Foreign Direct Investment, Indigenous Growth and Regional Entrepreneurial Capabilities: A Study of Irish Medical Device Industry Entrepreneurs

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Oner Tulum
Centre for Innovation and Structural Change
National University of Ireland Galway
Oner.tulum@nuigalway.ie

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Contact:

Angela Sice
Development Office
Tel: +353 91 492817
Email: **angela.sice@nuigalway.ie**

Dr. James Cunningham
Director
Tel: +353 91 493472
Email: **james.cunningham@nuigalway.ie**

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Introduction

Multinational enterprises (MNEs) provide the learning opportunities for skilled employees in their overseas subsidiaries to assimilate the capabilities to form their own technology enterprises and be successful 'technopreneurs' (Wong, 2001). Local regional development can be driven by such technopreneurs (Venkataraman, 2004; Lee & Wong, 2004). Ireland's recent economic growth has been strongly driven by foreign direct investment in fast growth hi-tech industries. The Irish medical device industry is one of the country's greatest success stories. This industry, which boasts annual sales in excess of €6 billion, employs around twenty-six thousand employees, and has an industry base consisting of 140 indigenous and foreign-owned companies. The industry has attracted 15 of the world's top 25 largest medical device corporations (www.imda.ie). Ireland's expansion in the global medical technology sector is a result of possessing the necessary "hard" and "soft" skills for medical device manufacturing

The successful development of the Irish medical technology sector is a consequence of the policy drive to attract high-tech FDI. Employment in the medical devices sector in Ireland more than doubled between 1996 and 2006 (Forfás, 2008, pg 16), with an estimated 24,000 employees working in over 140 companies (IMDA website). Foreign-owned firms have created over 90% of employment in the sector (Forfás, 2008) and the presence of significant operations by the world's top companies such as Boston Scientific, Abbott, Johnson & Johnson, Medtronic, Stryker, Merit Medical, Baxter and Tyco Healthcare has resulted in the Irish sector being compared to leading global medical centres: Massachusetts and Minnesota (Forfás 2008).

The development of the medical technology sector in Ireland typifies the nature of economic growth that the country has experienced over the past two decades. Led by the presence of significant operations by top foreign-owned multinational corporations in the field, the Irish medical technology sector has contributed to rising high-tech exports and knowledge-based employment. The purpose of this paper is to undertake a data analysis exercise utilising the

the research project's database to understand the development and dynamics of this sector. In particular, the study provides an understanding of the capabilities and skills of the sector by analysing its product composition, which departs from many existing studies that tend to focus on the composition of firms as opposed to products. Based on this case study analysis, the main argument presented is that the capabilities are in place to allow a transition to a new business model based on endogenous development and, through a cultivation of these capabilities, the opportunity is present for the sector to develop to a stage comparable with leading medical technology clusters internationally.

Following this introduction, an overview of technopreneurship and the role of technopreneurship in building and sustaining technology based sectors has been provided. Subsequently, the next section focuses on the development of the medical technology industry and, in particular, the product composition of the sector in order to identify the source of and to gauge its existing technological capability. Acknowledging the specialisation of activity at a regional level, the third section provides a more thorough understanding of the emergence and development of this regional cluster is provided in terms of its capabilities and skills, the interplay between third-level and industry, indigenous growth and emerging and converging technologies. Finally, conclusions are drawn in the fourth section.

1. Regional Capabilities and Technopreneurship

Technical skill transformation from incubator firms to indigenous firm foundation within region through new start-ups has been documented by Cooper (1986 & 1990). Chatterji (2008) illuminates a set of skills which is highly diffrenet from technical skills. It is the soft-skills (non-technical skills) as oppose to hard skill (technical skills) that leads to high-tech spin-offs in regions (Chatterji 2008, pg. 201). Certain soft skills that an entrepreneur develop during his or her prior experience in the incubator firm such as substantial knowledge on regulatory process; connections with the remote management, suppliers and major clients; and social networks that are developed prior to firm start-up. It is what Venkataraman (2004) calls "intangible" assets such as access to novel ideas, role models, informal forums, region specific opportunities, safety nets, access to large market and executive leadership that constructs the necessary foundation for technological entrepreneurship. (pg. 155)

As being one of the necessary conditions of new start-ups, the role of social networks in term of accelerating entrepreneurial activities within regions has been also studied substantially (Aldrich and Zimmer, 1986; Kamm & Aldrich, 1991; Hansen, 1995; Shaw and Conway, 2000). The role social networks that leads to entrepreneurial activities in various forms (serial, portfolio, technological, and etc.) has not been paid much attention in the Irish context. This paper aims to study a high-technology based industry, Medical Device Industry, entrepreneurial activities through technological entrepreneurship or "technopreneurship" perspective. Technopreneurship is highly growing concept that studies technology based enterprise formation and characteristics of this novel entrepreneurial form that requires technology production or process as the fundamental nature of entrepreneurial activities (Wong, 2001; Chatterji, 2008).

