Sectoral Systems of Innovation – Assessing the effect of Firm Age and Strategic Intent on System Fit

by

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A thesis submitted in part fulfilment of the requirements for the degree of Doctor of Philosophy

Warwick Business School - University of Warwick

December 2014

Abstract

Innovation is fundamental to the firm and ultimately to national economic growth and stability. Systemic support for identified sectors assumes that innovation depends not only on how individual firm and non-firm actors perform but also on the dynamics of their interaction as parts of a system. To date, research within the Sectoral System of Innovation framework perceived *fit* as a function of enablement between the firm and the system based on industry type. This is problematic as assuming firms are homogenous overlooks the impact of critical micro level contingencies such as age and strategic intent in achieving fit, and in turn enabling innovation.

Consistent with theory that organisational performance is a function of the fit between two or more factors within a system, this thesis departs from previous macro and meso system-level approaches by undertaking a micro level analysis of how fit is mediated by age and strategy contingencies in two contrasting sectors. Using interview and survey data of Irish software and manufacturing engineering companies, this represents the first empirical analysis of contingency-based system fit.

This study reveals a detachment between the universality implied in the design of Sectoral Systems of Innovation and the heterogeneity of firm context. Importantly, this finding provides strong evidence supporting previously intuitive calls for policy makers to place greater emphasis on firm dynamics. The findings in relation to firm age and strategic intent demonstrate that the nature of value creation hinges significantly on firm-level contingencies. This new departure extends current thinking on Systems of Innovation by clearly demonstrating the effects of firm-level characteristics, adding to the explanatory breadth of the existing framework. This contribution to theory has important implications for both firm managers and policy makers, enabling more effective interventions in their efforts to drive and support innovation outcomes.

Declaration

This thesis is submitted to the University of Warwick in support of my application for the Degree of Doctor of Philosophy. It is entirely my own work and has not been submitted in any previous application for any degree.

19th December, 2014

Acknowledgements

I would like to express sincere gratitude to my supervisor, Professor Stephen Roper for his insight, encouragement and patience. Sincere thanks also to Associate Professor Kevin Mole, my second supervisor, for his invaluable analysis and guidance. My appreciation also goes to my family, my friends and my colleagues at the Dublin Institute of Technology, in particular Dr. Katrina Lawlor and Professor Pamela Sharkey-Scott.

Finally, I would like to express my appreciation to all those who gave of their time in the course of this research, to those who participated in interviews, those who responded to the survey and those who offered insights in the exploratory and pilot stages.

List of abbreviations and acronyms

ACSTI Advisory Council for Science, Technology and Innovation

BERD Business Expenditure on Research and Development

BES Business Expansion Scheme

CEB County Enterprise Board

CIS Community Innovation Survey

CSO Central Statistics Office (Ireland)

DES Department of Education and Skills

DJEI Department of Jobs, Enterprise and Innovation

EGFSN Expert Group on Future Skills Needs (Ireland)

EI Enterprise Ireland

ESRI Economic Social Research Unit

FAS[1] Foras Aiseanna Saothair (National Training and Employment Authority)

FDI Foreign Direct Investment

Forfas Policy advisory board for enterprise, trade, science, technology and innovation

FP European Framework Programme for Research and Technology

FP7 7th Framework Programme

GDP Gross Domestic Product

GERD Gross Expenditure on Research and Development

GNP Gross National Product

GVA Gross Value Add

HEA Higher Education Authority

HEI Higher education institutions

HERD Higher Education Expenditure on Research and Development

IBEC Irish Business and Employers' Confederation

ICSTI Irish Council for Science Technology and Innovation

[1] Rebranded as Eolas in 2012

ICT Information and Communications Technology

IDA Industrial Development Authority

IP Intellectual Property

IPO Initial Public Offering

IRCHSS Irish Research Council for the Humanities and Social Sciences

IRCSET Irish Research Council for Science, Engineering and Technology

ISIC UN International Standard Industrial Classification of Economic Activities

MNC Multinational Company

NACE Classification system for industrial activity

NDP National Development Plan

NESC National Economic and Social

NTBF New Technology Based Firm

NSI National System of Innovation

OECD Organisation for Economic Co-operation and Development

PRTLI Programme for Research in Third Level Institutions

R&D Research and Development

RTDI Research, Technological Development and Innovation

SFI Science Foundation Ireland

SI Systems of Innovation

SME Small and Medium Enterprise

SSI Sectoral System of Innovation

SSTI Strategy for Science, Technology and Innovation

STI Science Technology and Innovation

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1.0 Innovation System Fit – a contingency perspective

1.1 Introduction

Productivity and associated per-capita income growth depend on a continuing process of innovation and technical change by means of new and improved products, novel business models and modes of production, distribution and marketing. The propensity to innovate presupposes internal entrepreneurial and strategic dependencies while reflecting environmental variables. Individual firms are known to play a central role in the development of innovations however the process that nurtures and delivers technological change involves a 'complex web of interactions among firms, other organisations and institutions'(Fischer, 2001, p.200). This web comprises the System of Innovation [SI]. While entrepreneurial traits are known to be significant, they fail to explain firm achievement independent of context as entrepreneurs depend heavily on the people, resources and opportunities in their environment (Baum & Locke, 2004) including upstream suppliers, downstream customers, government, economic and educational institutions.

Contemporary research emphasises the ways in which organisations are shaped by the complex character of the environment, yet SI theory largely ignores micro-level characteristics. Companies match internal and external resources with opportunities to create value by accessing and mobilising the means necessary for growth and as such, economies within and outside the firm are embedded in an institutional setting which shapes and is shaped by contemporary strategies and structures (Granovetter, 1985). At the core of this thesis are questions about the innovation resources companies have

access to, seen through the lens of firm age and strategic contingencies. Beyond analysis of the micro-foundations within which small businesses operate, is an interest in the macroeconomic implications of system-fit and how institutional and firm-level variables combine to enable or impede value creation. Lundvall claims that, absent innovation systems that encompass analysis of organisational and inter-organisational-fit, 'it is impossible to link innovation to economic growth' (2010, pp.317-318). This thesis sets out to address this gap.

