and indigenous enterprises will also respond to the presence of a pioneer MNE. As the location develops more sophisticated and specialized resources and capabilities, follower MNEs are attracted to the developing specialized skill pools, technological capabilities, related services and supportive institutions.

MNEs thus locate knowledge-creation activities in specialized technological clusters, which Lundvall (2007) termed ‘local innovation systems’, regions which possess a plentiful supply of specialized knowledge workers (Mudambi and Swift, 2012). At this local level, subsidiaries develop and advance their own managerial and technological capabilities (Cantwell and Mudambi, 2005), and the MNE subsidiary embeds itself in such local networks to access knowledge Andersson et al, (2002, 2007) or act as commercial listening post (Enright, 1998). This is a *“symbiotic process whereby MNEs set up operations to take* advantage of local competencies and, in turn, provide these locations with knowledge *inflows....strengthening local competencies”* (Mudambi, 2002).

Over time, the presence of the MNE subsidiary extends the dynamics of the cluster, often through its ability to commercialize local university scientific research (Agrawal and Cockburn, 2003 Carlsson and Mudambi, 2003). Large R&D intensive MNEs commonly function as anchors (Agrawal and Cockburn, 2003; Feldman 2003; Giblin, 2011) in networks of universities, competitors, suppliers and start ups, bringing with them their business models, international quality standards, reputation capital, process knowhow and their extant, ready to go markets (Giblin and Ryan, 2010; Giblin, 2011). They also serve to link the cluster to other first-tier clusters to for global networks and enhance their international reputation (Malmberg and Maskell, 2002). Frost et al. (2002) found that the more globally interdependent a subsidiary is, the deeper were its relationships with local network counterparts (and vice versa) through which both sides access specialized knowledge. Markusen (1996), however, argues that clusters can be weakened by dependence on large subsidiaries that maintain their external linkages with other subsidiaries and their HQs, but may neglect the local milieu, in what she terms 'satellite platform-type' industrial districts.

MNEs: Conduits of Knowledge Within and Between Industrial Clusters

MNEs serve as conduits for knowledge transfer both within and between clusters, and such internal and external knowledge flows enhance the cluster's dynamic evolution (Mudambi, 2002). Mudambi and Navarra (2004) describe three types of knowledge flows: first, from the subsidiary to the corporate parent so that HQ can benefit from locally sourced knowledge; second, from the host location to the subsidiary, allowing it to exploit its absorptive capacity by tapping into local competencies; and third, from the subsidiary to the local cluster, in which the former's competencies and capabilities spillover and to benefit local firms. MNEs have been found to both capture and to transmit valuable tacit knowledge (Mudambi and Swift, 2012).

Such subsidiaries operate in a *"dual-network"* of local and global connectivity and membership (Meyer et al, 2011) which Birkinshaw and Peterson (2008) see as a *"daunting challenge"*. This dual embeddedness may confer great advantages for the MNE, enabling it to operate simultaneously in internal and external networks, but there is a tension between granting the subsidiary the autonomy to embed itself into and operate in the cluster to create competencies, while still remaining integrated in the MNE, which can cause MNEs concerns about losing control over the subsidiary (Mudambi and Navarra, 2004) and thus lose its attendant ability to leverage knowledge from its multiple embeddedness (Meyer et al, 2011).

MNEs can also connect the cluster to other clusters in global locations (Hervas-Oliver et al, 2008), so improving the cluster's external connectivity. There is a hierarchy of clusters and the MNE is again the conduit between them. First- tier clusters are often the home-base of flagship MNEs that create the distributed networks of subsidiaries, which they commonly locate in second-tier cluster or even in unexplored regions (Manning, 2008). As well as such vertical linkages there are horizontal linkages across a finely sliced value chain of clusters which each have their embedded MNE subsidiaries. Thus MNEs link technological clusters together, and also facilitate their access to lower-order servicing clusters (Bathelt et al, 2004), so as well as acting as a fulcrum or anchor for the cluster, MNE subsidiaries can also anchor clusters of higher or lower orders in a 'hub and spoke' type network, where interactions are facilitated by MNE subsidiaries and coordinated by their MNE HQs in the first-tier clusters. MNEs act as a boundary spanners in a distributed global network and an ever more complex global value chain.