Irish indigenous start-up formation within the medical device industry has been escalating as more and more Irish venture succeeds in terms of bringing technologies from laboratory environment to the market place. Other than being role models (Venkatamaran, 2004) to many potential technopreneurs, founders of those successful Irish Medical Device ventures have been linking with other potential (or exisiting) entrepreneurs that leads to various forms of entrepreneurship. As "technology" being the main focus, those ventures has about change the nature of entrepreneurship within the medical device industry in Ireland.

3. Methodology

The study first utilized a highly granulated industry and product classification to define the industry boundaries and subdivisions based on product and production technology proximity. Defining and classifying the industry and the cluster in Ireland is key to obtaining a strong grasp of industry composition as well as where and how the capabilities for this evolving industry initially developed and transferred over time. It is crucial to locate the source of existing capability by tracing the trails (products) of agents (companies and entrepreneurs) within regions. The core dataset for this exercise is developed by collecting business demographics on companies in medical technology. The data also includes business information such as location, number of employees, year of founding, country of ownership and product profiles that are defined by a finely granulated technology classification system.

Furthermore, the database has been enriched with qualitative data generated through company webpages, archive searches and interview results. Some information obtained from discussions with industry representatives and leaders are also included in the database building process. Social Network Analysis has been conducted to study inter-organizational networks through key senior executives. Based on the analysis, a network map has been designed in which key serial and portfolio "technopreneurs" were surfaced This network map helps identify key positions of individuals within a complex social network. This map illustrates the entire process through which key figures in the industry have developed the "soft" and "hard" skills found to be so necessary for "technopreneurship".

As being one of research objectives, the project aimed at defining the industry boundaries by introducing a new Medical Device and Equipment (MEDEV) technology product sub-groups. Medical Device products are defined in the Kompass product classification by using 5 and 7-digit product classifications to populate the medical device industry in Ireland. 7-digit Kompass product codes are further grouped based on their technological proximity.

[Insert table 1 about here]

At it is seen on the table 1, Column A indicates the new product groups based on proximity, Column B indicates the number of products that each company produces within the group, and Column C indicates the product groups based on Kompass 7-digit Kompass codes. The new technology groups are used as product technology bands and after creating the populations for the new bands, each product is placed in the new bands to display the product concentration within the groups. This exercise is carried out to detect a systematic product concentration within the technology bands by using Math Lab. The same exercise is conducted by sorting companies based on their basic and demographic information such as date incorporated, size, origin and location.

After developing a complex technology-based company dataset, the dataset was processed in mathematical software, MATLAB[1] by using complex datamining techniques. A Scatter Plot

[1] MATLAB is a registered trademark of The MathWorks software company. The software is design to compute technical and model-based design. See the link for more information about the software (http://www.mathworks.com/company/)

technique has been chosen to display this complex data to easily determine within which segments of this industry Ireland has competitiveness and expertise.

[Insert figure 1 about here]

Figure 1 exhibits an interesting result in the SME-Special band. The majority of the products in this band are manufactured by foreign-owned companies. Figures 1also suggest that major foreign manufacturers are surrounded by smaller scale local suppliers. MDSV, on the other hand, indicates an indigenously driven industry segment. After firms are broken into two groups as indigenous and foreign first in Figure 1, the firms then sorted by their incorporation year in Ireland. When the time scale is included in the graph, more interesting results are drawn. For instance, roots of several foreign-owned firms manufacturing products in Dental Products (DENT), MDSV, SME- Special, and Diagnostic Equipment and Testing Devices (DETD), extend back to the early 1930s. However, among the indigenous groups, the firms extending back to the early 1930s are in different areas such as the manufacturing of products in the MDPD-B, Medical Reproduction Equipments (MDRE), and ORPR bands.

[Insert figure 2 about here]

Ages of the firms can be further examined in the following graph (figure 2). In the figure, the firms grouped in 7- to 10-year intervals. Firms that have products in SME-Monitor. band were founded earlier than mid-1990s. Firms in MDSV band, on the other hand, seemed to be founded later than 1990s with the few exceptions in 1970s. ORPR band presents an interesting result. Market entry of the firms that have products in this band are scattered around late 1970s, mid 1990s and.

4. Capability Emergence of Irish Technopreneurs

In line with the growing electronics and software sector, medical technology activity in Galway was initiated with an investment by another American corporation, CR Bard. In 1982 CR Bard established a facility involved in the development and manufacture of products in the area of coronary and vascular disease. Ireland provided corporations like CR Bard, Digital and Nortel Networks access to the European market, tax incentives and an English speaking

and educated workforce (Lucerna, 2009). New CR Bard plant attracted other major medical device firms such as Puritan Bennett, Abbott, Boston Scientific, Tyco and etc. As new firms considered moving into this region, the university and research institutes in Galway-Mayo corridor positioned themselves as a platform in which the industry, scientists and engineers interact and collaborate on tackling with various technical and administrative challenges. Hence Galway is considered as the heart of medical device industry in Ireland and the following section will use greater-Galway region as a case study to analyse this industry.