1.2 System-fit

The Systems of Innovation, firm age and organisational strategy literatures focus, largely independently, on how firms adapt to internal and external dynamics to best exploit opportunities and create value. Previous research has however, failed to address the respective effects of age and strategic intent on system fit. Observing the complexity brought about by change, Van de Ven and Poole (2005) urge researchers to move beyond the traditional static interpretation of organisations to a 'spatialised, temporalised' perspective (p.512). In a similar vein, Starbuck (1965) proposes that policies and procedures appropriate at one stage of an organisation's history can become dramatically unsuited to another. To properly explore fit from a theoretical and practical perspective, this research addresses the variables and interrelationships of age and strategic intent with a view to analysing their impact on the Sectoral System of Innovation [SSI] in two distinct technology sectors.

This thesis employs the definition of fit proposed by Drazin and Van de Ven (1985) that all contingency models share an underlying premise that context and structure must fit together if the organisation is to perform well. Specifically, they propose that the

‘structure and process of an organisation must fit its context (i.e. characteristics of the organisation's environment), if it is to survive or be effective’ (Drazin and Van de Ven, 1985, p.515).

Underscoring the role of the firm, the SSI concept recognises micro-behaviour in the core (Lundvall, 2007) yet the literature explicitly acknowledges a focus on generic rather than firm-specific needs. The thesis explores micro-level variables in conjunction with key system dimensions with a view to identifying management and policy interventions through richer understanding of the concept. Analogous to the idea of information system fit, this revised conceptualisation considers ‘fit as enablement’ (Strong & Volkoff, 2010, p.733) to the extent that the SSI enables the organisation to operate efficiently and effectively according to its profile with a resulting impact on firm-level innovation capacity. Suggesting that theory is often satisfied with relatively trivial characterisations of the firm, Kauffman’s posits a ‘fitness landscape’ (1993, as cited in Levinthal, 2000, p.365) that could be tuned according to the degree of complementarity between the organisation and the environment. Despite the practical and theoretical need to understand this phenomenon, the question has received scant attention in the literature

1.2.1 Systems of Innovation

In the context of a systemic, situational phenomenon, SI offer an important theoretical framework for the analysis of innovation capacity. The systems through which enterprises source productive and market knowledge, financial and relationship capital and the instruments to safeguard intellectual property are contextually grounded. This complex array of resources renders SI a particularly appropriate conceptual framework

for analysis. Rather than focussing solely on the supply of resources, the system approach is designed to give precedence to the organisational and technical capabilities needed for the productive application of resources. In turn, policy makers strive to promote and manage the social and economic infrastructure, which supports firms in generating innovative output, in turn fostering employment, technological and economic development.

Given the multiplicity of factors and feedback processes involved, the SI concept has been described as co-evolving and self-organising (Edquist, 2005) in that organisations at any given moment are not the 'most-fit' (Aldrich, 1999 , p.33) with their environment in an absolute sense, but rather reflect historically accumulated variations within the firm and the economy.

Sectoral Systems Perspective

The broad perspective of National Systems of Innovation (NSI) benefits from a more precise dissection of institutional structures and interactions through the Sectoral Systems of Innovation (SSI) lens. In the industrial organisation tradition, industry structure is perceived as a central determinant of firm performance (Porter, 1980) while Mowery and Nelson employ the term 'sectoral support systems' (1999, p.368) reinforcing the idea that competitiveness resides in intermediate structures between nations and firms. Given that the institutions supporting technical progress in one field may not align with the conditions required to support innovation in another (Nelson, 1993 ; Malerba and Orsenigo, 1997), the SSI framework addresses, at least in part, the criticism that NSI classifications are too generic.The logical interconnection between

the fates of individual organisations and populations of organisations renders it inappropriate to analyse them in isolation of their sectors (Kimberly, 1980).

Recognising that key sectors constitute the innovative engines of small economies in particular (Guerrieri & Tylecote, 1997; Read, 2008), SSI provide an appropriate focusing device for analysis. Environmental conditions vary from one industry to another and controls for these variations are created by focusing on two distinct sectors – manufacturing engineering and software.

While patterns of innovation differ across sectors, it is suggested that they are largely invariant across countries. This is at the core of the SSI concept. Employing the United Nations International Standard Industrial Classification of Economic Activities (ISIC) which groups industries into high-technology, medium-high-technology, medium-low-technology and low-technology sectors, software falls into the high-tech class while traditional engineering is classified as being medium-low tech.

Underscoring the significance of contingency, research highlights heterogeneity within sectors, suggesting that future work should explore firm-level patterns of innovation including influences such as the age, sector and location of the firm (Pavitt, 1984; Storey, 2004). Critical analysis of SSI design brings the question of alignment to a new level – that of firm specificity. The present study analyses the moderating effect of firm contingencies on key dimensions within the selected SSIs.

Dual Sector/Technology approach

Given the aforementioned effect of industry characteristics on firm performance, comparative analyses of innovation and enterprise in different SSI can make an important contribution to system design. Sorenson and Stuart (2000) suggest that the

intersection between industry-type and firm-level processes constitutes a promising opportunity for research to fill empirical gaps in our understanding of how firm-environment relationships affect fit. The dual-sector (Traditional Engineering and Software), dual-contingency (fit based on age and strategic intent) approach adopted by the thesis addresses both gaps.

New Technology Based Firms (NTBFs) are defined as those firms that are less than ten years of age with operations based on exploiting technological resources (Mäki and Hytti, 2008). Concentration of SME productivity and job creation research in so-called NTBFs represents a strong policy pillar but this approach is interpreted as somewhat biased and to the detriment of fostering innovation and technology diffusion across the wider economy (Hirsch-Kreinsen & Jacobson, 2008; Hoffman et al., 1998; Robertson & Jacobson, 2011). Despite support for a broader policy response, lower-tech sectors are commonly regarded as 'unusual suspects' (Mendonça, 2009, p.470) in economic development. While there is some evidence that rapidly growing enterprises are more widespread in technologically sophisticated sectors, empirical data increasingly point to a lack of growth concentration among high tech firms (Mason and Brown, 2010; Parker et al., 2010).

Understanding mechanisms of influence within firms at different points in their life course and their strategic evolution, is a central focus of this study. Suggesting the benefit of determining how quickly obsolescence accrues and how it varies within and among populations, Ranger-Moore (1997) recommends that 'researchers should replicate their work across populations experiencing nearly constant turbulence with those experiencing frequent but temporally separate periods of turbulence' (p.918). By

establishing the extent to which firm contingency affects SSI fit across contrasting high –medium tech and medium-low tech sectors, this research examines *emergent* and *traditional* sectors making a contribution to both academic and public policy perspectives.