Technology *"clusters can rise or decline"* (Jenkins and Tallman, 2010) - they have life cycles, and their constant imperative is to remain open to those advantages that flow from the parent MNE's external linkages(Narula and Dunning, 2010). A number of studies have reported on the emergence, growth and decline of industrial clusters (Malmberg and Maskell, 2002; Tappi, 2005; Bergman, 2008), and many conditions and factors have been identified as relevant at each stage of the cycle (Menzel and Fornahl, 2009). In the mature stage, over-dependence on its specialization and excessive standardization, despite beneficial efficiencies and knowhow, can result in 'lock-in' to technological capabilities (Hassink et al, 2005; Malmberg and Maskell, 2002), and institutional inertia (Narula, 2002), leaving it seriously vulnerable to a disruptive technology that can cause technological obsolescence, exhaustion and to the cluster 'hollowing-out' or even its extinction. The cluster, therefore, needs to protect itself from and stave off technological inertia.

Entrepreneurs must be encouraged to introduce new technological possibilities and new product categories that either complement or replace existing specializations, and the cluster must aim to reshape itself by learning from and building on the knowledge of existing MNE affiliates as well as other types of organizations, such as universities or public research centers. If entrepreneurs are the agents of change, MNE affiliates may act as a source and conduit of the requisite knowledge, and as such can anchor and possibly extend clusters' lifespans (Giblin and Ryan, 2010). Combining local knowledge held in the technological cluster with international knowledge and technologies gained from MNE affiliates facilitates variation of activities around the global value chain's higher order needs. Zaheer and Nachum (2011) have coined the term *"location capability"* (p. 96) where an MNE both recognizes place potential and how to avail itself of it. Subsidiaries in high-order value-creating clusters, with expanded mandates from HQ (Meyer et al, 2011), spill over and advance technological and business model knowhow into local clusters. Local supplier firms upgrade and sometimes even, over time, surpass the technological capabilities of the transplanting subsidiary through accelerated learning and assets assembly (Makino et al, 2002), allowing them to operate outside their local cluster and become a preferred supplier in their home cluster.

Technology entrepreneurs that operate freely and widely across a global environment of social networks act as boundary spanners or brokers to gatekeepers of technological and commercial knowhow. Such entrepreneurs can connect to expertise from outside their local cluster. Dai and Liu (2009) found, for instance, that diaspora returnee entrepreneurs outperform their local counterparts by possessing more sophisticated knowledge, more international orientations and greater involvement in global networks, via which they can accelerate local development (Sonderegger and Taube, 2010). Bel and Fageda, (2008) go as far as to suggest that such enhanced connectivity outweighs resource availability as a criterion for cluster success. Furthermore, such entrepreneurs diffuse information and knowledge and bridge ties to span geographical boundaries and to access resources. These entrepreneurs are commonly ex-employees of MNE's that spin out and undertake start ups (Klepper, 2001), utilizing the contacts and knowledge of both local clusters and global operations they gained while working for the MNE subsidiary. This social process requires a greater understanding than is currently reflected in the literature, and is addressed in this case study.

