THE ROLE OF MNES IN THE GENESIS AND GROWTH OF A RESILIENT ENTREPRENEURIAL ECOSYSTEM

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This article reports on a longitudinal process study of the critical role of anchor MNEs in the metamorphosis of a high-tech industrial cluster into a local entrepreneurial ecosystem. It draws on entrepreneurial ecosystem and international business literatures to frame the study of the genesis and evolutionary processes of an entrepreneurial ecosystem that emerged from two MNE subsidiaries, both of which had evolved into advanced R&D centres of excellence around a technology specialism. It shows how multiple new venture spinouts by former MNE employees introduced technological heterogeneity that catalysed into a resilient entrepreneurial ecosystem. The theoretical and policy implications that can be drawn from this case study emphasise the existence of both technology specialism and heterogeneity for resilience in an entrepreneurial ecosystem, and that reaching such a position is evolutionary in nature.

Keywords: Entrepreneurial ecosystem; MNE; evolution; heterogeneity; resilience; longitudinal

1. INTRODUCTION

Entrepreneurship is critical to the sustenance and growth of local economies. Dynamic interactions between elements of a local entrepreneurial system have been claimed to increase entrepreneurial performance of regions (Boschma, 2015). These interactions evolve over time, often into what has been termed to be an 'entrepreneurial ecosystem' (Cohen, 2006). After Cohen's original theoretical incarnation of an entrepreneurial ecosystem, there was a lag in academic interest in the phenomenon as the generation of theory on cluster development and life cycles pre-dominated (Menzel. and Forndahl, 2009; Boschma and Forndahl, 2011; Martin and Sunley, 2011). However, as shortcomings in cluster theory on the nature of entrepreneurship emergence and development were identified, there has been an increase of interest in the entrepreneurial ecosystem concept and the centrality of the entrepreneur and entrepreneurship to the process (Isenberg, 2010; Stam, 2015; Mack and Mayer, 2016; Acs et al., 2017; Audretsch and Belitski, 2017; Stam and Spigel, 2017; O'Connor et al., 2018; Liguori et al., 2019).

Whilst rapid progress has been made, the processes involved in the formation and transitioning of an entrepreneurial ecosystem to different phases of development needs to be further explored, and examined as evolutionary rather than static processes (Spigel, 2017; Mack and Mayer, 2016; Alveldalen and Boschma, 2017; Brown and Mason, 2017; Spigel and Harrison, 2018; Colombo et al, 2019). As a result, further research is required on how entrepreneurial ecosystems form and evolve over time (Malecki, 2018). The bulk of existing research has lacked historical and contextual nuance (Spigel and Harrison, 2018) which has prevented a thorough understanding of the dynamics underlying the genesis of an entrepreneurial ecosystem. In other words, the mechanisms underpinning the formation of an entrepreneurial ecosystem have been more assumed than explained and seldom supported by in-depth empirical analysis. As a result, there are several questions which remain unanswered to date.

Which actors play which roles and in which contexts? Who are the leaders, shapers and dominant players in an entrepreneurial ecosystem? Are there stages in the evolution of entrepreneurial ecosystems and, if so, are these standard or heterogeneous? These issues need to be explored across a range of entrepreneurial ecosystems to tease out the common and exceptional elements that help to develop a general theory of an entrepreneurial ecosystem with stronger explanatory power.

Within this context, we focus on two research topics which have been largely overlooked by the existing theory: 1) the explanation of the genesis of an entrepreneurial ecosystem from a longitudinal perspective; and 2) the analysis of the role of MNEs in the formation of an entrepreneurial ecosystem. The decision to focus on MNEs comes from the recognition over the last two decades of their contribution to the development and evolution of numerous industrial clusters and production regions (e.g. Buciuni and Pisano, 2018; Breznitz and Buciuni, 2015). More specifically, MNEs can (a) catalyse an industry cluster (Manning 2008; Giblin and Ryan, 2012) or (b) tap into an existing high-tech cluster (Mudambi and Swift, 2012) that may later evolve into an even more dynamic and stronger cluster (Ryan and Giblin, 2018). What is less clear, however, is how such an MNE-anchored industry cluster can pave the way for the emergence of an entrepreneurial ecosystem. Therefore, we ask the following research question: *how do MNEs generate entrepreneurship and shape the form of innovation trajectories that can evolve in an entrepreneurial ecosystem over time?*

We address this question by means of a longitudinal study of the genesis of an entrepreneurial ecosystem and its underlying determinants. In particular, by focusing on the role played by multinational enterprises (MNEs) in the transformation of the Galway's medical devices cluster, we provide an original analysis of the micro mechanisms whereby an entrepreneurial ecosystem forms and develops. By analysing the genesis of an entrepreneurial ecosystem, we tap into a growing and yet still underdeveloped stream of research which focuses on the

creation and shaping of favourable conditions in a region that enable a culture of entrepreneurial behaviour and new ventures formation.

The results that emerge from our analysis matter for several reasons. First, they contribute to calls for longitudinal case studies of entrepreneurial ecosystems (Spigel and Harrison, 2018; Malecki, 2018) and shed further light on the micro mechanisms underlying their formation. In particular, our process study shows how an idiosyncratic entrepreneurial ecosystem was catalysed by anchor MNEs that incubated entrepreneurs that went on to shape the evolution of this entrepreneurial ecosystem in terms of its configuration, dynamics and technology trajectories. They also contribute to theory by explaining the process whereby individual entrepreneurs accumulate knowledge on business model innovation and global market intelligence by working at MNEs and later utilize these competences to spin out and launch new ventures in related and unrelated technological domains. In so doing, we provide an improved understanding of the processes by which entrepreneurial ecosystems form and transform across time. This is useful as the focus of much research to date on entrepreneurial ecosystems has been on the identification of best practices rather than the broad processes we delineate in our study (Spigel and Harrison, 2018).

The paper is structured as follows: the next section of the paper draws on both the entrepreneurial ecosystem and international business literatures to provide a theoretical framework for the study. This is followed by a discussion of the methodology used in the study. The following section presents the findings from the research the evolution of Galway's entrepreneurial ecosystem. This provides the basis for a discussion on how this idiosyncratic context builds theory on entrepreneurial ecosystems. Concluding remarks are drawn in the final section.