Recognising that key sectors constitute the innovative engines of small economies such as the current research setting, SSI provide an appropriate focusing device, blending parsimony with depth. Analysis is particularly critical in the case of small firms operating in peripheral economies where niche strategies are innately dependent on export competitiveness for growth and scale. Reflecting on small country innovation systems such as Ireland, Edquist and Hommen (2008) refer to economic growth based on different patterns of sectoral specialisation, production structures and technology trajectories. Given the effect of industry characteristics on firm performance, comparative analysis within and between different SSI can make an important contribution to system design.

1.2.2 Firm Contingency

While technological innovation is generally recognised as the primary driver of economic growth, precise firm and system-level determinants are less well understood. This may be due to the neglect of micro perspectives in prior analyses, even though resources and institutions are known to fit differentially rather than within defined boundaries. Given the firms' heterogeneity, calls for policy reorientation to foster specific business dynamics are gaining increased currency (Katz and Gartner, 1988, Mason and Brown, 2010; Shane , 2009; Storey and Greene , 2010).

Even within narrowly defined industries, the literature provides evidence of considerable disparity in firm behaviour (Bartelsman, Scarpetta, & Schivardi, 2005).

Pointing to a theoretical gap, Lundvall (2007) concludes that the co-evolution of constituent variables within SSI has been afforded insufficient attention while Zahra and Bogner (2000) suggest that empirical research is needed to determine the precise nature of relationships between the firm and the environment and how interactions and mismatches may influence performance. Just as the institutional infrastructure supporting start-ups is likely to prove unproductive for adolescent and mature organisations, the resources that support a venture's survival may be completely different from those required to deliver technology leadership or longevity. The strategic management literature focuses on ecosystems as sources of competitive advantage for *individual companies* (Iansiti and Levien, 2004) however; emphasis on firm-level context in SSI design is limited.

While evolutionary economists recognise the significance of organisational adaptation in the face of technological and competitive change, there is a gap in our understanding as to whether there are systematic relations between SSI-fit and observable firm-level variables. Just as changes in external conditions such as demand and competition require appropriate strategies and tactics, internal factors are significant in that they provide the context within which owners and employees create and deliver competitive advantage. Research reveals that the future of organisations may be less determined by outside forces than by firms' historical development and as such, firm-system fit may be more influenced by prior history than by environmental dynamics (Aldrich and Ruef , 2010; Carroll and Hannan , 2000). This poses questions as

to whether conformity in the processes of aging and strategic intent might provide superior understanding of system-fit.

This research employs two firm-level contingencies that suggest significant bearing on SSI-fit. In regard to firm age, policies may be derived to help newer, transitioning, restructuring and older firms to compensate for weaknesses and capitalise on strengths through more responsive SSIs. In the case of strategic aspiration, policies might be directed in tandem with the needs of lifestyle firms through to organisations intent on technology leadership, rapid growth or exit through acquisition. To follow is a summary rationale for the selection of the age and strategy contingencies.

Age

Age is known to be an important moderator of the effectiveness with which organisations deploy resources as they grow, evolve, decline or stage revivals throughout their life course. For example, innovation has been found to have a stronger impact on younger firms than more established SMEs which suggests that new firms possess distinct capabilities to create and appropriate value, off-setting liability of newness (Rosenbusch, Brinckmann and Bausch, 2011).

Theory charts various stages from the pre-entry experience of the entrepreneur, to start-up, survival and growth but beyond basic chronology, age exerts seemingly contradictory consequences on innovation suggesting implications for system-fit. Reasoning that management problems and principles are rooted in time, Greiner (1972) posits that organisational lifespan constitutes the most obvious and important dimension to interpret and model firm development while Levie and Lichtenstein (2009) argue that such an approach provides little more than an illusion of

predictability in entrepreneurial firm development. This thesis identifies patterns in resourcing innovative activities in the context of lifecourse.

A young firm spawning an innovation may not have access to the necessary means for its commercial exploitation as the resources for invention are often different from those for commercial exploitation while older firms' inventive capacities may be burdened by the counter effects of age. Such focus would help to redress the tendency among scholars to apply a narrow understanding of the SI concept, which leaves significant elements of innovation-based economic performance unexplained. Jordan and O'Leary (2011) cite the age and sector variables as important in modelling controls for business characteristics that ultimately affect innovation output.

Strategic Intent

Rather than representing a standalone outcome, innovation results from organisational and strategic intent. On-going competitive advantage requires that firms pursue strategies that match the internal motivation driving the enterprise with conditions in the external environment. Based on analysis of a company's environment, marketplace, competitors and internal capabilities, managers craft strategic intent (Hambrick and Fredrickson, 2001), acquire, develop and allocate resources and identify how they can be leveraged. This has led to the call for research to link firms' resource pools to their strategy choices in different environments with the aim of clarifying the interplay between strategy, resources and performance. According to Oinas (2005), the strategies of individual firms need to be considered in explaining the functioning of SI in accounting for economic performance.

Business strategy is recognised as being among the most difficult constructs to measure (Hambrick, 1980), insofar as the constituent dynamics are likely to defy categorisation. The range of options open to the firm includes organisational and functional management strategies, product-market strategies, technological prowess, profit maximisation, acquisition and diversification (Autio, Sapienza, & Almeida, 2000; Bell, Crick, & Young, 2004; Morris, Schindehutte, & Allen, 2005; Storey, 1994). Emphasising the importance of internally motivated economic change, Teece and Pisano (1994, p.538) developed the Dynamic Capabilities paradigm, to accommodate the 'dynamic' associated with the shifting character of the environment including the pace of innovation and, 'capabilities', emphasising the role of strategic management in adapting, integrating and reconfiguring internal and external skills, resources and functional competencies in concert with the changing environment.

While growth is an output of the firm's entrepreneurial and managerial knowledge capacities (Penrose, 1959), it is clear that not all entrepreneurial firms seek it as a primary objective (Porter, 1996). Firms are not undifferentiated profit maximisers reacting to markets independent of strategic intent (Mason, 1939). Indeed growth intent is generally a precursor to firm strategy, directing critical decisions (Bird, 1992). This study represents an initial effort to distinguish empirically, the moderating effects of strategic intent on access to the systemic resources necessary for innovation using rich firm-level data.

Strategies that accelerate growth at one stage of the life cycle may disrupt development at a different stage. Defining a strategy for development within the context of the firm's sector and life-course presumes the capacity to secure the

organisational and institutional conditions and resources to realise it. Stressing adaptability, Miller (2003) suggests that strategy should not be market-driven but market-relevant, guided primarily by those market forces a firm can exploit better than its rivals rather than by what customers want and what competitors can do. This is in keeping with the notion of system fit in the context of enablement. The SSI may have a differential effect on future returns based on the availability of human, financial and other resources.