METHODOLOGY

This study adopts a longitudinal mixed-method case study approach (Eisenhardt, 1989; Welch, Piekkari, Plakoyiannaki, and Mantymaki, 2011) to examine the research questions set out above, an approach which offers multiple benefits for studying the issues involved. First, a recent review of the state of the art on linkages between international trade theory, economic geography, strategy and international business (Beugelsdijk, McCann and Mudambi, 2010) has explicitly called for detailed and sophisticated firm-level, industry level and regional-level case studies to open the 'black box' of the organizational and knowledge relationships which mediate and facilitate the links between place and space, and between multiple locations and MNE behaviour: our case approach offers vital insights into important phenomena in this context, something which is often overlooked in the pursuit of robust explanation (Welch et al, 2011). Second, extant research on clusters has largely been cross-sectional and has failed to track the evolution of clusters and of the firms within them over time (Mudambi and Swift, 2012) and particularly the process by which a cluster overcomes the vulnerabilities of being over-dependent on a technological specialization, and the potential obsolescence. This research gap has limited our understanding of how a technological cluster can maintain its growth phase, extend its maturity phase and guard against possible extinction. The data set produced for this study offers important insights into cluster formation, growth, evolution and particularly the dynamics of mature clusters. Our aim is to provide thick description (Birkinshaw, Brannen and Tung, 2011) - particularly of clusters' mature stages - which is lacking in much of the extant literature on clusters and in international business more generally.

The Galway Medical Devices Cluster

Over the past thirty years or so Ireland has evolved from a relative economic backwater (Powell, 2003) to one of the world's most foreign direct investment (FDI)-dependent economies (Barry and Kearney, 2006; Ernst and Young, 2011; McDonnell, Lavelle, Gunnigle and Collings, 2007; Giblin and Ryan, 2010). Thus the stock of FDI per head of population in 2000 was twice the EU average (Barry, 2004), while by 2006 US investment in Ireland totaled some US$83 billion, larger than the combined US investment in all the BRIC economies (Hamilton and Quinlan, 2008). Notwithstanding the fact that Ireland was one of the first 'eurozone' countries to fall into recession at the start of the current global economic crisis (Central Statistics Office, 2008), its FDI sector has continued to perform relatively well (IDA Ireland, 2011; Irish Management Institute, 2011). FDI in Ireland is concentrated in a number of key sectors[i]. By far the largest concentration is in international and financial services (including software) which employs almost 63,000 people; the second largest sector is medical/dental instruments and supplies (approximately 22,000 employees), followed by pharmaceuticals (almost 21,0000 employees) and computer, electronic, and optical equipment (16,500 employees) (Forfas, 2010).

Our study focuses on one key sector of activity in the Irish economy - the medical devices sector. As noted above it is significant employer in the Irish context and fifteen of the world's top twenty medical device companies have Irish operations (IDA Ireland, 2010). Although the MNE sector is by far the most significant player, a small base of indigenous companies bring total employment to approximately 24,000 over some 140 companies (Irish

Medical Devices Association (IMDA, 2010). Activity in this sector is concentrated quite heavily in the West of Ireland, with Galway as its economic centre (Forfas, 2008: 23; Giblin and Ryan, 2010). Thus the unit of analysis for our study is the West of Ireland medical devices cluster, with a particular focus on Galway. Our empirical analysis is based on a longitudinal mixed-method case study approach (Eisenhardt, 1989; Welch, Piekkari, Plakoyiannaki, and Mantymaki, 2011), and encompasses two distinct but related studies, as outlined below.

STUDY 1:

Having chosen to focus on the Galway medical devices cluster, the first stage of our study set out to consider the development of soft capabilities and their importance in the cluster context, focusing on understanding the dynamics of the softer capabilities, and on how they developed and were deployed in the West of Ireland medical devices cluster. In line with Beugelsdijk et al's (2010) call for more nuanced research, this stage provided important insights at the industry and regional levels by focusing on the development and evolution of the cluster's ecosystem for which a qualitative methodology was deemed appropriate. The primary data collection method was semi-structured qualitative interviews with subjects selected according to their expert knowledge of the cluster's dynamics, and thus their potential for contributing to theory building (Eisenhardt, 1989). In total, twenty five interviews were conducted with key stakeholders in the regional medical devices sector. Nine were with representatives of key interest groups in the sector, including industry associations, regional development agencies, policy and industrial development agencies, and academic institutions, which provided us with an important understanding about the context of the sector. The other sixteen interviews were with managers of medical device companies in the cluster, including thirteen with indigenous entrepreneurs who had established start-up firms in the cluster, and three with senior managers of large locally-based MNE subsidiaries.