However, in 1993 the technology sector in Galway received a major setback when Digital closed the hardware manufacturing facility with the loss of 760 people. The reason for the closure related primarily to technological developments and changing customer needs within the industry. More specifically the emergence of the personal computer market and the failure of Digital Corporation to break into this market (Needham, 1999) resulted in losses for the Corporation in the early 1990s. Manufacturing plants were consolidated as it needed to implement a more cost effective structure. Significantly, however, the Software Centre remained opened in Galway and was taken over by Compaq and subsequently Hewlett Packard.

The closure of the Digital manufacturing facility in Galway resulted in a number of initiatives being undertaken by Digital Corporation, the Government and local business groups that resulted in the foundation of start-up enterprises in the region (Needham, 1999). The Corporation itself offered internal services to redundant staff that included job search facilities, career change programmes and an enterprise development/start your own business programme (Needham, 1999). In addition, the Government along with national industrial development agencies and local business support groups formed an inter-agency task force from which the most significant outcomes were the provision of funding for start-up enterprises, access to advisory services and the establishment of the Galway Technology Centre (Green et al. 2001). The Centre provides workspace for early stage and developing high-technology enterprises.

As a result of these initiatives, many ex-Digital staff used their acquired managerial skills to form businesses in various areas including, electronics, software, manufacturing and services (Needham, 1999). In addition, existing foreign investments in technology were encouraged to

remain in the region while new foreign investment was sought (Green et al. 2001). In particular, one of the world's leading medical technology corporations, Boston Scientific, established a facility in 1994, occupying some of the redundant Digital space. Whilst initially it was a relatively low-value added manufacturing facility, over the 1990s and early 2000s the MNC opened an R&D facility to develop as well as manufacture medical devices particularly drug-eluting stents within the field of cardiology. Furthermore, in 1998 the cardiovascular division of CR Bard was acquired by AVE (Arterial Vascular Engineering), which was subsequently acquired by Medtronic the following year. Both AVE and Medtronic held this division in Galway and the facility concentrates on the development and manufacture of drug-eluting stents and their components.

While Medtronic and Boston Scientific are presently by far the largest employers (employing over 4000 people between them in the region), a number of smaller-sized indigenous and foreign-owned companies have established in the past decade adding to the vibrancy of the cluster. The establishment of these new firms as well as the frequent mergers, acquisitions and management buy-outs taking place underscores the cluster's dynamism. However, foreign investments from world-renowned corporations, including Tyco Healthcare (formally Nellcor Puriten Bennett in the region), Beckman Coulter and Merit Medical as well as Boston Scientific and Medtronic drive the cluster (Giblin, 2007). While divestments from the region, most notably Abbott in 2007 also mark its landscape and accentuate the vulnerability attached to a dependence on foreign investors, it is the upgrading of many of these investments from initial manufacturing sites to product development facilities that has resulted in a transfer of knowledge, skills and capabilities to the locality (Giblin, 2007). The next subsection explores these capabilities and skills in more detail.

The influential presence of Boston Scientific and Medtronic has resulted in many of the companies being involved in cardiology related devices, particularly drug-eluting stents and their components, such as guidewires, balloon catheters, hypotubes and filters. As result the Galway region has been recognised for its specialisation in coronary devices (Brown, 2005; Stommen, 2005). 14 out 40 medical device products manufactured in Galway are within the Specialized Surgical and Medical Equipment (SME-Special.) technology band (Lucerna, 2009). The products within this band are mostly minimally invasive cardiovascular interventional products.

5. Indigenous Growth, Emerging Technologies & Converging

The effects of DEC closure on the formation of start-ups in newly developing subsectors within ICT such as integrated-circuit design, software and etc were highly visible (Giblin, 2007; Needham, 1999). Medical device start-ups, Galway region in particular, were also emerging as a result of indigenous-focused policies that have been implemented through various government agencies. Post-DEC era policies, as discussed previously, created incentives for redundant but skilled DEC employees (Needham, 1999) and ex-vendors to link with the globally emerging new sectors. Figure 3 is created to display the annual venture formation by Irish and Foreign owned for MEDEV industry group based on Lucerna company data. The figure demonstrates annual number of Irish and Foreign owned start-ups in Irish medical device industry

[Insert figure 3 about here]

A curved, Polynomial, trenline is constructed to observe the changes overtime with subtracting sharp fluctuations (Figure 3). The Polynomial trenlines indicate a slow decline in foreign owned start-ups during the post-DEC period. On the other hand, Irish owned start-ups present a consisting upward trend during the same period. It is worth further investigating the phenomenon of where the closure of an anchor firm is followed by an indigenous start-up growth. The process can be basically summarized on the following concept map of Irish skill transformation.