1.2.3 Policy-Practice Implications

Insofar as economic policy is directed at influencing firm output, Cyert and March (1992) suggest that the behavioural theory of the firm should inform policy alternatives though they concede that this is unlikely to provide precise answers given the paucity of detailed information about the demography of firms and sectors. This research seeks to link firms' resources to SSI dimensions and clarify the interplay between age, strategy and the SSI. Figure 1-0 provides an illustrative schema of the thesis encompassing system dimensions intersecting with firm-level contingencies with the potential to affect system-fit. The SSI lens supports the development of the framework used to address the research question while providing the basis for empirical analysis.

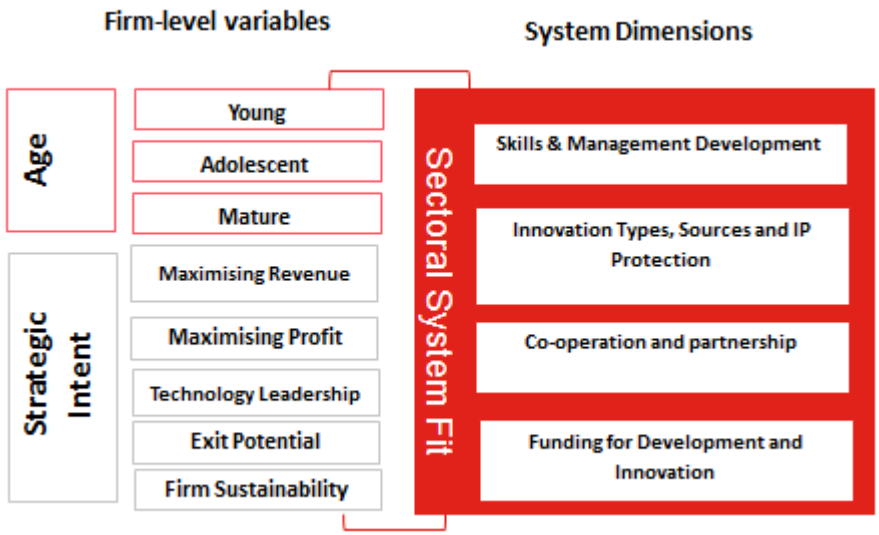

Figure 1-0: Illustrative Schema of the thesis – Conceptual Model of SSI-fit.

The following paragraphs outline the make-up of the significant dimensions addressed in the research.

1.2.4 Innovation System Dimensions

Endogenous growth theory suggests that innovation is produced within the system subject to economic incentives. It is regarded as an output resulting from a range of inputs. Knowledge, risk funding, human and physical capital and research and development are pillars typically associated with firms' innovative capacity. Education, funding and output are more clear-cut whereas the structures which embody them are abstract. Identifying the factors that shape indigenous firms' ability to generate and commercialise innovations is a key policy concern.

Skills and Management Development

In keeping with SI thinking, the activities that generate the skills and know-how forming the basis of competitive advantage are less internationalised than all other

dimensions of company activity (Pavitt & Patel, 1999). The availability of firm-appropriate skills and competencies depend heavily on sectoral factors; the degree to which knowledge is generic or application-specific, levels of tacitness and transferability, complexity in terms of specific disciplines, technologies and competencies needed and the degree of independence or embeddedness involved in innovative activities.

Innovation output sources and intellectual property protection

Commercial innovation typically takes the form of product, service, process, organisational and business model outputs. Such outputs include more nuanced aspects of innovation such as developing new routes to market, improving production capacity and reducing labour inputs. This is extended by way of inputs such as reverse engineering and patent disclosure; licensing and external R&D. Firms are increasingly engaged in mixed modes of innovation including the creation of services in support of more traditional product offerings and the use of hybrid business models to counter the liabilities of new and small firms.

Cooperation and partnership

In addition to investment in intermediary goods and services, collaboration comprises engagement with other firms or organisations in acquiring, developing and exchanging knowledge and resources (Edquist, 2000). As firms tap into wider pools of knowledge, innovation and operations have become more reliant on influencing assets outside of their ownership (Iansiti and Levien, 2004). The practice of closed innovation is yielding to the pace of technological change. Competition will spur inbound and outbound knowledge transfer as networks and partnerships facilitate acquisition of creative and

commercialisation resources to deliver more competitive outcomes. The transfer of tacit, un-codified knowledge is increasingly facilitated by shared experiences and trust, developed through interaction (Jordan and O'Leary, 2011). Despite the strategic logic of co-operation, effective partner selection and lifecycle management is known to present numerous challenges which are said to be amplified in the Irish context (Forfás, 2004b).

Funding for development and innovation

The need for a functioning capital system as a tool for funding innovation has been widely documented while the lack of investment finance has long been accepted as a serious constraint to SME growth. Funding availability and costs are known to have a significant impact on SME growth prospects with particular emphasis on access to external finance. As policy makers and private lenders behave similarly in respect of a reluctance to finance innovation without near term prospects of commercial return (Czarnitzki, Hottenrott, & Thorwarth, 2011), conservatism can be compounded amid risk aversion and a desire for autonomy among small firm owners.

1.3 Context: SMEs in Small Economies

There is growing recognition that the effective exploitation of new knowledge or technology is particularly important for small, newly industrialising countries for whom the capacity to contribute to economic growth by exploiting new and existing goods and services dwarfs the potential to make a contribution to global knowledge (Fagerberg, Mowery and Verspagen, 2008). Small, open, peripheral economies offer limited domestic market potential to SMEs who, in turn are challenged to develop and commercialise products and services in export markets if they are to realise sufficient

returns. Coincidentally, the role of Foreign Direct Investment (FDI), while creating significant value for such economies, can bring about instability. The vagaries of economic cycles driving increased possibility of retrenchment and withdrawal may lead to re-evaluation of dependencies for small country economies driving increased focus on indigenous output. This research is set in the context of Ireland, a small, peripheral economy with a significant reliance on FDI for economic sustainability. It recognises the need for research focused on small firms because of their importance to wealth creation through employment, innovation, diversification, trade and export twinned with their role as initiators, catalysts and conduits of technological change.