Recognizing the role of the entrepreneur at the centre of cluster development, the former provided significant insights into the nature and source of the capabilities entrepreneurs deployed in starting their own business, and - in contrast - the latter provide some initial insights into the role of the MNE in the cluster, which we explored in greater detail in study two.

The data was collected in two key time-blocks. In 2005 three interviewees were conducted with the senior MNE subsidiary managers, nine with key interest groups and another three with entrepreneurs from indigenous cluster firms. In 2010 the interviews focused on indigenous entrepreneurs (including two of the three from 2005 - the third company had been acquired by an MNE in the interim). (This second round of interviews did not focus on the MNE sector, as they were interviewed in 2008 for study two.)

STUDY 2:

Having gained an understanding of the technical capabilities which characterized the cluster and of the industry and regional ecosystem in which the cluster formed and evolved, we next focused on the firm level, in line with Beugelsdijk et al's (2010) suggestion. Specifically, we conducted in-depth case studies of four key MNE subsidiaries which were central players in the cluster. The study employed a multiple (Yin, 1994) or collective (Stake, 1998) case study approach. In selecting our cases we sought MNE subsidiaries that varied in size and turnover, but two key criteria informed our selection: each case was an MNE subsidiary in the medical technology/devices sector based in the regional cluster (Galway); and second, given that our study setting meant we only studied MNE subsidiaries in the medical technology/devices sector based in the Galway regional cluster, apart from selecting MNE subsidiaries that varied in size and turnover, a key criterion that informed our selection, was that each case selected was an innovation-active subsidiary that had a formal research and development (R&D) unit on site. Data collection in each case was primarily through semi-structured interviews and documentary analysis, which focused on corporate websites, newspaper reports, industry websites and magazines and internal company documentation provided by interviewees (such as corporate policies, magazines, annual reports etc). In all, we conducted twenty-three qualitative interviews for Study two between March and June 2008. Interviewees included a cross section of key informants at each subsidiary. In each case the initial interviewees were the most senior manager in the local operation, R&D managers, senior R&D staff and product managers.

Data analysis

Although data analysis was ongoing throughout the project, the analysis that forms the basis of this study was completed after the project was ended. The analysis for the current paper brings together the key insights from the two related studies identified above.

We examined the data using a basic template (King, 2004) that we developed from the literature on cluster formation and the processes by which they overcome the vulnerabilities of over-dependence on a technological specialization and the potential obsolescence involved. Given our level of analysis was the Galway cluster, we were interested in understanding the key themes as they related to that cluster, although clearly the firm level was also important in understanding the context of the various interview responses (from which the quotes in this paper are taken). Our analysis was conducted by combining and comparing the data from the two studies outlined above, and used sensitizing concepts (Blumer, 1959) drawn from the clusters life cycles, IB and economic geographies literatures summarized above to interpret and group the data.

FINDINGS

The Role of Upgrading MNEs in Cluster Genesis and Development

The starting point for the Galway medical technology cluster was the arrival in 1982 of the pioneer MNE then known as CR Bard, which after a number of takeovers morphed into Medtronic, but it was the arrival in 1994 of the global industry leader Boston Scientific that heralded an explosion of cluster entries. Boston Scientific was attracted to the Galway region and incentivized by the Irish Industrial Development Agency (IDA) to avail themselves of the vacant production facility recently vacated by the closure of Digital's manufacturing plant and the plentiful supply of ex-Digital assembly workers, as well as by some fiscal attractors. Initially, both CR Bard's and Boston Scientific's assembly operations were simple, and placed the plants at the bottom of their value chains, and neither corporate parent had given their subsidiary a product development mandate. But, remarkably, by 2011 the cluster had evolved into a globally-renowned, vibrant and dynamic technology cluster, with over 40 manufacturing firms including eight of the world's ten top medical device MNEs. Its members have world-class research and development skills and facilities and partner first-tier clusters in the industry global hierarchy, and the cluster as a whole has accrued significant reputational, technological and social capital. The absorptive capacity of the technology cluster's subsidiaries has played a fundamental role in capturing the benefits of knowledge spillovers, and depends greatly on the extent to which the subsidiaries are embedded in their international environments.