2. THEORY DEVELOPMENT

2.1 The Genesis of an Entrepreneurial Ecosystem

Over the past decade, a growing body of research has focused on the evolution of industrial regions and the manner in which such regions have reacted to globalization (e.g. Christopherson et al., 2014; Breznitz and Buciuni, 2015). In particular, Evolutionary Economic Geography theory emerged as a new discipline that sought to improve the understanding of the spatial evolution of firms and industries through an explicit dynamic perspective (Boschma and Frenken, 2006; Kogler, 2015; Martin and Sunley, 2015). Despite recent endeavours, this discipline has fallen short by failing to take account of the micro-level dynamics as the principal drivers of regions' evolution across space and time (Boschma and Frenken, 2011, Kedron et al., 2019). A similar criticism of incompleteness can be made of cluster analysis and theory. This is a field where the role of leading firms has been shown to profoundly affect the competitiveness of regional industries (Feldman, 2003; Klepper, 2010; Giblin and Ryan, 2012) but which fails to adequately explain how entrepreneurial activity is nurtured and expanded. Various regional development, innovation systems and entrepreneurship scholars have sought to address these shortcomings by positioning entrepreneurship at the core of local economic development. From this the field of entrepreneurial ecosystems (Cohen, 2006; Isenberg, 2010; Mason and Brown, 2014) emerged at the nexus of regional development and strategic management theories (Acs et al., 2017).

Nonetheless, the entrepreneurial ecosystem literature clearly links to research on clusters (Alveldalen and Boschma, 2017; Spigel and Harrison, 2018; Autio et al., 2018; Malecki, 2018). However, while clusters can provide opportunities for entrepreneurs (Feldman et al., 2005; Rocha and Sternberg, 2005; Delgado et al., 2010), cluster theory does not place the entrepreneur nor entrepreneurial thinking at the core of cluster survival and resilience (Acs et

al., 2017; Spigel and Harrison, 2018). Some scholars nevertheless assert that an entrepreneurial ecosystem represents a distinct or novel cluster type or may emerge and evolve from a pre-existing technology cluster (Autio et al., 2018). Others propose that entrepreneurial ecosystems have entrepreneurial dynamics that transcend an industry cluster (Malecki, 2018) or cut across industries and technologies (Auerswald and Dasi, 2017). The defining aspect of an entrepreneurial ecosystem is that the entrepreneur and the pursuit of entrepreneurial opportunity and robust entrepreneurial spawning is central (Autio et al., 2018; Malecki, 2018). The entrepreneurial ecosystem concept is therefore both broader in scope (cross or beyond industry) but narrower in the unit of analysis (entrepreneur and entrepreneurship) than cluster theory (Auerswald and Dasi, 2017).

Much of the early work on entrepreneurial ecosystems was policy-oriented (Isenberg, 2011; Mason and Brown, 2013; 2014). Academic research on developing theory on entrepreneurial ecosystems is quite nascent (Isenberg, 2010; Acs et al., 2014; Autio et al. 2014; Mack and Mayer, 2016; Acs et al., 2017; Audretsch and Belitski, 2017; Spigel, 2017; Stam and Spigel, 2017; O'Connor et al., 2018) but growing (Malecki, 2018). Entrepreneurial activity is most usefully studied at a local context where culture is bounded, the decisions are made, firms grow and individual traits matter (Feldman and Kogler, 2010; Audretsch and Belitski, 2017). Entrepreneurial ecosystem theory represents a holistic approach to entrepreneurship focusing on the role of independent and interacting actors within the entrepreneurial ecosystem (Stam, 2015; Audretsch and Belitski, 2017; Stam and Spigel, 2017) and the processes of how it is developed, adapted and sustained (Spigel and Harrison, 2018). An entrepreneurial ecosystem is rooted in place and has a relatively distinct geographic boundary (Auerswald, 2015; Stam, 2015; Brown and Mason, 2017; O'Connor et al., 2018) within which dynamic processes of diversity, resilience and adaptation are seen in play (Boschma, 2015; Roundy et al., 2017; Malecki, 2018). Such a 'place-oriented' entrepreneurial ecosystem framework determines who

becomes an entrepreneur and how actors effect and shape entrepreneurial action and outcomes of the local ecosystem (Autio et al. 2014; Audretsch and Belitski, 2017; O'Connor et al., 2018). A variety of actors can impact the birth and growth of an entrepreneurial ecosystem (Mack and Mayer, 2016). These include the local university (Miller and Acs, 2017; Cunningham et al., 2019), diaspora (Baron and Harima, 2019), large anchor firms (Mason and Brown, 2014; Colombo et al., 2019) and MNEs (Neck et al., 2004; Bhawe and Zahra, 2019), the focus of this study. The State (Fuerlinger et al., 2015) is also a critical actor, supporting organisations, both public and private, such as incubators and accelerators, that fund and mentor actors in the entrepreneurial ecosystem (Hochberg, 2016). Operating alongside Government business development agencies are business and trade associations that orchestrate and nurture interactions between horizontal firm actors and coordinate collective lobbying for resources to support entrepreneurship and the growth and resilience of the entrepreneurial ecosystem. The entrepreneurial ecosystem thus comprises of a set of independent and interacting components, each of which contributes to its dynamism and trajectory (Stam and Spigel, 2017).

In summary, an entrepreneurial ecosystem should be considered as an evolutionary concept (Isenberg, 2010; Spigel and Harrison, 2018; Malecki, 2018; Colombelli et al., 2019), within which broader contexts such as regional, temporal and social settings matter and must be accounted for in any research (Autio et al., 2014; Zahra and Wright, 2011; Alveldalen and Boschma, 2017). Some efforts have been made to identify the typological stages of evolution of an entrepreneurial ecosystem: 'embryonic' and 'scale-up' (Brown and Mason, 2017). Mack and Mayer (2016) describe how an entrepreneurial ecosystem transitions from birth to growth and on to either virtuous sustainment or insipid decline. Auerswald and Dasi (2017) suggest that the evolution is not necessarily linear across stages but rather recursive as an adaptive life cycle. However, the objective of a strong entrepreneurial ecosystem is not so much to avoid

dwindling into decline (Malecki, 2018) but to create resilience and sustainability over time to prevent technological inertia (Narula, 2002; Hassink and Dong-Ho, 2005; Williams and Vorley, 2014; Roundy et al., 2017). The sustainability of the entrepreneurial ecosystem derives from the introduction of heterogeneous variation and adaptation that can extend an entrepreneurial ecosystem's lifespan. The ultimate objective of an entrepreneurial ecosystem is its continuous renewal (Malecki, 2018). This resilience of an entrepreneurial ecosystem emanates from both coherence around specialisms (Roundy et al., 2017; Spigel and Harrison, 2018) and heterogeneity from the diversity of new firm formations across multiple technologies (Malecki, 2018). Large firms within the entrepreneurial ecosystem can serve as anchors that facilitate such resilience in the entrepreneurial ecosystem (Clarysse et al., 2014).