1.4 Motivation

Examining significant relationships between SSI dimensions and firm-level contingencies in contrasting sectors is intuitively appealing while providing an important opportunity to make a contribution to theory development. Through systematic assessment of the impact of firm age and strategic intent at the point where it interacts with the SSI, the aims of the research are first; to examine the relationship between micro-level contingencies and system dimensions to measure fit. Secondly, it seeks to contrast significant associations by researching the high-tech, *knowledge-intensive* software sector in conjunction with the low-to-medium tech *traditional* manufacturing engineering sector. Given differences in the underlying technologies, strategic dynamics and maturity of the firms that populate sectors, the results have wide-ranging implications for practice and policy.

This thesis is based on several motivations. The first is to provide as complete a picture as possible of the regulating effect of firm-level contingencies on SSI fit, this implies

potential reinterpretation of fit with respect to enablement of innovation. The second is to add to knowledge in key areas related to the age and strategic aspiration associated with system fit. The third is to draw connections between various strands of the theoretical and empirical literature that have in the past focused on aspects of fit but failed to capture the complexity of firm dynamics.

Despite a longstanding theoretical and practical focus on SME innovation by academics and policy makers, the degree and effects of interaction between firm and system-level variables have not been investigated heretofore. The framework assessed how previously un-examined associations at the firm-system level regulate fit. The results indicate that the relationship between firm age and strategic aspiration is significant in respect of a number of measures.

Given that the co-evolution of industry and supporting institutions occurs as a result of positive and negative feedback mechanisms, closer attention to company-level contingency mechanisms is merited. Policy bodies may be encouraged to assess fitness between age and strategic contingencies on the one hand and structural and institutional agents on the other, allowing for the creation of more enabling intervention strategies. Increased awareness of the micro conditions which promote positive interaction with the SI represents a valuable contribution.

1.5 Conclusion

This research offers theoretical and empirical contributions to the knowledge of innovation system design by developing new theoretical, practice and policy perspectives while testing previously unexamined theories. Centred on the

organisation-environment relationship, the research aligns with what has emerged as one of the richest streams in organisational theory - the extent to which context specificity embeds opportunity and constraint. The approach proposes that the key contingencies heterogeneously affect fit with selected dimensions.

Integrating the innovation systems, age and strategy literatures, a framework was developed to capture the effect of firm-level contingencies on the degree of fit with SSI dimensions – in short, establishing how endogenous factors might result in differential advantage for firms in the same sector. Employing the SSI framework, this research examines the relationship between firms' internal contingencies and system dimensions with the potential to impact innovative potential. The workings of SSIs are shown to be unsystematic in regard to micro-level characteristics. Intra-industry differences in system-fit have heretofore resisted explanation due to the absence of data that adequately represent the theoretically important concepts of firm age and strategic intent.

Against the backdrop of growing calls for a more fine-grained approach to policy design and evaluation (Carlsson et al., 2002; Edquist, 2006; 2011) and more recent appeals for context-specific systems of entrepreneurship (Acs, Autio, & Szerb, 2014; Autio, Kenney, Mustar, Siegel and Wright, 2014), this research analyses SSI fit relative to firm-level contingencies. In the context of potential to stimulate growth and productivity, SME innovation is recognised as a competitive necessity however, if growth is context specific; it can be argued that harmonised innovation policies, even at sectoral level, fail SMEs by understating the effect of firm-level variables.

This research suggests the need for a more granular depiction of firm characteristics in the SSI domain. Despite the intuitive appeal of gaining an in-depth understanding of the effect of firm-level variables, these outcomes have not achieved wide currency in theoretical debates. The framework adopted begins to respond to criticisms that SI theory is in need of more dynamic models (Edquist, 2006; Lundvall et al., 2009) and by extension, that the fabric of innovation policy merits a more fine-grained approach to firm context. Analysis of the results indicates that empirical support for the framework is mixed, but the insights into system fit and particularly into the design, implementation and evaluation of policy, represents an exciting and valuable contribution to our knowledge of the increasingly important firm-policy nexus.

1.6 Structure

The thesis is presented in seven chapters (see Figure 1-1 Thesis Structure overleaf). In addition to outlining the aims and objectives of the research, this chapter discusses the theoretical context for the research question and outlines the importance of the domain. **Chapter two** articulates the theoretical motivation for the application of the SI concept in conjunction with the literature on firm age and strategic intent, elucidating the link between innovative capacity, firm access to resources and internal dynamics. The conceptual framework for the research encompasses a review of the extant literature on SI, firm age and strategic intent as they pertain to innovation in SMEs. The chapter concludes by drawing together the system-firm contingencies and how they may be expected to affect innovation capacity. **Chapter three** describes the empirical setting reflecting the structural specifics of the SSI of the Irish manufacturing engineering and software sectors in an economy where industrial output is dominated

by Foreign Direct Investment. The heterogeneity of the sectors illuminates SMEs' perception of fit in distinct systems within a national context. **Chapter four** discusses the methodological approach adopted to operationalise the analysis along with the rationale for the research design including the development and administration of interviews, derivation of cohorts and dual sector surveys. The research population comprises SMEs employing ten or more people, thus excluding micro firms. The contingency model used to analyse the determinants of sector-system fit is presented using a phased approach in which the output of early empirical analysis was applied to later strands of research. **Chapters five and six** present the results of the empirical investigation and significant relationships between SSI dimensions, firm age and strategic aspiration are illustrated and analysed for both sectors respectively. **Chapter seven** interprets the findings from a theoretical, policy and practitioner perspective and outlines the contribution of this research. The chapter concludes with a discussion of the study's limitations and opportunities for further research.