The local region swiftly responded to the presence of Boston Scientific and Medtronic. The local university - the National University of Ireland, Galway - answered the requirements for a specialized labor pool, introducing its first biomedical engineering degree in 1998, within the Department of Mechanical Engineering, which then the Department of Mechanical and Biomedical Engineering in 2002 it producing greater graduate numbers (Giblin and Ryan 2010).

The MNE subsidiaries also encouraged local suppliers to raise their standards while producing related cardiology products such as guidewires, balloon catheters, hypo-tubes and filters, which are used in balloon angioplasty and stenting procedures. One supplier -

Creganna - actually switched industries from electronics to serve the needs of the medical device MNEs, and several others were able to expand their customer base to other world clusters. Over time, the suppliers' skills improved to such a degree they began to provide components to the MNEs' HQs in their home clusters. Creganna even set up a subsidiary operation in Boston Scientific's home cluster in Greater Boston.

Both anchor plants, Boston Scientific and Medtronic, upgraded from simply assembling coronary drug eluting stents to undertake R& D and product development activities, either in co-operation with their HQs or even surreptitiously within the local subsidiaries, further increasing local competencies, and allowing these Galway cluster subsidiaries to attained strategic positions in their MNEs' global value chains, as the following quotes record:

" *the (HQ R&*D site) has developed a kind of prototype and then it goes to *Galway and we say we (HQ) need to develop this product and that's where you get their expertise for actually developing the product at that stage" (MNE A HQ , VP* R&D, 2010).

"We take products all the way through from concept to commercialization" (MNE B, R&D Manager, 2008)

"Even HQ is oblivious to the varied and intricate steps we have built into this, it's our baby" (MNE A, R&D Manager, 2008).

"That plant (Galway) has done a good job coming up the curve quickly and *being world class in manufacturing" (MNE A HQ, VP R&D, 2010).*

"The spectrum of responsibility from our local management team reflects our experience talent and capability to run global operations…. (HQ) positioned the subsidiary to *have a strategic role in the MNE chain" (MNE B, CEO, 2008)*

However, intellectual property (IP) vulnerabilities meant the two anchor MNEs were disinclined to co-operate on new product development, due to their mutual fear of unintentional spillover loss or even deliberate IP stealth in what is, historically, a highly litigious sector. But technology cluster members communicated informally about non product development activities, and its members constituted a critical lobbying consortium that supported their broader needs and both guided and directed local public economic policy.

From Cluster Specialization to Adaptation and Variation: The Interplay of MNE subsidiaries, local research and entrepreneurship

Over time, follower MNEs such as Covidien, Abbott and Merit Medical were attracted to set up subsidiaries in the Galway region, and cardiovascular stents became the cluster's specialization. Furthermore, this specialization transferred to indigenous spinouts. Initial analysis shows that there is a concentration of activity in Specialized Surgical and Medical Equipment in the Galway cluster, and that indigenous firms produce in the same category as MNEs. This high level of specialization increased the efficiency and reputation of the firms and the cluster in this category. Galway became internationally renowned as a cardiovascular technology cluster, whose activities moved it into a higher order realm in the corporate global value chain. As the cluster evolved and upgraded its activities its reputational capital grew, and its member firms' technological capabilities were increasingly recognized:

"Corporate R&D (US) found the drug and a way of delivering it through a stent...but all the product development happened here (Galway)...Originally we used to go to the States and learn stuff, whereas now they send a lot of people over here.... to learn (about) drug *eluding stents" (MNE A, Director of Product & Technology Development, 2005).*

But as the cluster matured it became vulnerable to technological lock-in and the destructive threat of a disruptive technology, which threatened to lead to it being downgraded or - in a disastrous scenario - becoming extinct:

"Medical devices is a mature industry and bar the next generation stents, there is no room for us to *engage in radical innovation" (MNE A, R&D Engineer, 2008).*

"It is imperative to develop new capabilities, because if you're not at the crest of the wave you'll pay a very high price" (MNE B, R&D Manager, 2008).