[Insert Figure 4 about here]

The entire evolutionary process of medical device industry in Ireland can be grouped within three distinct periods in the region. During the first, *Economic Stagnancy*, period economic activities have shifted to export oriented manufacturing activities. In this period the government also targeted successful technology-based FDIs inflow through fiscal, low corporate tax regime and other sorts of financial assistance as well as natural geographical incentives, such as easy access to UK and EEC. The new economic policies have led to a significant growth during the second, *Boom*, period. Irish managers were given opportunities to set up plants and manage them for foreign Multi National Corporations (MNCs). Irish

engineers gained highly valuable “hands-on” trainings on managing production tasks from initial product and production design to regulatory “problem solving” and product approval tasks in order to manage highly delicate relation with headquarters. The Irish success has attracted more global firms to locate in the region and to tap into this new distinct regional skill resources. The tasks that are challenged were technological as well as administrative from time to time thus a local and distinct competencies were derived from very routine activities in the region.

This new competency has led to the formation of two distinct skills formation: Managerial Skill or Soft Skill and Complementary Capacity Development or Hard Skill. With the new sets of skills, Irish managers were more confident to pursue the ideas that were developed during their MNC experience. In fact, each MNC relocation decision in the regions has led to the formation of many indigenous start-ups. This fact is clearly demonstrated in the Figure 5 as the technopreneurs and their start-ups as well as their network with the other firms. The names of technopreneurs and executives are represented in different ellipses. Each shaded hexagon shape indicates the start-up, the darker ones indicate the MNC managerial experience and the lighter ones indicate the foreign acquisition. In hexagon shapes, the dates on top of company name indicates the incorporation date and the date below the company names indicates the appointment and the resignation dates of each executive. In this experiment, Galway regions in particular has been home to many Team technopreneurs who have prior MNC managerial experience and are part of serial technology-based business start-ups. A technopreneurial team is defined as a group of individuals who are part of initial or later stage technology business start-up process (Hsu, 2008 and Neergaard 2005). The core data for the map is acquired from FAME business database and supplemented with the data through internet content and archive searches.

[*Insert figure 5 abut here]*

As Figure 5 exhibits, John O’Shaughnessey, Charles Taylor and Paul Gilson were also senior executives of one of the earliest the US Medical Device firm, CR Bard, before its acquisition by Arterial Vascular Engineering (AVE) which was later acquired by Medtronic. CR Bard acquisition was followed by the first wave of serial start-ups by O’Shaughnessey, Taylor and Gilson team. The very first series of start-ups, Salviac, Carotid Interventional Systems (CIS) and MedNova, resulted with great success and CIS and its parent company MedNova

acquired by the vascular division of the US life science company Abbott. Another successful Irish Start-up, Crospon Technologies, was also a team effort by John O'Dea, John O'Shaughnessey, and Conor McNamara. Prior to Crospon, John O'Dea set up the R&D facility for Puritan Bennett before starting a new venture which was a great success and resulted with the acquisition this venture by the US company called Respironics (Daly, 2007).

The juxtaposition of different technological spheres has been an important element in the growth of the indigenous medical technology cluster in Galway. The development of capabilities in electronics through the presence of companies like Digital in the region provided an initial platform from which medical technology activities have grown. The Galway-based company, Creganna provides a case in point. This company, which established in 1980, was involved in metal works and the provision of engineering solutions to the electronics industry but by 2003 it had divested interests in electronics to focus solely on the medical device market. It is now one of the largest indigenous employers in medical technologies in Ireland with over 520 employees across its Irish and US bases (Corrigan, 2008). With Boston Scientific and Medtronic both involved in the production of drug-eluting stents in the region and the growth of companies like Creganna around this activity the convergence of pharmaceutical and medical technologies has also been at the core of the cluster's development.

As companies look for new opportunities, the potential for product development in the convergence of particularly ICT and medical technologies has received attention recently (Allen, 2008) and is one in which Galway is ideally placed to exploit. Along with the growing medical technology cluster in the 1990s, the closure of Digital signalled the growth of an ICT cluster in Galway (Green et al., 2001), particularly in the area of software (Giblin, 2007). Although it entails a smaller concentration of firms than in Dublin, the software industry in Galway is characterised by the presence of foreign-owned affiliates, such as Hewlett Packard and Nortel creating most of the employment and a larger number of small and medium sized enterprises. Many of the firms are involved in software product development, particularly bespoke software, systems software and application software development as opposed to lower value-added localisation activities (Giblin, 2007). With clusters of software and medical technology firms in Galway, the potential for using local expertise in the convergence of these technologies is significant but has not as yet been greatly exploited.

The endeavour to converge IT and medical technology has been undertaken by one medical company in the region by collaborating with Hewlett Packard in the US. Through a license agreement with this corporation, the local indigenous company Crospon will produce and commercialise a drug-delivery patch applied to the skin, which enables "precise control of dosage timing, access to dosage history, patient activation mechanisms and inherent safety protocols for preventing adverse drug interactions"[2]. The skin patch, developed by HP Labs[3] based on the core technologies of their thermal inkjet printer (Brown 2008), will involve a three-way convergence of IT, medical technology and pharmaceuticals. While Hewlett Packard initially foresaw regulatory barriers in bringing the concept to market but were considering it as a potential business partnering project, the bringing together of the corporation with Crospon through Enterprise Ireland led to the licensing out of the intellectual property (Brown, 2008). Hewlett Packard runs an IP licensing programme and Enterprise Ireland approached the corporation in Palo Alto, California to encourage them to consider Irish companies for licensing agreements. From this, the relationship with the Galway-based medical technology company developed.