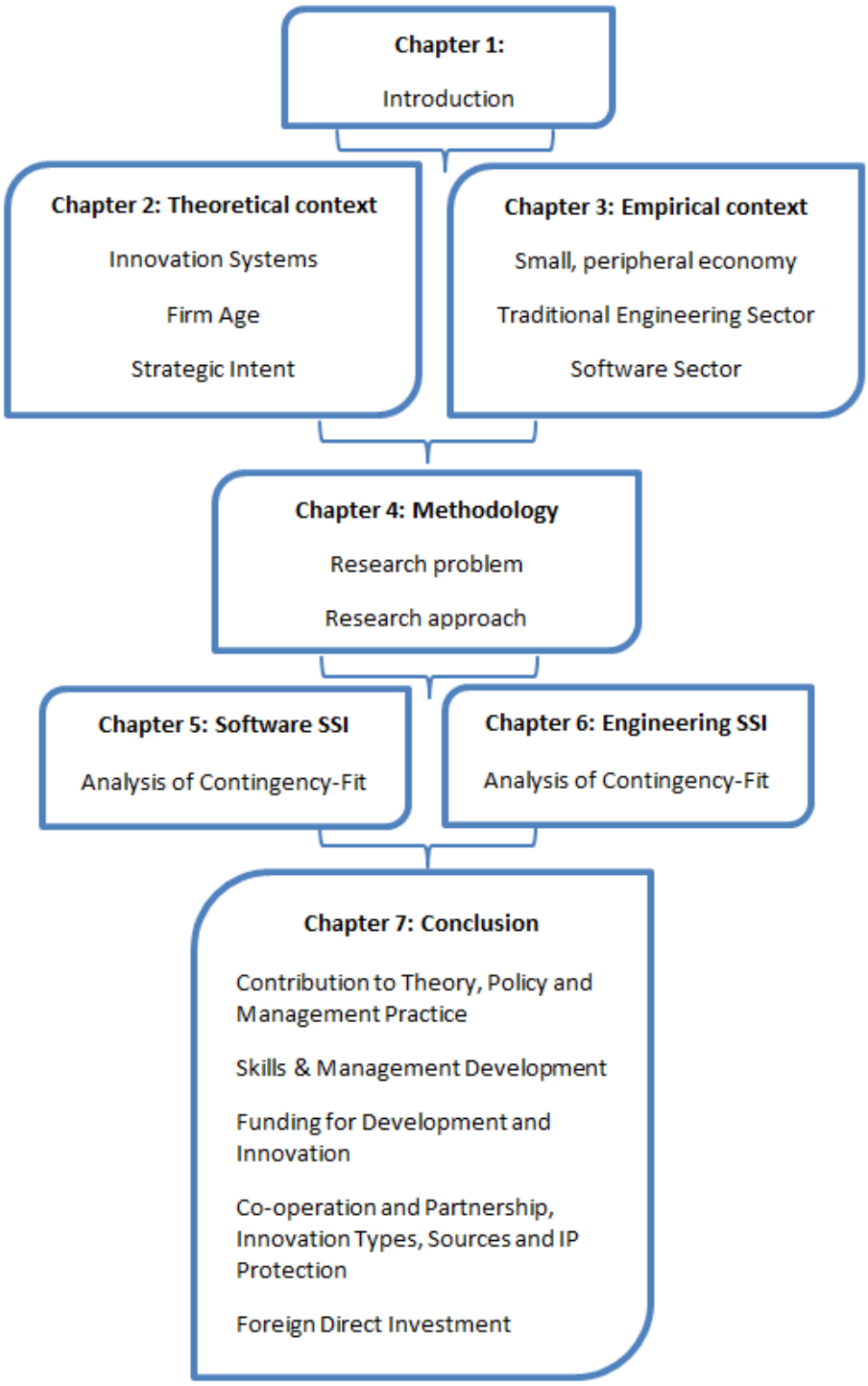

Figure 1-1: General Thesis Structure

Chapter Two

Literature Review

Innovation Systems, Strategic Intent and Firm Age

2.0 Literature Review

The impact of the environment on organisations is well documented. In the context of institutional theory and social construction, the firm is viewed as operating within the fabric of an economic context. A fundamental issue in economic theory is the extent to which organisational development is the product of external forces rooted in their social and economic systems, or whether it results from the structural or behavioural characteristics of the firm.

This chapter firstly examines the origins of, and developments in SI as a theoretical framework and its utility as a tool for understanding and analysing environmental fit over time. As industries differ in their needs, SSI are afforded particular consideration given that firms-in-sector are regarded as homogenous. Thereafter, the literature on firm age is introduced with respect to implications for system fit and innovative capacity. The literature on strategic aspiration in small firms is then discussed. While there is a substantial and growing body of literature in relation to the systems, firm age and strategy domains, extant research is scant on the interrelationships between them. The conclusion draws each of the elements together, underlining the gaps in the literature and prompting the research question as to how micro processes may enable or constrain system fit, and in turn, innovative potential.

The 1980s witnessed the emergence of a body of literature aimed at the study of national policy and development issues. Since the inception of National Systems of Innovation (NSI) (Freeman, 1987, 1992, Lundvall, 1992, Nelson, 1993; Nelson and Rosenberg, 1993), the concept has been adopted by policy makers and academics in their quest to understand enablers and impediments to economic growth and

competitiveness. At its broadest, the systems of innovation (SI) concept presents 'a way of describing and analysing the set of institutions that generate and mould economic growth, to the extent that there is a theory of growth in which technological innovation is the key driving force' (Nelson, 2000, p.11).

While a common infrastructure sets the context for innovation in an economy, it is ultimately firms, influenced by their microeconomic environments, which develop and commercialise innovations (Furman et al., 2002). Lundvall (2010) describes the firm as the 'central motor' (p.340) in the SI. In recognition of this, the original NSI concept has been adapted to reflect regional, technological and sectoral specificities however, little is known about how the framework adapts to support individual firms as they mature and adjust their strategies.

SI have emerged as an important academic and policymaking tool designed to help understand the structure and performance of systems and processes supporting macro innovation (Soete, Verspagen and ter Weel, 2010) and ultimately enabling firm-level innovation. As a collective construct, they present a multidimensional, integrated view of innovation by comparison with the traditional market failure based perspective.

In the context that technology represents the theoretical and practical knowledge, skills and artefacts used to develop products and services as well as playing a role in their production and delivery (Burgelman, Christensen and Wheelright, 2008), the integrative capacity of the SI concept, encompassing the fundamental shift from natural to human resource endowment (Wicken, 2009) and the inclusion of market and non-market institutions, highlights the concept's analytical potential compared to competing frameworks. Among adjacent models are Porter's (1990) Diamond

Framework and the Triple-Helix model (Etzkowitz and Leydesdorff, 2000). Porter presents national systems as host environments to single industries competing in an international context rather than a system in its own right (Lundvall, 2010) whereas Etzkowitz and Leydesdorff (2000), consistent with the knowledge-based society – the basic premise of the triple helix model, give primacy to university-industry-government relations in keeping with the science-driven innovation paradigm.

Drawing on the SI, firm age and strategy literature this research proposes a distinctive analytical approach to assessing system-fit. Analysing the effect that the environment has on organisations, and the counter effect that organisations have on their social environments, Stinchcombe (1965) interprets 'social structure' as any variables that are stable characteristics of the society outside the organisation (p.142).