Technological adaptation was needed to avoid such technological obsolescence, and the cluster expanded towards related arenas of 'minimally invasive' products, developing into endoscopy and gastroscopy. Unrelated technology platforms were also introduced into the cluster; created to develop new products in disparate areas of medicine. This development took a number of forms. First, the MNE subsidiaries diversified their R&D focus into related spheres. Second, in 1999, the National Centre for Biomedical Engineering Science (NCBES) was established to conduct research on medical devices and then the Regenerative Medicine Institute (REMEDI) was established in 2004, under a Government-funded third-level research facility program to encourage industry-academic scientific collaborations. REMEDI is based at NUIG, and has Medtronic, Creganna-Tactx Medical, EnBio, Ovagen, Proxy Biomedical, Smith & Nephew and Ziel Biopharma as its industrial partners. Its advent expanded the cluster's knowledge base into stem cell biology and manufacturing, gene therapy, orthobioloigies and immunology as well as cardiovascular areas (REMEDI, 2010). More recently, the BioInnovate program, developed in partnership with Stanford University and the Cleveland Clinic, has facilitated new entrepreneurial products from clinical exposures.

The third source of variation came from entrepreneurial spinouts ranging from related to unrelated medical technology products. While an (exceptional) few were academic entrepreneurs, the majority of technological entrepreneurs were ex-employees of the Galway cluster MNE subsidiaries:

"There are quite a few colleagues which have left and set up new companies...I just think of all of this builds up the region....If one of these spinoffs were to come with the next *great thing we might acquire them"* (MNE A, Director of Product & Technology Development, 2005).

These technology entrepreneurs availed themselves of the cluster's ever increasing technological and reputational capital, as well as of the social capital they had accumulated from years of working in the MNE, including connections at both corporate HQ and affiliated subsidiaries, and from attending tradeshows, industry events and conferences. Critically, they had made these connections in their time at the MNE with the superior ecosystems of corporate home clusters - including such actors as top clinicians, patent lawyers and venture capitalists who barely even existed at the second-tier Galway cluster.

The technology entrepreneurs were able to tap into the resources and knowledge bases of the MNEs' home clusters - they knew the brokers, gatekeepers, connectors in their social networks. They had figured out not only the gaps in the MNEs' medical device product portfolios, but also understood the business model for success in the global medical technology industry.

"You just got to find pathways in there....it's not the guys two or three tiers down don't help, the guys that are publishing in the (top) journals, they are the ones you need." (Indigenous E, Founder, 2010).

"There is an awful lot of entrepreneurial skill coming from the MNEs, the engineers *that leave and set up on their own, that's very much there and I think it's a spawning ground for small businesses like us" (Indigenous F, Founder, 2010).*

Over time - importantly for the cluster - increasing numbers of these technological entrepreneurs created products in non-cardio categories, often exploiting technological convergence, for instance with ICT. This second wave of entrepreneurs had global orientation and knowhow, targeting international markets, operating in global production networks and connecting into foreign clusters to accumulate resources and access knowledge. At the same time, at the local level, they could avail themselves of university science, national and regional government support and social contacts with former colleagues, industry members and the medical device industry association. As a consequence they were linked into and tapped into the local cluster network, the global industry value chain, and the MNEs' home first-tier clusters, be it Massachusetts for Boston Scientific or Minnesota for Medtronic. Critically, these connections furnished them with access to research hospitals such as the Mayo clinic in Minneapolis and Massachusetts General in Boston. The VP of R&D at one Boston-based MNE confirms its first-tier home cluster - including research activity, a group of hospitals and universities, the reputation of Harvard - provided a huge knowledge base that Irish firms could tap into.