2.2 MNE's Role in the Evolution of a Strong Entrepreneurial Ecosystem

A MNE is a particular form of large firm that operates and creates value across many countries (Dunning and Lundan, 2008). They have been shown to anchor entrepreneurial ecosystems (Neck et al., 2004; Spigel and Harrison, 2018; Bhawe and Zahra, 2019). Governments regularly offer financial and other incentives to attract MNEs to locate in particular regions to create employment, often with high wages (Berrill et al., 2018), and bring advanced technologies. There is a long running 'curse or blessing' debate in the literature and amongst policy-makers as to whether the entry of MNEs to a region has positive or negative entrepreneurial spillovers (De Backer and Sleuwaegen, 2003; Audretsch and Keilbach, 2008; Berrill et al., 2018). MNEs have been shown to have a positive impact as incubators of entrepreneurship that can generate new ventures through spinouts of former employees who draw on the learning that they have gained within the MNE (Neck et al., 2004; Acs et al., 2013). However, MNEs have also been shown to inhibit entrepreneurship in the locations in which they are based by attracting local

talent that have a preference for the high wages and job security of paid employment that MNEs can offer (Bhawe and Zahra, 2019; Berrill et al., 2018).

MNE subsidiaries often enter host regions as factor-seekers but evolve into innovation creators (Gupta and Govidarajan, 1991; Delany, 2000; Frost, 2001; Cantwell and Mudambi, 2005). This can result in a subsidiary's ascension to a prominent and important role within the MNE as a 'Centre of Excellence' for R&D and new product development (Holm and Pedersen, 2000; Frost et al., 2002). Research-intensive subsidiaries can also act as anchors in the entrepreneurial ecosystem (Feldman 2003). This increases the local footprint of the subsidiary and increases its influence with local Government and enterprise actors to take initiatives to deepen and diversify knowledge stock in the local entrepreneurial ecosystem. The research-intensive MNE is also an extremely attractive partner to local university research institutes for joint knowledge creation that further expands the region's knowledge base (Cantwell and Mudambi, 2011). MNE subsidiaries also bring with them international quality standards, process and production know-how and knowledge on the international markets they serve, a global business model perspective and an international reputation in the marketplace (Giblin and Ryan, 2012). These represent valuable knowledge sources for prospective and nascent entrepreneurs in the region. The concentration of MNE subsidiaries in an entrepreneurial ecosystems therefore deepens its technology base and enhances its capacity as an incubator for entrepreneurship. These ventures are commonly in new technology domains; these can be related or unrelated to the MNE's core technology domain (Boschma and Frenken, 2011, Kogler, 2017). This increased heterogeneity amplifies the resilience of the entrepreneurial ecosystem (Roundy et al., 2017). Moreover, it has been shown that pioneer entrepreneurs that spinout from MNEs and later successfully exit their built venture seldom exit the entrepreneurial ecosystem but rather stimulate its renewal and growth by channelling their time and energy as role models, mentors and angel financiers

(Mason and Harrison, 2006; Ryan et al., 2018) into the extension and growth of an entrepreneurial ecosystem in a virtuous cycle (Agarwal et al., 2010).

This discussion points to a need for deeper investigation of the activity and role of MNEs in an entrepreneurial ecosystem's genesis and dynamic evolutionary growth trajectories. We therefore explore the role of the MNE as a key actor in an entrepreneurial ecosystem. We examine its role in the emergence and evolution of the entrepreneurial ecosystem's technology trajectories, specialism embeddedness and adaptation into related branch and unrelated variety technology through the incubation of entrepreneurship inside its R&D laboratories. Specifically, this paper aims to empirically investigate how MNEs can enable the evolution of a vibrant and dynamic entrepreneurial ecosystem that enables entrepreneurship and shapes its development and sustenance in more secure technology domains.

The next section of the paper describes and explains the longitudinal case study approach methodology used in this study..

3. RESEARCH METHOD

3.1 Study Setting and Research Approach

Qualitative research has been deemed an appropriate way in which to develop a rich understanding of entrepreneurship and its processes in an ecosystem's spatial and temporal contexts (Karatas-Ozkan et al., 2014). Since these processes drive changes that become more evident over time, a long-term examination of an entrepreneurial ecosystem's evolution is advised (Malecki, 2018). Accordingly, this process-oriented study reports on a longitudinal mixed-method case study approach (Eisenhardt 1989, Yin, 2003; Pettigrew, 1990; Welch et al., 2011; Langley et al., 2013; Berends and Deken; 2019). It uses, as the revelatory case, the entrepreneurial ecosystem around the city of Galway in the West of Ireland which has

undergone a transformation from a narrow industry medical devices cluster into a broad medical applications ecosystem that has become more and more agnostic to industry and technology (Autio et al., 2018; Malecki, 2018). There are, of course, limitations to the research in that it only involves one idiosyncratic entrepreneurial ecosystem in a particular form and state of transition and catalysed by MNE actors. However, the aim is theory building rather than generalisability. Moreover, whereas from a methodological perspective the entrepreneurial ecosystem literature has tended to take a static and cross-sectional approach to exploration (Mack and Mayer, 2016; Spigel, 2017; Alveldalen and Boschma, 2017), we conduct a process study of this particularly revelatory transitioning entrepreneurial ecosystem that utilises longitudinal data. This allows us to examine the entrepreneurial ecosystem's evolutionary processes and specifically the role of two anchor MNEs in its genesis and growth.

3.2 Data Collection

Our multi-level longitudinal study draws upon both quantitative and qualitative data. Regarding the former, both patent data and an historical company database were used. Patent applications from medical technology companies based in Galway from 1980 to 2017 were collated and analysed. The European Patent Office (EPO) PATSTAT database served as the source of relevant patent documents (,i.e. information on novel products and processes). The focus of the study was on patents applied for by inventors located in the Galway entrepreneurial system and assigned to either an MNE or an indigenous company in our sample. These were analysed in two ways, first the timing of the innovative output, which has increased significantly after a moderate start since in the mid-1990s, and the technology classifications reported in the patent document, which indicates specialization and associated diversification patterns over time. We combined this information with data collected on all known companies within the medical technology and wider ICT applications sector in Galway. This involved the

generation of a company database listing companies in order of the year the company was established in the region using the Irish Company Registration Office. Given the longitudinal approach of the study, the database includes medical technology companies that have ceased trading as well as those still in operation. Data were collected on each company from FAME (the commercial company database) and from various secondary sources, in particular, Irish industrial development agencies, newspaper searches and website searches. For each company, we recorded the indigenous or foreign nature of the operation, the primary activity of the company; including area of medicine and supplier or own device/component developer, and the current operational status of the company (e.g. still live, divested, merged, acquired, joint venture). In addition, in order to track entrepreneurs the names of the founders of each of the indigenous companies is recorded in the database. Using LinkedIn (the professional social network) as well as broader internet searches, we recorded the prior work experience of each of the founders – positions held and organisations worked with prior to establishing their own company. This helped us to understand where founders developed knowledge and skills before establishing their own firm (e.g. whether from working in foreign-owned subsidiaries or indigenous enterprises) and to ascertain any patterns over time that would indicate changes in the entrepreneurial ecosystem.

Building on the first level of analysis, we used a longitudinal qualitative analysis to make sense of the quantitative data we gathered to shed light on those micro dynamics that have enabled the entrepreneurial ecosystem to generate innovations in related and unrelated domains over two decades. A total of 51 in-depth interviews with various actors belonging to and impacting the Galway entrepreneurial ecosystem (34 founders/Directors of indigenous companies and 17 stakeholders in supporting organisations) were undertaken in 2005, 2010 and 2017, a twelve year period in which the entrepreneurial ecosystem experienced strong growth in the context of a global economic downturn and associated recovery.