Another company in the region, Vysera, which is involved in the design of anti-reflux valves based on biomimetic material and used for the digestive tract, has recently undertaken a "software modelling project that will add value to future product design" (Corrigan, 2008). Although, perhaps not a direct use of software for the functioning of a medical device, the increased awareness of companies of the use of software to add value in different ways is significant for the industry and local economy. Indeed, John O'Dea of Crospon states that "the proximity between the IT and medical device sectors could be harnessed here with Ireland playing a key role in the emerging technological space" (Allen, 2008). The opportunities of using IT technologies to develop systems that communicate with implantable medical devices (Allen, 2008) or to control and manage the delivery of drugs as in the case of the HP-Crospon skin patch are immense.

[2] See www.crospon.ie for more detailed description of this technology
[3] HP Labs is an advanced research group for Hewlett Packard and has sites in India, China, United Kingdom, Israel, USA, Russia and Japan.

6. Discussion and Conclusion.

As impressive as such increase in indigenous growth is, there are challenges to the development of this technological convergence whether at a local or national level. It requires a collaborative environment (Allen, 2008) with connectivity linkages between various actors; including firms from different technological domains, regulatory bodies, end-users (e.g. clinicians), legal bodies, funding agencies and research centres. Industrial development authorities, like Enterprise Ireland and IDA Ireland can be used as a means for opening and building communication linkages between these various actors. Most significantly however, such a collaborative environment necessitates inter-organisational trust (Allen, 2008) and long-term commitment to capitalise on local technological expertise in the highly competitive industries of IT and medical technology.

As one of the success stories of the Irish economy over the past two decades, this paper examines the case of the medical technology sector in Ireland. It shows the evolution of the industry from low value-added branch plant manufacturing to upgraded product development and world-class manufacturing capabilities. Using the data from the the research project, which enables an understanding of the product composition of this industry, the capabilities and technological capacity of the sector can be analysed. A further examination of the data reveals an early stage establishment of manufacturing sites by foreign-owned multinational corporations and the increase in indigenous start-up activity, primarily since the mid-1990s has led to the formation of soft (managerial) and hard skills (complementary capacity development) from the presence of the multinational corporations which translates into the establishment of start-up enterprises in the region. Data analysis from the The research project project indicates the formation of hardskill capabilities as indigenous activity mirrors the activity of foreign-owned enterprises in the region. Furthermore, the convergence of technologies around electronics, medical technology and pharmaceuticals has been a key factor in the evolution of the regional cluster and its future development will depend on the exploitation of local opportunities for new technological convergences.

Overall, this analysis provides a systematic understanding of the internal dynamics of the medical technology industry in Ireland. As the economic model of attracting FDI based on cost competitiveness and grant incentives has now become relatively inadequate in Ireland,

the need to make the successful transition to a new model based on endogenous development is paramount. The argument made here, substantiated by an analysis of the medical technology sector using a distinctive methodological datamining approach, is that the seeds to make this transition are in place. The old model has been successful in establishing a global and vibrant high-tech industry within a few decades. However, to advance such an industry to a level comparable with other high-tech regions internationally, like Massachusetts, requires encouraging skill transformation processes, exploiting new skill formation in the form of indigenous enterprises and entrepreneurship, and most significantly promoting the convergence of technologies to lead the way in the emergence of new technological spheres. The required technopreneurs may be sourced in the MNCs wherein they are acquiring the necessary capabilities to setup and manage new technology ventures.

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TABLE 1. THE RESEARCH PROJECT GROUPS V2		
Technology Bands	**# Prods**	**Kompas Product Names**
Surgical & MedicalEquipment - Specialized (SME-S)	87	Medical and Surgical Equipment
Surgical & Medical Equipments - Basic (SME-B)	21	Medical and Surgical Equipment
Surgical & Medical Equipment - Support System (SME-SS)	15	Medical and Surgical Equipment
Surgical & Medical Equipment - Sterilization & Preservation (SME-SP)	40	Medical and Surgical Equipment
Surgical & Medical Equipments - Monitoring(SME-M)	33	Medical and Surgical Equipment
Basic Surgical & Medical Instruments (SMI-B)	91	Medical and Surgical Instruments Medical and Surgical Instruments
Dental Equipments (DENT)	**82**	**Dental equipment and Instruments** **Dental Laboratory Equipments** **Dental Prostheses**
Medical Reproduction Equipments (MDRE)	65	Equipment and instruments for medical laboratory Laboratory equipment
Orthopaedics & Prostheses (ORPR)	49	Orthopaedic Equipment Prostheses (Excludes Dental Prost.)
Medical Products - Basic (MDPD-B)	43	Rubber and Synthetic Products-Medical Use Plastic Products-Medical Use Plastic Surgical and Orthopaedics Products Medical Glassware
Veterinary Equipments (VETE)	37	Veterinary surgical and medical equipment
Electro-medical and electro-biological equipment (EMBE)	33	Electro-medical and electro-biological equipment
Diagnostics Equipments & Testing Devices (DETD)	28	Medical and Biochemical Diagnostic Kits Ophthalmic testing equipment Cardiovascular Products and Coronary Vasodilators Gastrointestinal Endoscopy and Urological Devices
		Hearing aids