The technology entrepreneurs in the Galway cluster commonly created start-ups in partnership with colleagues who simultaneously left the same MNE, or with ex-employees of the other MNE subsidiaries in the cluster with whom they have developed relationships. The cluster has both first time and serial entrepreneurs, with the more experienced being willing to mentor the newcomers, providing advice contacts and confidence to them and conferring legitimacy on their activities. The cross-directorships and information sharing of this increasingly influential grouping supported their joint lobbying and direction-setting activities for the cluster as it evolved, building investor confidence in cluster entrants:

"…we needed someone with a lot of experience who has been through it before and could direct us in the right paths. So most definitely having [an experienced cluster *businessman] on the board has led us in…the right direction and we haven't looked back.* He has been a very important cog to us in the last eight years and he is still chairman of our *company in 2010".* (Indigenous B, General Manager, 2010)

"...you know people like [name of experienced entrepreneur in the cluster] who had been through it all here before, you know, who was a very willing, you know, willing with information and j*ust very generous with his information and time… you know I think I would have been struggling to do it in Dublin or even in Limerick."* (Indigenous H, Founder, 2010)

In the next section of the paper we analyze these findings and combine them with the international business and economic geography literatures.

DISCUSSION AND CONCLUSIONS

The paper reveals the role played by the MNE, its subsidiary and home ecosystem at various stages of the host cluster life cycle. We present a longitudinal study of how the MNE and its subsidiary behave as the cluster matures and specializes, and then guards against potential technological obsolescence from over-dependence on specialized technological capabilities and technology wipe-out from disruptive technology, areas which are generally under-examined. The life cycle extension story of the mature Galway technology cluster is not so much one of reinvention or renaissance as one of adaptation around embedded and evolving specialization in technological capabilities. The cluster succeeded in leveraging its particular reputational and social capital to avoid being dangerously locked-in to a narrow bandwidth of technological activity - but without relinquishing its specialized capabilities in this category. While it is inevitable that there will be industrial churn, and individual firms will enter and exit a technology cluster - the capabilities that are embodied in people and process are more persistent.

The elongation of this mature technology cluster occurred in two waves. To stave off the possibility of its hollowing-out or extinction, the mature cluster adapted, first in related technology activities and later into different technologies and novel product categories. This diversity came about in two ways: first, MNE subsidiaries moved into new development areas of , both internally in related fields and externally, in more novel arenas, in collaboration with the local university. Second, technology entrepreneurs emerged, principally driven by ex-employees of the MNE subsidiaries in the host cluster and more exceptionally in academic incubators. These startups deviated from the cluster's existing specialized technology activities, into both related and unrelated categories, so both the subsidiaries and academic institutions served as entrepreneurial incubators of variation and adaptation in the technology cluster.

The local technology cluster benefitted particularly from the technology-shaping presence of MNE subsidiaries, particularly those that acted as pioneers (Manning, 2008) and as anchors (Agrawal and Cockburn, 2003; Feldman 2003; Giblin, 2011) and the response of the local constellation of academic institutions, enterprise agencies and upgraded suppliers. But, despite this upgrading of the local cluster from simple assembly to product development activities, the local ecosystem for still lagged that of the subsidiary parent's home cluster in terms of technological advancement and entrepreneurial activity, which was dominant in the global hierarchy, and which had an institutional thickness that furnished more opportunities for new product development and new venture creation. To succeed, technological entrepreneurs in the local cluster needed access to the home technology cluster 'mothership', which came via their connections and experiences and their social capital developed while working for 'flagship' subsidiaries (Rugman and D'Cruz, 2000) in the host cluster. The local cluster is a 'satellite' ancillary to the mothership cluster. Its adjuvant status as an auxiliary technology cluster, accrued social and reputational capital affords and facilitates access to resources and activities at the supportive mothership. Just as subsidiaries 'tap into' local clusters to source knowledge, technological entrepreneurs can reverse the flow to 'tap into' the home cluster of the MNE parent.