For the company interviews, founders of indigenous firms were selected for interview in order to understand how the entrepreneurs had developed their knowledge, skills and network base. We selected particular companies to interview that would represent the variety of activities within the entrepreneurial ecosystem. For example, founders of supplier companies and founders of companies designing and developing their own devices were interviewed. Directors of indigenous companies that have been acquired by foreign companies were also selected for interview. Three rounds of interviews were conducted with the indigenous medical technology companies. The first set of interviews in 2005 provided an understanding of the origins of indigenous activity within the sector. Semi-structured interviews, each of one to one-half hours in duration, were conducted with the founders of five indigenous companies. Two of these companies were founded principally as component suppliers and three were involved in designing and developing their own devices for the international marketplace. The second round of interviews was conducted in 2010 and consisted of interviewing the founders of thirteen indigenous enterprises. Each interview lasted between one and two hours. For consistency these enterprises comprised of four of the companies interviewed in 2005. The other nine companies were 'born-globals' which had developed their own devices or components for devices. The third round of interviews were conducted in 2017. This involved interviews (again lasting one to two hours) with the founders of thirteen indigenous enterprises. A further three interviews were carried out with Directors of companies that were indigenous companies that by 2017 had been acquired by foreign-owned enterprises. The purpose of these interviews was to gain a better appreciation of how indigenous activity has evolved in the region and to understand how entrepreneurs had acquired the necessary skills, knowledge and networks to establish their businesses. This third set of interviews consisted of five interviews with suppliers and eleven with companies that had developed their own devices, components and applications.

In addition to these company interviews, a further nine interviews in 2005 and eight interviews in 2017 were carried out with organisations that support the development of the regional medical technology ecosystem. These interviews were all semi-structured in nature and lasted 45 – 60 minutes. The 2005 interviews with supporting organisations included national semi-state industrial development agencies, regional semi-state industrial development agencies, one medical technology-related research centre and the technology transfer office at the local University. In 2017, interviews were conducted with two academic Professors of Biomedical Engineering in the region that are Principal Investigators of projects undertaken in collaboration with local medical technology companies; the founder of the medical technology entrepreneurship programme – Bioinnovate - that encourages start-up activity; the Industrial Liaison Officer and the Scientific Programme Manager of a local medical technology research centre; the manager of a research facility based at the local hospital; the manager of a medical technology accelerator programme for small enterprises – BioExel; and the manager of a centre that delivers technology solutions through collaboration with industry. The aim of these interviews was to gain multiple perspectives on the development of the entrepreneurial ecosystem and the role that support organisations play in instigating and supporting new entrepreneurial opportunities in the region. For this reason, only those organisations and key stakeholders that directly support medical technology indigenous enterprises and entrepreneurs either through research, funding or mentoring were selected for interview. In Ireland, semi-state industrial development agencies (national and regional) are a major source of early stage funding for most high-technology start-ups, given that the private venture capital infrastructure is still emerging. Therefore, such industrial bodies along with research-based organisations and those programmes directly training and mentoring medical technology entrepreneurs (i.e. Bioinnovate and BioEXEl) were selected for interview. These organisations provide an

architectural view of the sector and an understanding of the local environmental conditions facilitating or hindering the entrepreneurial ecosystem's evolution.

3.3 Data Analysis

Our quest was to explain the role of MNEs in the genesis and growth of an entrepreneurial ecosystem and to describe and explain the temporal evolutionary processes (Langley et al., 2013). Initially, the interviews were transcribed and data organised for analysis (Eisenhardt and Graebner, 2007). In the preliminary analyses of interview data, we manually isolated themes and concepts that helped us describe and explain the phenomena we observed (Gioia et al., 2013). In our analytical strategy we remained highly context-sensitive (Michailova and Mustaffa, 2012; Cuervo-Cazurra et al., 2016). We ordered key events and milestones chronologically and built a chain of evidence and narrative accounts of the evolution of this entrepreneurial ecosystem (Roundy et al., 2017). We employed triangulation of our primary qualitative data with secondary data in our analysis to deepen our interpretation of the interview data and enhance the reliability and trustworthiness of our findings (Sobh and Perry, 2006; Cuervo-Cazurra et al., 2016). Specifically, we tracked and collated secondary sources on key events, critical happenings and notable milestones in the entrepreneurial ecosystem's evolution over the course of the study. This took two forms. First, we traced and kept contemporary notes in an extensive file on key events: examples include the announcement and subsequent establishment of a Centre of Excellence for Manufacturing or R&D in a case firm, the opening of a new Research Centre or Study Programme in the local university and new venture funding. To this end we continuously monitored press releases, press articles and website announcements. Secondly, we trawled back over press and websites for events we had heard of in our interviews but might have missed in our ongoing secondary data collation.

The sequencing and interpretation of events, many critical, provided explanations of the entrepreneurial ecosystem's context and how it has changed over time (Welch and Paavilainen-Mantymaki, 2014). This permitted us to develop a process-based interpretation and explanation of entrepreneurial ecosystem evolutionary dynamics over time and in distinct time periods (Langley et al., 2013). We complemented our qualitative interpretive analysis with our patent information. Combining qualitative and quantitative data allowed us to detect general patterns in the evolving context of the entrepreneurial ecosystem. We refined our analysis through successive iterations between theory and data (Ryan and Bernard, 2000; Silverman, 2000). This guided our development of an explanation of the role of the R&D-intensive MNEs in the evolution of this idiosyncratic entrepreneurial ecosystem.

4. FINDINGS

4.1 Origins of the Entrepreneurial Ecosystem: MNE Subsidiary Entrepreneurship and Specialism Emergence

The first activity in the field of medical technology in the Galway region was the establishment of a foreign-owned firm in the area of diagnostics in 1973. However, it was not until the arrival of CR Bard in 1982 (which was subsequently acquired by Medtronic in 1999) and Boston Scientific in 1994, attracted by IDA Ireland incentives, that a network of specialist activity around cardiovascular devices in particular began to emerge. The establishment of these facilities in Galway coincided with the rapid international expansion in the production of balloon catheter devices for use in angioplasty procedures, whereby a balloon is used to widen a narrowed artery in the heart reached using a catheter. At the time of their establishment in the region both CR Bard/Medtronic and Boston Scientific were mandated by their respective HQs to engage in the manufacture of angioplasty devices that were based on research and