APPENDICES

Figure 1: Product Landscape of Irish Medical Device Industry (By Origin)

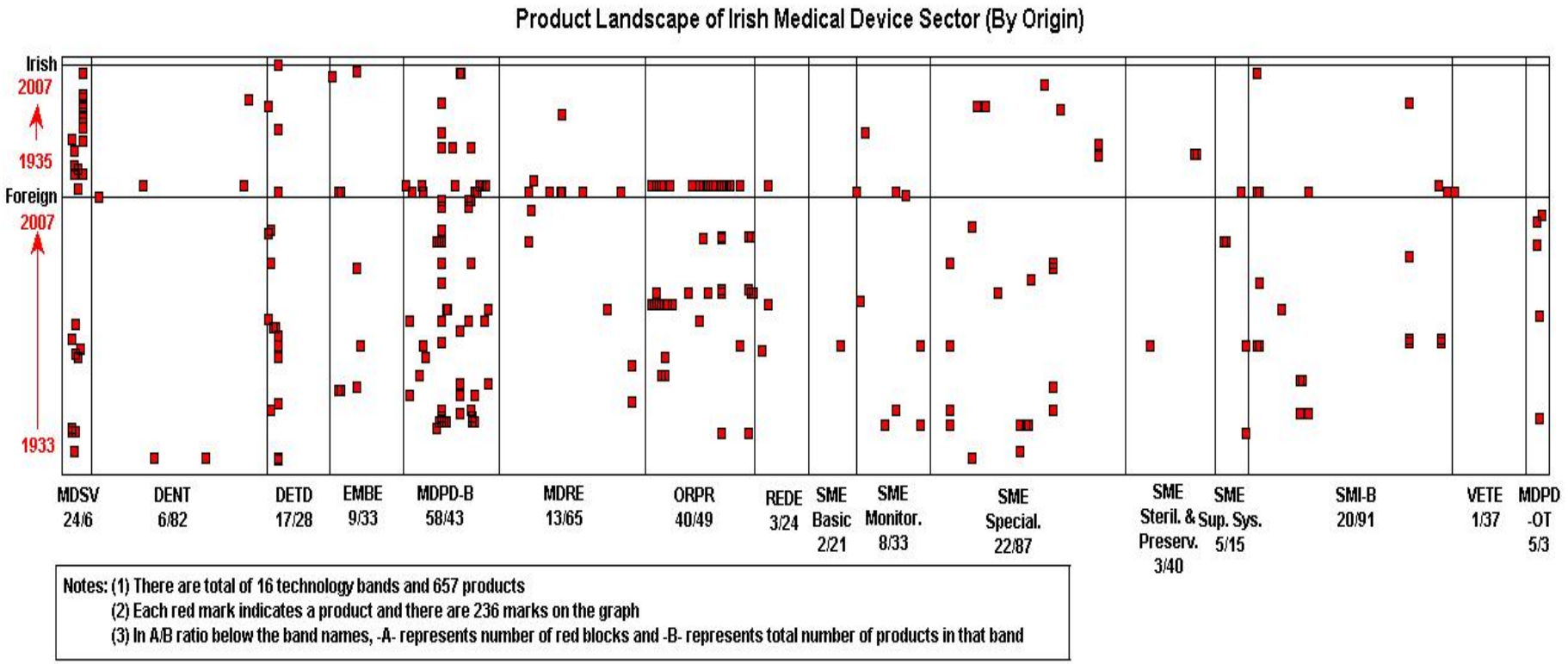

Figure 2: Product Landscape of Irish Medical Device Industry (By Incorporation Year)