Contribution to Theory

This paper links literature from international business on how the MNE taps into clusters (McCann and Mudambi, 2005; Beugelsdijk el al, 2010), and from economic geography in providing valuable insights into the place and life cycle of clusters. It examines knowledge flows within and between clusters, and reveals how some technology entrepreneurs can benefit from a reverse flow to the parent HQ's home cluster for some technology entrepreneurs, so contributing to our understanding of the nexus between the nature and origins of clusters, and the benefits cluster members enjoy (Mudambi and Swift, 2012). In doing so, it reveals MNE roles at various stages of technology cluster's life cycles, up to and including possible dissolution and extinction, and describes the cluster's external connectivity and how this determines and affects its evolution in terms of building technological, social and reputational capital.

This revelatory, longitudinal study supports the notion of 'physical attraction' (Cantwell and Mudambi, 2011; Mudambi and Swift, 2012) over the 'oligopolistic deterrence' (Shaver and Flyer, 2000) view. The anchor subsidiaries in the technology cluster - Boston Scientific and Medtronic - do not cooperate on product development (to guard against unintentional knowledge spillover) but both these pioneer MNEs shape the cluster's technological trajectory and lobby jointly for its interests, guiding university provisions in the locality and the advancement of supplier capabilities (Best, 2005).

Policy and Managerial Relevance

Policy-makers need to assist the creation of local technology clusters characterized by smart specialization (Foray et al. 2009), which have to be managed via a holistic approach, so that next-generation technologies can be evolved without the cluster forfeiting its specialist technological capabilities. Policy needs to encourage adaptation and variation through research into new technologies and into the convergence trends existing technologies, whether both related and unrelated. Clusters need to embed distinctive technologies that reflect both past accumulation and current technological accumulation. Pioneer MNEs that are anchored in the region function as the fulcrums of the embryonic cluster: policy makers must respond swiftly their arrival, ensuring universities invest in appropriate technologies and provide suitable courses to supply the skilled labor pool these subsidiaries need. In effect, universities supplement the presence of the MNEs in creating technological capabilities for the cluster. Policy can foster technology cluster linkages and lubricate its social processes, by coordinating interactions between competitors, customers, suppliers, researchers, entrepreneurs, technology experts, knowledge service providers and even funders, thus enhancing the cluster's global profile and expanding its reputational capital, which then serves to attract secondary follower inward investment. The need is to establish credibility as a world-class research and development site and good place to conduct business - so joined-up thinking by policy-makers is required.

Limitations and Future Research

Our longitudinal, multi-method case study was intended to build theory on the role MNE subsidiaries play at various stages of the life cycle of a technology cluster: but, inevitably, it has some limitations. First - since the aim was theory building rather than generalizability - it only involved a single technology cluster: further research could usefully explore other technology clusters in different locations and in different sectors and technologies. Second, the cluster we investigated is located in a small open economy, and the technology entrepreneurs who were our respondents appreciated the limitations of a small domestic market and limited resources of the local milieu. Further research would be worthwhile on the international outlook, social processes and connectivity of technology entrepreneurs in larger economies with significant home markets, capital and resource endowments. Third, the anchors in this technology cluster were pioneer MNEs - but in many technology clusters the fulcrums are a world-class university, research lab or a flourishing entrepreneurial culture, and clusters anchored in these different ways may have different life cycle paths than that described in this paper. Fourth (and related) the anchor MNEs and their followers into the Galway technology cluster studied were all of USA origin - other clusters with less homogenous inward firms and more diverse cultural backgrounds warrant investigation.

Conclusion

Technology clusters adapt to survive and prolong their value-creating existence. This paper reveals how a local host cluster extended its maturity by simultaneously enhancing its specialized technological capabilities and evolving new ones, in both related and unrelated arenas of innovative activity. In so evolving, the cluster avoided the dangers of technological lock-in, institutional stagnation and collective failure. MNE subsidiaries are shown to be central to this virtuous cycle of vibrant cluster life and wellbeing.

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Figure 1: Product and Service Landscape of the Galway Medical Technology Sector by Origin of Company