Companies give simultaneous consideration to strategy, markets, products and technologies and how these interact over the firm lifecycle, yet despite the thorough exploration of SI over the last quarter century, the concept has proved difficult to operationalise at the micro level owing to the resources required (Robertson & Smith, 2008). While numerous studies have addressed system-level support, none has adopted a micro perspective with a view to testing whether firm-specific contingencies are more or less conducive to performance through a more differentiated perspective on system-fit (Carlsson and Jacobsson , 1997; Donaldson, 1996).

Emphasising the systemic, embedded character of the process, Van de Ven (1986) defines innovation as 'the development and implementation of new ideas by people who over time engage in transactions with others within an institutional order' (p.590). The notion of engagement over time reflects the assumptions of structuration theory

whereby structure is embedded in practice and both are recursively connected with actors exercising agency by making a difference to the systems in which they are embedded (Giddens, 1984). Structuration is an appropriate lens as it embraces the connection between structure and the practice of constituent firms characterised by reciprocity and feedback mechanisms. While the SI literature is not formally situated in the context of structure and agency, Giddens' views on the reflexive role of individuals and social structures suggests parallels with the SI framework which recognises processes of change through the co-evolution of dimensions such as skills, funding, innovation types, co-operation and intellectual property protection. Critical to that is the recursive process of organisations building or acquiring the resources and competencies needed to deliver innovation in conjunction with supporting institutions. With respect to the effect of contingency on system fit, Lundvall (2007) suggests 'an inherent risk that the system embeds a structuralist mode of explanation that neglects the critical role of agency' (p.110) - a core aspect of this research.

Firm contingencies

Taking the view that organisations and institutions are distinct, there is a need to look at organisation-specific factors. The proposition that organisational structure and process must fit its context to survive and prosper (Drazin and Van de Ven, 1985) is apposite. In the management literature, contingency theory suggests that appropriate organisational structures and styles are dependent on a set of 'contingency factors', usually related to the environment (Tosi & Slocum, 1984, p.9) and further, no single organisational configuration is effective in all circumstances (Tidd & Hull, 2006). Indeed organisations are not best fitted to their environments in any absolute sense, but rather their strategies and operations reflect the historical path created by a

combination of accumulated and selectively retained variations (Aldrich & Ruef, 2006; Donaldson, 1996). Donaldson (1996) argues in favour of organisational optimality vis-a-vis contingencies such as size, age, strategy and technology. This recognises the importance of micro-level factors and their potential implications but despite its relevance for managers and policy-makers, this area remains relatively unexplored by management researchers. This study addresses the gap by exploring how firm specific factors influence *system-fit* in the software and manufacturing engineering sectors, employing SSI as a lens. Three key factors are explored:

- Firm-system fit based on associations with organisational age
- Firm-system fit based on associations with strategic aspiration
- Firm-system fit based on associations with sectoral classification

Similar to the bivariate interaction construct put forward by Drazin and Van de Ven (1985, p.515), this study measures fit as 'the interaction of pairs of organisational context-structure (system) factors which affect performance', otherwise viewed as system enablement.

Structural and Behavioural Contingency

Organisation-environment models and strategy-policy frameworks differ markedly in how contingencies are modelled, and in the role that organisations play in the process (Rumelt , 1979). Carroll and Hannan (2000) posit two classes of environmental change:

> 'Exogenous processes (environmental conditions) which shape and change organisations, but are not directly systematically affected by firms; and endogenous processes (population dynamics), in which the environment changes in line with organisation and population-based variations' (P.193).

The former is consistent with the SI literature as currently constituted whereas the latter is in keeping with the thrust of the current research.

Effect of firm maturity

The SI framework has evolved to meet the needs of distinct countries, regions, sectors and technologies through sub and supranational systems. With specific regard to technological systems, these are often matched by policies that support 'embryo, infant and adolescent technologies' (Carlsson and Jacobsson, 1997, p.285) however this diversity is not reflected at the firm level. Firms transition from novice to expert decisions through time and experience (Bingham and Eisenhardt, 2011) learning through failure and success. Just as the methods and assets required to manage engineering enterprises are distinct from those for software companies, the resources needed to create a founding team, develop a first product or cultivate a business model are different from those required to servitise an existing product, license technology or diversify a portfolio. The literature to date, while recognising the need for differentiated systems, has failed to capture the relationship between SSI dimensions, life-course (Aldrich, 1999; Boswell, 1973) and strategic aspiration (Roper, 1998; Storey, 2004). This study addresses this gap by testing bivariate interactions between firm age, strategy and SSI components.

2.1 Dynamics of Firm-System Fit

Empirical studies following the Resource Based View (RBV) suggest that firm specific factors dominate industry effects in driving performance. This is further supported by evidence indicating greater variations within than between industries (Hawawini, Subramanian, & Verdin, 2003; Rumelt, 1991) demonstrating in many cases, that

industry-wide factors matter less than firm-specific dynamics. However, system-specific assets have a significant bearing on the availability of resources (Saxenian, 1994), creating the potential for unearned advantage. This supports the logic of a micro-level approach.

Environmental determinism and purposive perspectives

There are two main perspectives on the drivers of innovation - internal and environmental. If the private sector is the most important driver of innovation (Lundvall, 2011; Wessner, 2005), this suggests that policy should be crafted in light of firm dynamics and how they evolve. On the other hand, if environmental determinism and selection have a greater bearing on capacity (Aldrich and Pfeffer, 1976; Alchian, 1950), the question arises as to how firm dynamics can best be managed in accordance with environmental enablers and constraints. Cognitive aspects of entrepreneurship are beyond the scope of this study – rather the focus is on the potential of organisations and institutions to understand and potentially leverage SSI fit based on age and strategy dynamics, an area that has received much less explicit attention.

2.2 Analytical framework

The forces at work within NSI are a source of significant academic and policy interest, particularly in cases where framing conditions are insufficient to support innovation-led growth. Given that failure is an intrinsic consequence of the innovation process, SI should be evaluated and improved based on informed analysis and promotion of adaptive responses. While the state plays a pivotal role in the functioning of SIs, the firm ultimately determines their overall efficiency (Furman et al., 2002; Peters, 2005). Underscoring that interplay, Lundvall (1992) characterises the core facets of the

system as ‘social’ - reflecting learning as a process - and ‘dynamic’, incorporating positive feedback loops and reproduction.