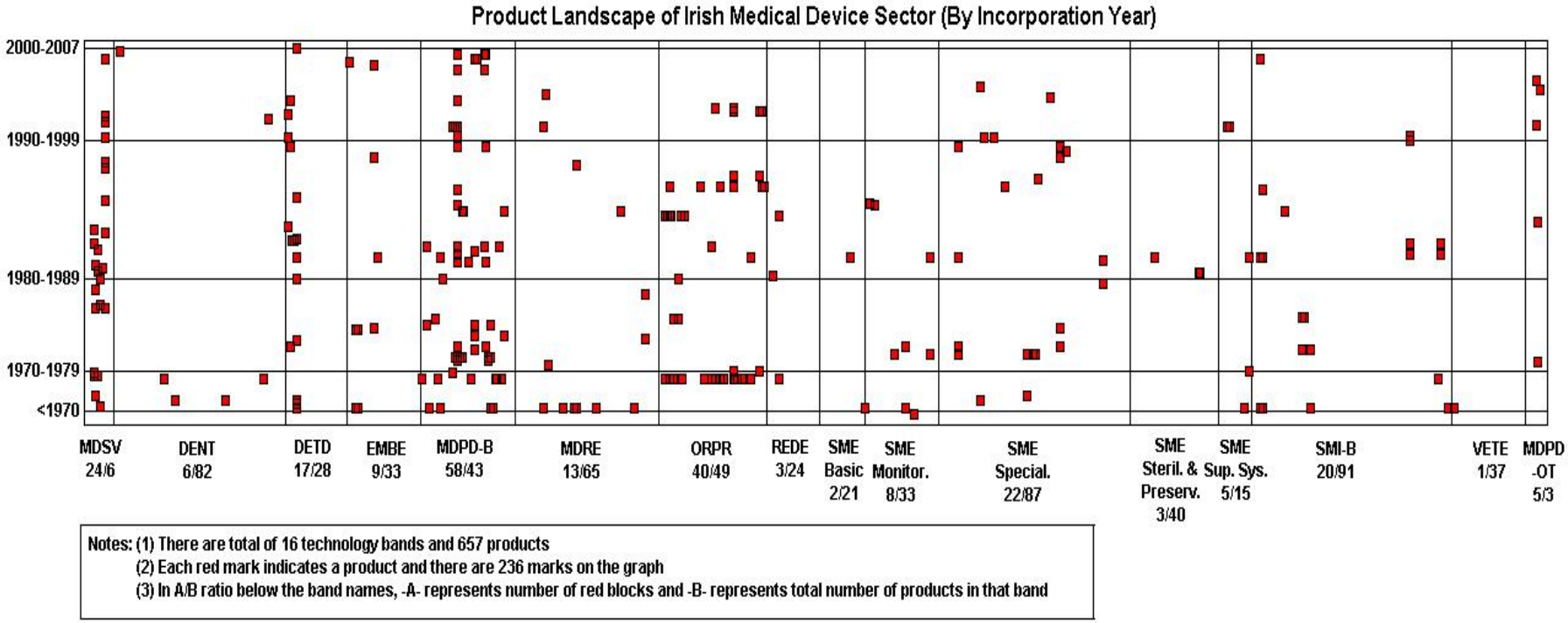

Figure 3: Irish vs. Foreign Owned MEDEV Start-ups

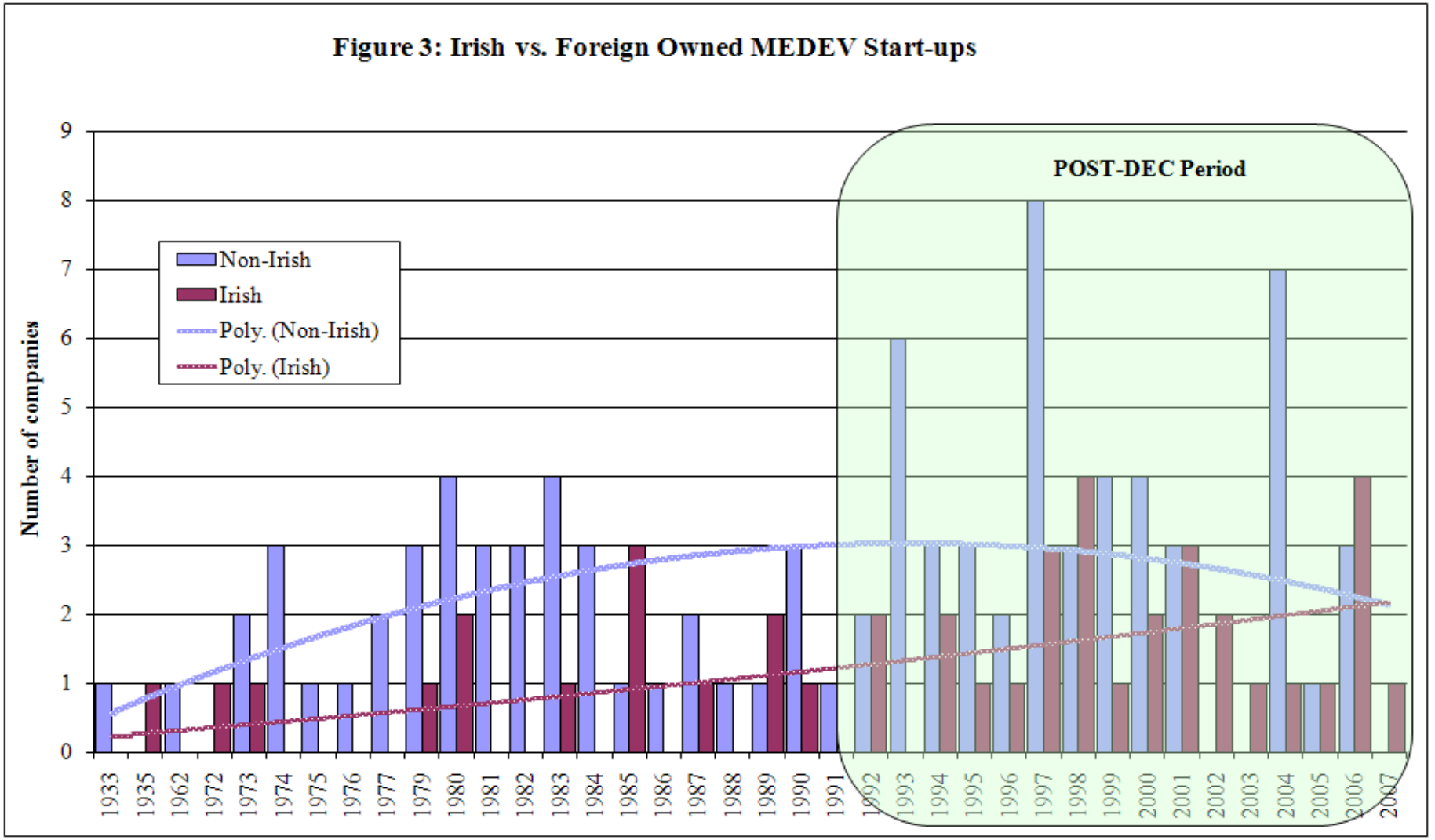