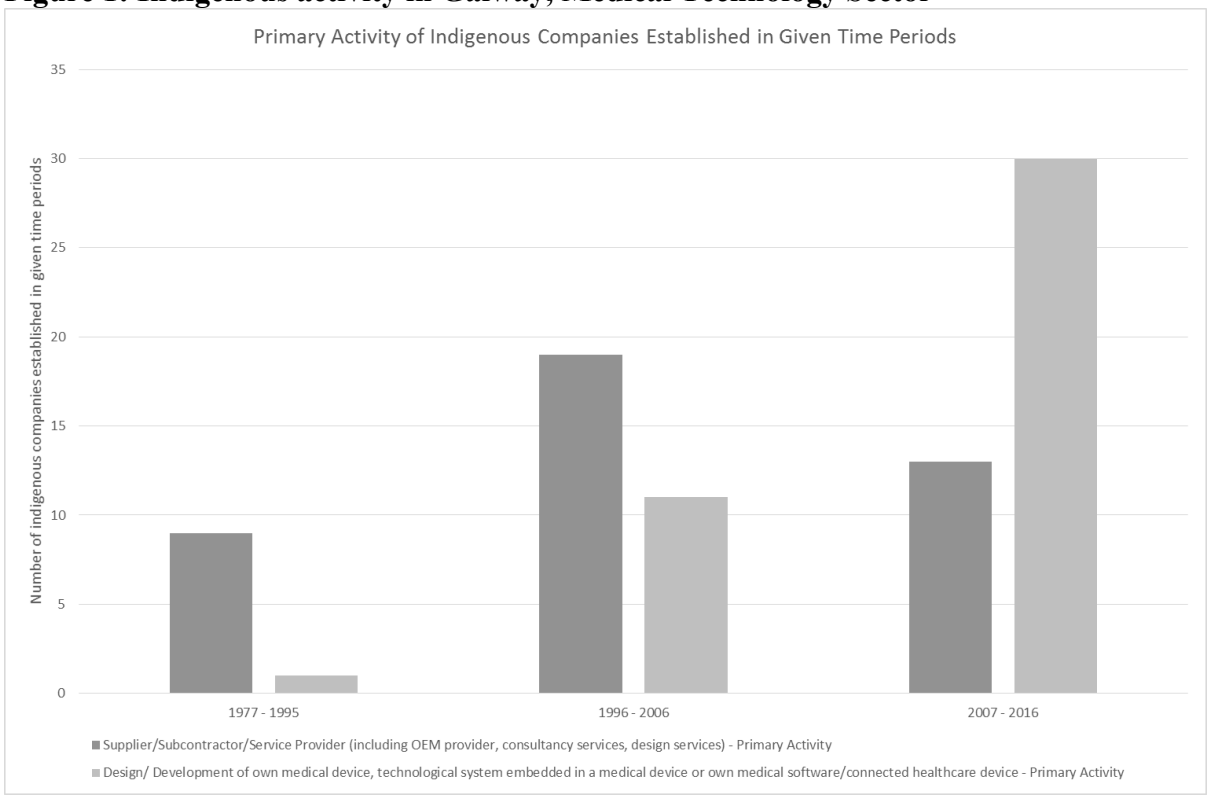
design undertaken elsewhere in the corporation. Having demonstrated their capabilities for meeting targets and improving efficiencies through incremental innovation, by the mid-to-late 1990s both subsidiaries had moved into R&D activity combined with manufacturing. CR Bard/Medtronic officially opened a 17.1 million euro R&D centre in its Galway facility in 1996 and in the following year Boston Scientific opened a new product development centre staffed with specialists engaging in R&D. At that point in time Boston Scientific and Medtronic collectively employed 2000 people in the region.

By the end of the 1990s and beginning of 2000s another significant advancement in the angioplasty area emerged internationally. This was the development of a drug-eluting stent for use in a coronary angioplasty procedure that allows for the controlled release of drugs from the stent to the artery wall to prevent future blockages. The main global companies involved in drug-eluting stents were Boston Scientific, Medtronic and Johnson & Johnson/Cordis. The two subsidiaries in Galway became key players within their respective corporations in designing, developing and manufacturing these stents. As a result Galway became known for its specialisation in this area (Giblin & Ryan, 2012). During the 2000s the Medtronic subsidiary received the status of becoming a designated Centre for Excellence in the development and manufacture of treatments for cardiovascular diseases. In 2013 the corporation invested in a Customer Innovation Centre in the Galway subsidiary at a cost of €7.7 million demonstrating the subsidiary's advancement. In 2009 Boston Scientific's Galway subsidiary won a €91 million investment in Research, Development & Innovation that allowed for early stage innovative activity and by 2012 the Galway site was designated a Global Centre of Excellence for Drug Eluting Stents. As they had become large scale employers focused around advanced R&D laboratories and Centres of Excellence these two subsidiaries served as anchors within the cluster and thereby deepening of the regional knowledge base and, as we will show,

becoming principal catalysts for the incubation and emergence of an entrepreneurial system in the region.

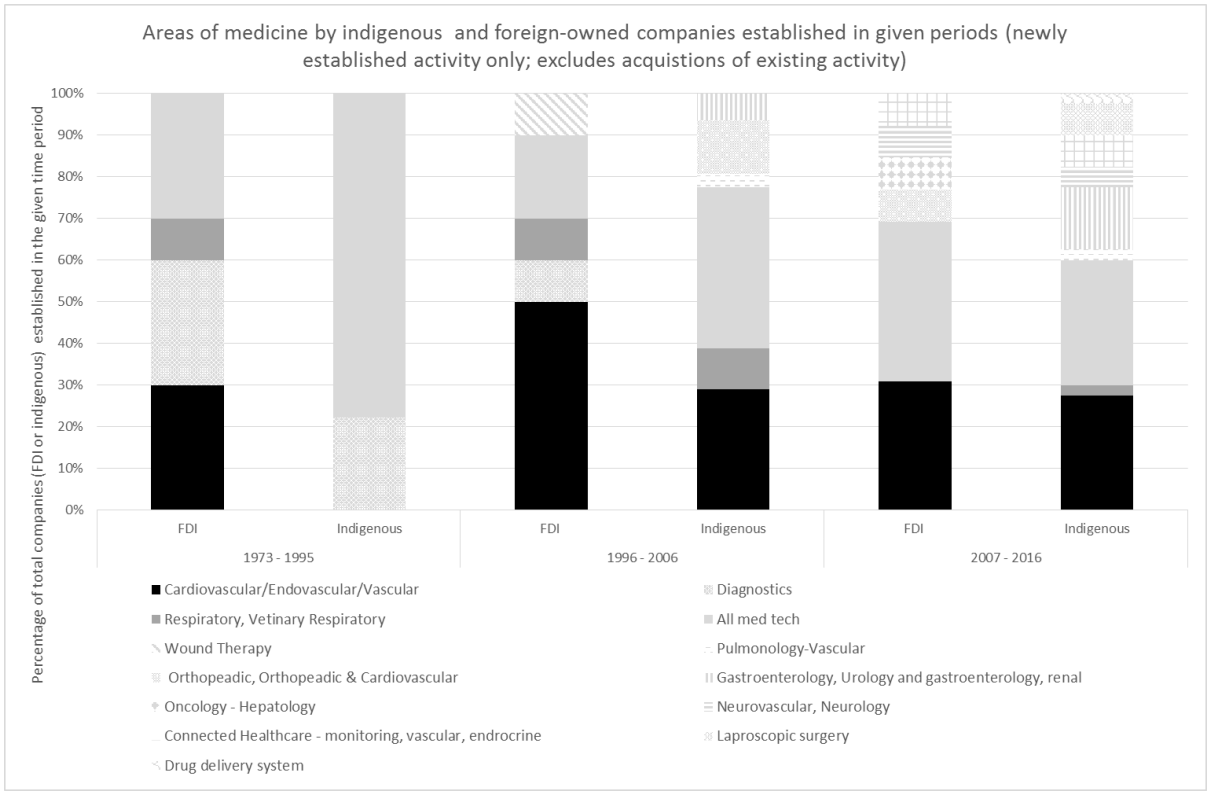
The engagement in such higher-value added activity locally by these subsidiaries was an important stimulus for the emergence of indigenous entrepreneurial activity. As Figure 1 illustrates, the first wave of indigenous activity in the 1980s and early 1990s was predominantly vertical supplier, subcontractor and service provider companies providing goods and services mainly to the local MNE subsidiaries. From the late 1990s more horizontal type entrepreneurial activity had emerged. These indigenous firms could be classed as 'born global' since from their start they produced their own devices or technological systems embedded in devices for an international marketplace. As one entrepreneur stated: "From day one you have to be global because it's a global industry" (Indigenous I, 2010). This horizontal entrepreneurial activity dominated the type of indigenous companies being established over the more recent period of 2007 to 2016 (see Figure 1).

Figure 1: Indigenous activity in Galway, Medical Technology Sector



A clear specialisation in vascular-related medicine (cardiovascular and endovascular) emerged in the ecosystem. As demonstrated in Figure 2, about 30% of newly established foreign-owned and indigenous firms in each time period were primarily involved in producing devices, components or systems to meet needs in vascular medicine. However, whereas the specialism persisted and underpinned the entrepreneurial ecosystem, early signs of increasing diversity and variation in new domains are evident. Patent data from 2009 shows that of the thirty-one medical-technology related patents identified as filed from the region, just over half were directly related to vascular devices, stents or stenting procedures, while the other patents extended outside this area of activity. Many were in related branch technology. For example, by 2006 pulmonology-vascular activities were identified as being undertaken (see Figure 2) related to the cardiovascular activities that existed prior to 1996. In particular, indigenous companies founded between 1996 to 2006 were operating in more varied areas of medicine as is illustrated in Figure 2.

Figure 2: Specialisations and diversity in the ecosystem



4.2 Evolution of a Strong Entrepreneurial Ecosystem: Heterogeneity and Resilience

In the period 2007 to 2016, newly established indigenous and foreign-owned companies were involved in areas of medicine that had not been served by companies in previous decades, such as neurology and connected healthcare (see Figure 2). Patent data up to 2017 also shows that the knowledge base underpinning the growing entrepreneurial ecosystem has followed multiple innovation trajectories. Patent classification allowed us to categorize distinct innovation paths based on the typology of new technologies. Medtronic and Boston Scientific increased the number of different technological classes in which they successfully applied for a patent from 7 to 12 and from 9 to 22, respectively between 1980 and 2017. However, innovation in unrelated domains, which eventually led to new category products such as connected healthcare, intelligent biopsy systems and nebulizers, has been mostly developed by indigenous new ventures established as spin offs of multinational corporation subsidiaries. By 2017 indigenous firms were involved in unrelated technological areas, such as medical software and connected healthcare for drug delivery. For example, companies have merged IT with medical devices to produce monitoring and reporting devices for the early detection of medical problems; this is illustrated by Bluedrop Medical that has developed an internet of things device to detect ulcers that result from diabetes. This company is an example activity shifting towards applying IT solutions to medical problems. Another example is CompanionQMS, a recently established company that has designed a software platform specifically for medical technology companies to achieve and maintain regulatory certification for quality management. The founder of this company, who had been a Product and Quality Engineer in two local MNCs, identified an entrepreneurial opportunity that is predominantly in software development - a different technological domain.

Evidence from our longitudinal analysis shows that the vast majority of entrepreneurs who founded their own ventures across multiple technologies had spent many years working in the R&D labs of the Galway-based branches of MNEs, particularly Medtronic and Boston Scientific (Figure 3). The critical 'eureka' moment that triggered their exit to start their own business was the recognition of market opportunities in technological domains outside their employer's core business. These were spotted whilst working in the MNE R&D lab and had either been missed, ignored or deemed outside of the mandate of the MNE subsidiary. For example, one of the first indigenous companies in the region that developed their own device was Mednova, established in 1996 by three ex-employees of CR Bard (currently Medtronic). With this first endeavour these entrepreneurs identified an opportunity for producing a cardiovascular device (a filter) in angioplasty procedures which was related to the activity of the MNC subsidiary. After Mednova was acquired by Abbott in 2005, two of these entrepreneurs established a new enterprise that focused on producing a bio-convertible filter device to prevent blood clots reaching the lungs during surgery, representing a move into pulmonology-cardiovascular and thereby adding further diversity to the ecosystem.

Interviews with the founders of these new companies in the entrepreneurial ecosystem demonstrate that they had built up significant international connections over the course of their careers working in local MNE subsidiaries. This international connectivity afforded by the MNE subsidiary provided the founders with critical international contacts, alongside wider market, business model, clinical and regulatory:

"When we were all in these multinationals, we built up relationships and you get to know people and you get to know the market, I know I can approach these people and I know I have some ideas and I know this doctor and he can get involved with me to check out the idea" (Founder, Indigenous B, 2010).

"Quite frankly it's [MNE subsidiary] the only place to get a grounding in the business because it's very international…..understanding markets, links in with clinicians – and it's a very relevant part of building the knowledge base to take flight in this business". (Founder, Indigenous Firm K, 2010)

"…they [MNE subsidiaries] are almost like a university for the people who go in there, they are so well trained in the worldwide regulatory requirements …so they learn a huge amount about the market, the products, where all businesses are going…Some smart guy in there spots it and says I'm going to set up a company and do that…we know what to do, we know what has to be done, we know the people to hire and they come out of there with a lot of credibility when you go to investors". (Founder, Indigenous Firm C, 2010).