Figure 4: Theoretical Framework of the Study

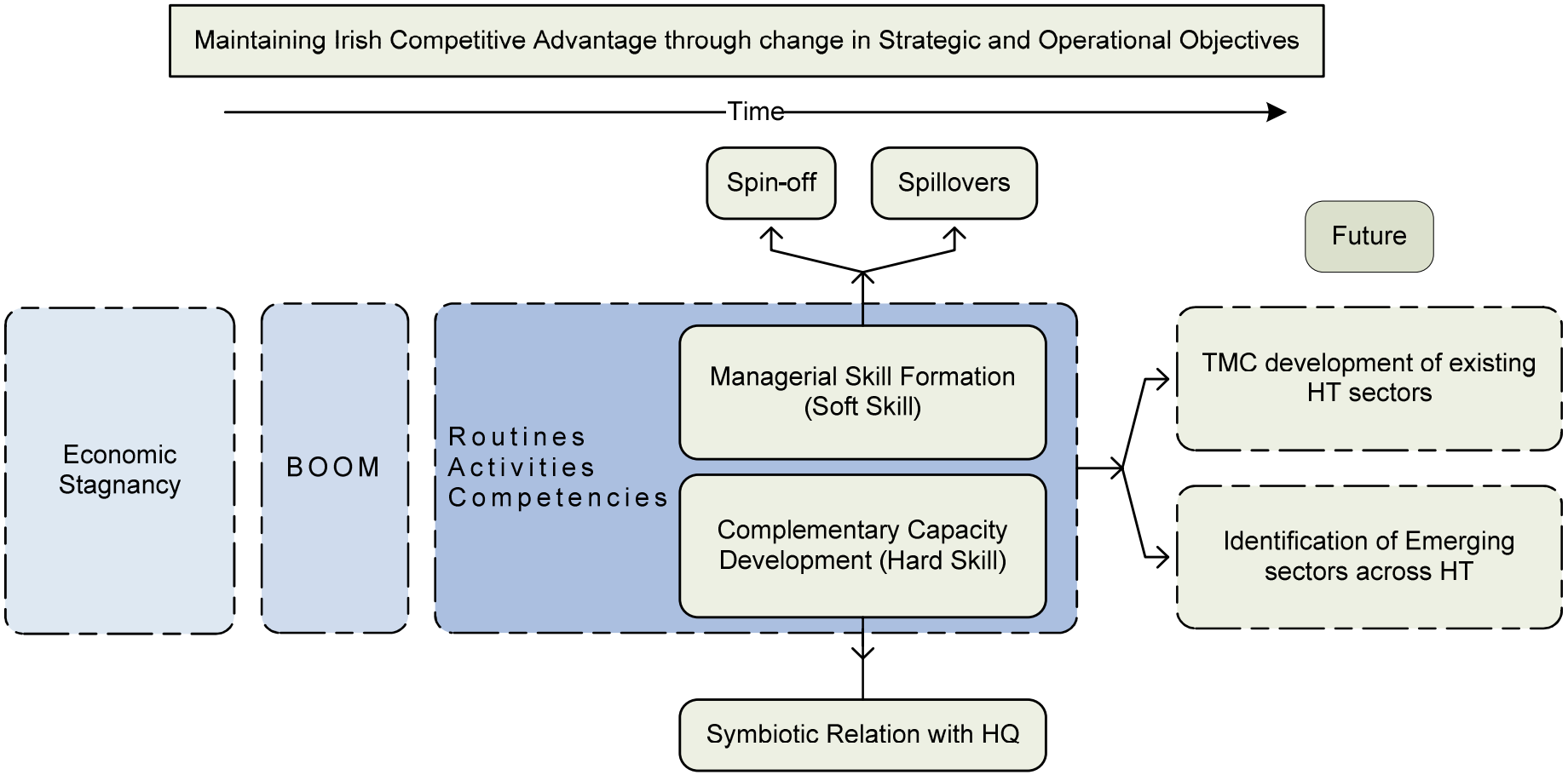

Figure 5: Irish Indigenous Start-ups Genealogy Map