Whether in related or unrelated technological and market domains, innovation in the Galway entrepreneurial ecosystem was strategically sustained by private-public cooperation. Specifically, the local university – NUI Galway - has played a central role in the evolution of the entrepreneurial ecosystem. It responded to the needs of the emerging and growing knowledge network (both indigenous and foreign-owned) by building the local research infrastructure and specialised training resources and focusing on supporting nascent entrepreneurs through infrastructural support and mentoring (see Table 1). The university also responded to the growing activity around medical technology, and beyond into ICT, by establishing medical technology research centres that were mainly formed through industry-academic partnerships. The university established the first medical technology research centre in Ireland in 1999, called the National Centre for Biomedical Engineering Science (NCBES). Through public and private funding it established three other research centres: REMEDI (2003), ICCM (2014) and CURAM (2014) (see Table 1). REMEDI has both indigenous and foreign-owned companies (including Medtronic) as its industrial partners. Its establishment expanded the entrepreneurial ecosystem's technology base into regenerative medicine therapies such as stem cell biology and manufacturing, gene therapy, orthobioloigies and immunology as well as cardiovascular areas (REMEDI, 2010). Furthermore, as knowledge was

gained locally on advancements in technology the University responded with the establishment of the National Centre for Biomedical Engineering Science (NCBES), which was, at the time (1999), the first research centre in the country in the area of medical technology. The NCBES was set up to bring together scientists, engineers and clinicians to develop diagnostic and therapeutic devices and to engage in research-related projects on cardiovascular, musculo-skeletal, rehabilitation and neural bioelectronics research. From the outset CR Bard/Medtronic became an official research partner of the NCBES and began to engage in joint research-based projects with academics and researchers in the Centre. Boston Scientific joined soon after as a partner for technology development particularly in unrelated branches.

The university also established a targeted entrepreneur and new venture development programme called Bioinnovate. This programme was funded by the Government agency, Enterprise Ireland, and mentored by Stanford University which had originated the programme successfully in the USA. The programme enrolled and brought together clinicians, business people, biomedical engineers, regulatory and legal experts to form diverse new product development teams. These teams search for entrepreneurial opportunities and develop new product ideas, with the most promising ones taken from an exploratory to development level. Commercialisable ideas with high-growth potential are then funded by Enterprise Ireland for further concept development and then opened up to external funding. This initiative has proven successful resulting in the further proliferation of entrepreneurial activity in the region.

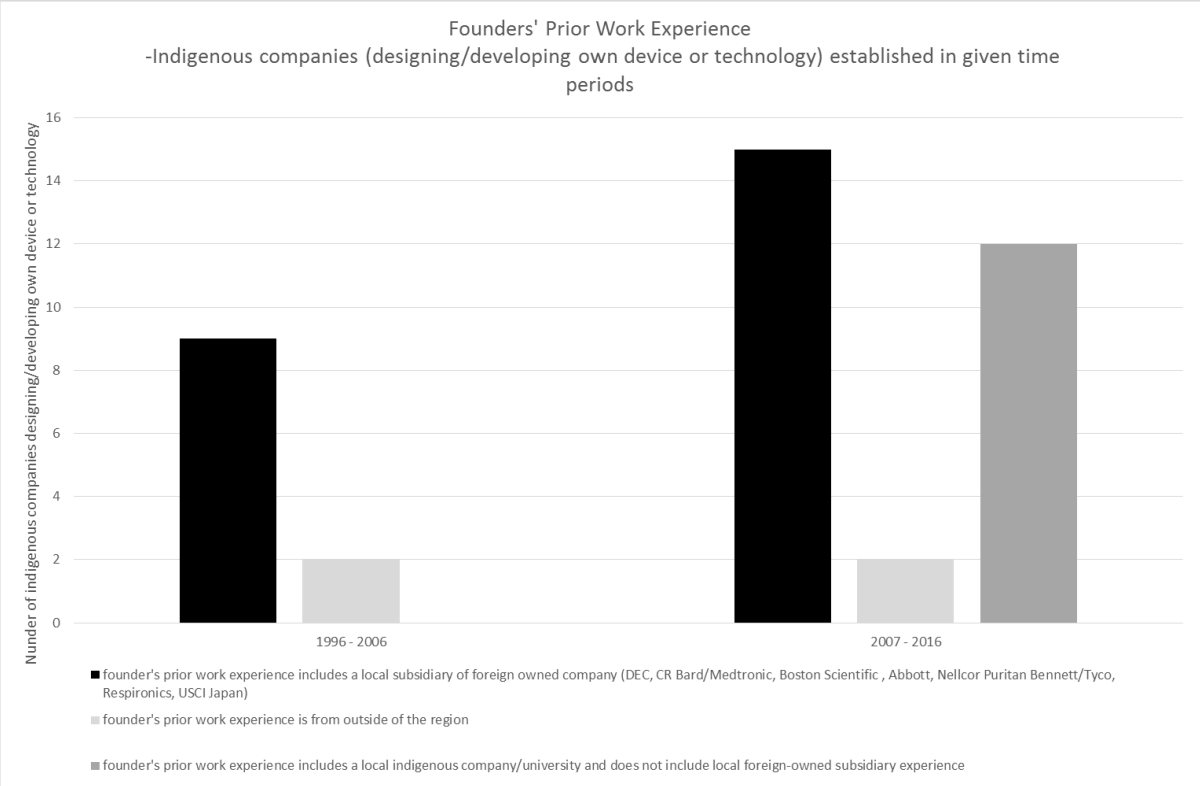
The CURAM research centre is especially notable as it merged knowledge on medical devices with ICT applications to diversify the knowledge base of the region. This was a policy endeavour to move beyond core medical device technologies into broader medical applications and thereby further broaden the knowledge base for entrepreneurial activity.

Year established	Activity	Details of Activity
1980	Mechanical Engineering Department	Skills and academic interest
1998	Biomedical Engineering Degree	Skills development specific to Medical Technology industry
1999	National Centre for Biomedical Engineering Science (NCBES) established	First research centre in Ireland in the field of medical technology.
2003	Regenerative Medicine Institute established (REMEDI)	Research institute in stem cell and gene therapy
2009	Specialist Postgraduate Diploma in Medical Device Science	Graduate skills development specific to medical technology sector
2010	Bioinnovate Ireland training programme initiated.	Training programme aimed at generating medical device start-ups
2013	Masters Programme in Biomedical Engineering	Graduate skills development specific to medical technology sector
2014	Irish Centre for Cell Manufacturing Ireland (ICCM)	The only approved centre in Ireland to engage in IN stem cell manufacturing
2014	Centre for Research in Medical Devices (CURAM)	Researching and developing implantable 'smart' medical devices.

Table 1: Teaching and research activity in the local university targeted at medical technology.

In the period 2007 to 2016 the entrepreneurial ecosystem evolved and strengthened through increased heterogeneity. After the initial period of co-specialism, many pioneer entrepreneurs successfully exited but went on to form further new ventures or act as mentors or financiers to prospective and nascent entrepreneurs. Other pioneering entrepreneurs grew their firms and in turn became incubators of the next generation of entrepreneurs. This created a virtuous cycle of development of the entrepreneurial ecosystem. Figure 3 illustrates the emergence of indigenous firms whose founders had prior experience either in local indigenous companies or the local university.

Figure 3: Prior work experience of entrepreneurs



There is an evident shift in the impact of MNEs on emergent entrepreneurship from their vital early incubation role. When asked in the 2005 round of interviews what would be the impact if Boston Scientific or Medtronic were to leave the local region the response from entrepreneurs was forthright and unequivocal. One entrepreneur stated that "it would be a significant blow to the local economy if one of these foreign subsidiaries were to leave Galway" (Indigenous firm, 2005). The same question asked in 2017 of founders provides evidence of the evolution of a strong local entrepreneurial ecosystem as follows:

"Of course it may not be ideal if one these corporations were to completely leave Galway, but there has been such a growth in med tech entrepreneurship that it certainly would not be the end of Med Tech here; if anything one of these leaving would spur all those engineers and managers currently working in these to set up their own companies – we have seen this happen already over the years" (Indigenous firm, 2017).

5. DISCUSSION AND CONCLUSIONS

This paper has investigated how MNEs can give rise to the genesis of an entrepreneurial ecosystem in terms of the technology trajectories it takes and the incubation of spinout entrepreneurship in related and unrelated technology branches. In doing so, we contribute to the literature on entrepreneurial ecosystems in a number of ways. First, we contribute to the literature that seeks to explain the link between cluster theory and the concept of an entrepreneurial ecosystem (Spigel and Harrison, 2018; Autio et al. 2018; Malecki, 2018) by showing how a transition from a cluster (Autio et al., 2018) to an ecosystem can occur. The longitudinal case study that is presented shows how the MNE subsidiaries initially anchored and guided the entrepreneurial ecosystem into a specialism around cardiovascular device activity. Over time, these dominant MNEs (in partnership with local university research centres and supported by Government enterprise agencies), and the spinout indigenous enterprises founded by ex-employees of the subsidiaries that emerged in both related and unrelated technological areas to this specialisation, enabled diversity to occur simultaneously with the original specialism. Through recent examples of the establishment of indigenous enterprises e we see this gradual evolution of the ecosystem from a cluster of activity centred on medical device technology converged with pharmaceuticals into more diverse technological areas in which the core competencies lie beyond medical technology. In the case of some connected healthcare companies established by founders with biomedical-mechanical engineering backgrounds, embedded software systems is the more significant capability than medical technology. This process of evolution blurs sectoral boundaries and makes industry distinctions less relevant. It has also reduced, although not eliminated, the dependence on a specific industry technology – in this case cardiovascular devices - which is the focus of an industrial cluster (Spigel and Harrrison, 2017; Autio et al., 2018). Ongoing coherence around a narrow specialism can make an entrepreneurial ecosystem vulnerable to decline (Mack and Mayer,

2016) resulting from technological lock-in and an incapability to adapt quickly to technological disruptions. Over time, the entrepreneurial ecosystem, which in our case has its genesis in MNE activity, develops multiple trajectories to ensure its heterogeneity (Malecki, 2018) and thereby strengthening its resilience (Roundy et al., 2017) while still maintaining the original specialism.

In a further illustration of the transition from industrial cluster to entrepreneurial ecosystem, our case shows how the firms created by the original spinout entrepreneurs from the MNEs in turn become incubators of a new generation of entrepreneurs or following a successful exit have nurtured new entrepreneurial activity with advice and capital. Therefore, the generation of architectural knowledge of 'what works' by pioneering entrepreneurs (Autio et al., 2018, p. 83) in terms of business modelling and how to pursue entrepreneurial opportunities has been important for fostering new ventures. The production not just of market and technical knowledge in related and unrelated products but also entrepreneurial knowledge in the region has resulted in a broader range of new ventures, a key characteristic of an entrepreneurial ecosystem that differentiates it from an industrial cluster (Spigel and Harrison, 2018).

The paper also makes a contribution to theory by combining the international business and entrepreneurial ecosystem literature and thereby adding to the sparse, and mixed evidence on the MNE as an actor in an entrepreneurial ecosystem (Bhawe and Zahra, 2019). Whereas Bhawe and Zhara (2019) point to the benefits of MNE entry to a host region for incumbent local firms with high absorptive capacity we show that MNE entry can also be the genesis for the development of a strong entrepreneurial ecosystem and explain the role of MNEs in the formation and strengthening of an entrepreneurial ecosystem. More specifically, we found that MNE subsidiaries, as conduits of 'global pipelines' (Bathelt et al., 2004) into and out of the entrepreneurial ecosystem, can result in them shaping the technological trajectory of new

entrepreneurial ecosystems and underpin their evolution over time. The MNE can both instigate an entrepreneurial ecosystem and also promote its development through spillovers and spinouts. There is an important 'connector' role to global entrepreneurial ecosystems that the MNE subsidiary can play. MNE employees develop global connections, particularly with customers, that provides a source of innovation and places them in a position to later exploit entrepreneurial opportunities in establishing their own globally oriented hi-tech start-ups. These international connections can also enable the employees of MNEs to identify new business opportunities in untapped global market niches.

Our study is also of significance for policy. First, it provides policymakers with insights into the dynamics sustaining the competitive advantage and innovation capabilities of geographically bounded entrepreneurial ecosystems. If attracting foreign investments is often seen as the one best ways to foster local economic development, ensuring that a local entrepreneurial ecosystem is established and thrives over time should be regarded as the second necessary condition for sustaining a regional economy. Secondly, policy-makers coping with the volatility and the centrifugal forces of globalisation would benefit from understanding how entrepreneurship is nurtured and developed and the dynamics underpinning it in a local milieu. Reflecting on the empirical analysis discussed in this paper, we contend that the evolution of an entrepreneurial ecosystem relies on two critical factors: i) the initial accumulation of a distinctive stock of knowledge locally; ii) the continuous improvement of such a stock of knowledge through the exploration of new trajectories of specialisation. In the case of the Galway entrepreneurial ecosystem, while the first condition was enabled by the establishment of the global subsidiaries of MNEs, the exploration of new knowledge frontiers occurred as former employees identified and exploited market opportunities. The close interdependence existing between global subsidiaries, local entrepreneurs and regional institutions, notably

universities, facilitated the integration of these two necessary conditions enabling the transition from the accumulation of distinctive knowledge to the exploration of new trajectories.

As the formation of an entrepreneurial ecosystem occurs over time rather than at a single point in time, the MNE can be considered a wellspring that gives rise to the ecosystem from a cluster (Autio et al., 2018). At the same time, while an entrepreneurial ecosystem can evolve in this manner, the linkages to clustering are seen to persist for an elongated period of time. The significance of having coherency around specialisms as well as heterogeneity for a resilient entrepreneurial ecosystem (Roundy et al., 2017) is such that reaching an 'ideal' state is an idiosyncratic evolutionary process. Consequently, the contention that an entrepreneurial ecosystem must become industry and technology agnostic to be a 'true' form (Spigel and Harrison, 2018; Malecki, 2018; Autio et al., 2018) may ultimately be overly idealistic for practice.

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