Integrative framework

The interaction between SI dimensions and firm contingencies is illustrated in Figure 2-0 (overleaf) using an integrative research model (after Papadakis, Lioukas and Chambers, 1998) of the SI, age and strategy perspectives contained in the review. SI dimensions are shown on the left, with SSI representing the central plank of analysis; age-specific and broader life course characteristics are depicted in the middle; and strategic orientation on the right.

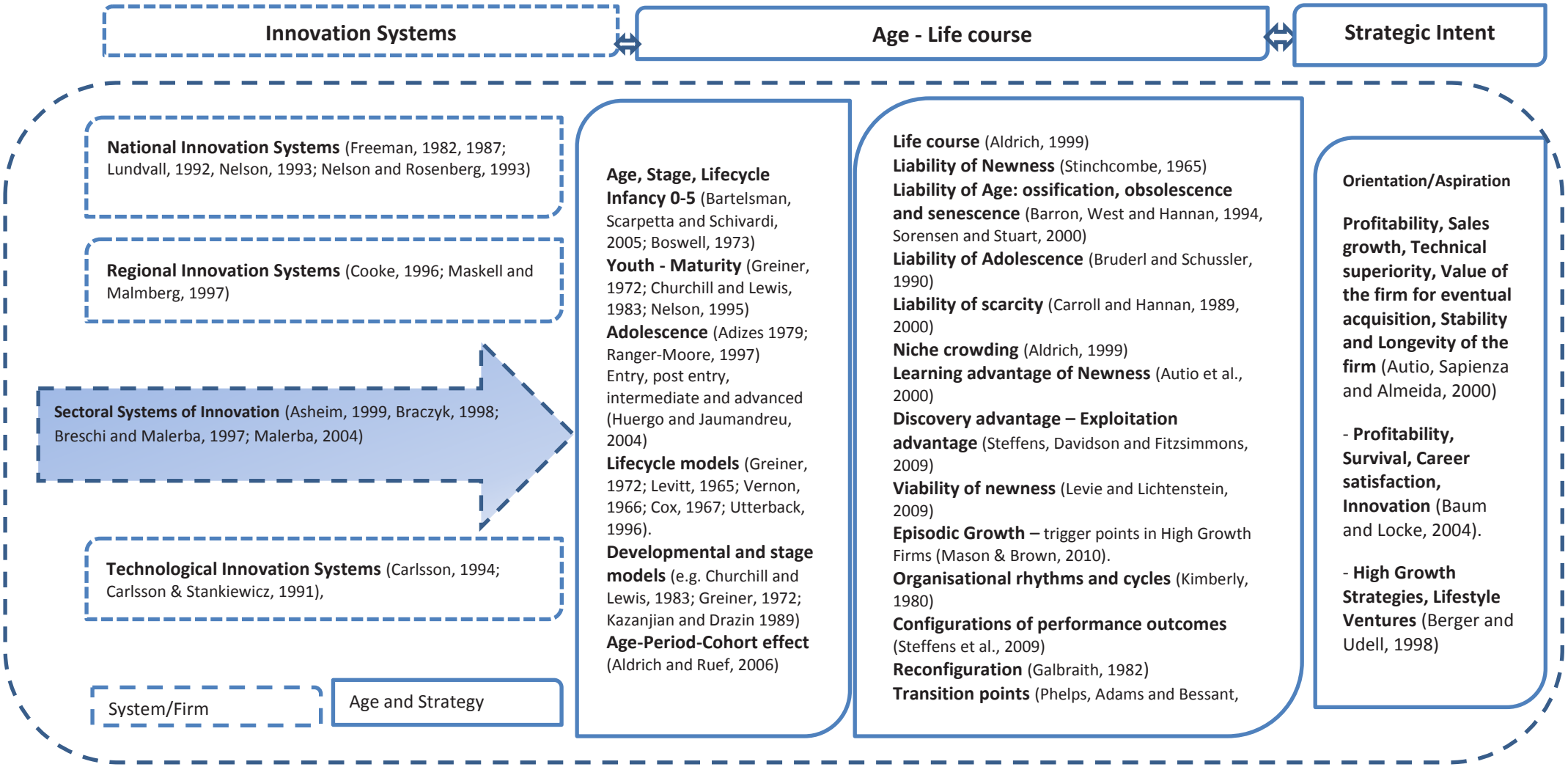

Figure 2-0: Integrative Research Framework – SSI-Firm Fit

2.3 Innovation

Much of the contemporary understanding of innovation originates in the work of Schumpeter (1950) who asserted that innovations typically represent improvements in product or process utility which drive economic activity through market preference. The literature widely acknowledges that innovation is not an exogenous factor leading to predictable results, but rather an endogenous phenomenon, reliant on and shaped by, interactions between firms and their environments (Fagerberg, Mowery and Verspagen, 2008).

Within small firms, much product innovation is incremental (Roper, 1997). Firm-level research indicates that close interaction with users, suppliers and competitors has a greater impact on innovation than public or university-based research (Lundvall, 2011; Granstrand, 2004). Thus Kline and Rosenberg (1986) recommend that innovation and diffusion be approached holistically, given that originating new ideas is generally less important for business performance than how those ideas are exploited and diffused (Lundvall, 2011) however prioritisation and selection remain key to market advantage and profitability. The relative weighting on diffusion emphasises growth, competitiveness and employment, each of which is central to SI governance and output.

2.3.1 Technological innovation

There is broad acceptance that innovation and technological change are important sources of productivity and material welfare. Specifically, technological innovation is said to be the most powerful engine of change (Aldrich, 1999). The central thesis of Freeman's (1987) seminal work on technology policy and economic performance

is that technical and related social innovations are the main sources of economic dynamism, and that technological capacity constitutes the competitive engine of both firms and nations. This echoes the assertions of many theorists (e.g. Burgelman, Christensen and Wheelright, 2009; Teece, 1986; Zahra and Bogner, 2000), that technological change is the most powerful driver of success in contemporary markets. The intrinsic economic power of technology places innovation policy at the heart of debates on achieving sustained and sustainable economic growth. However, reflecting the belief that creativity and the creation of new technologies are necessary but not sufficient to ensure development and growth (Mowery and Nelson, 1999), SIs recognise that innovation outcomes result from interactive learning and engagement between organisations in the context of national, sectoral, regional, technological, and institutional systems.

Having introduced the mutual impact of the firm and the environment on the potential for innovation, the following section examines the influence of technological change in the SI context.

2.4 Systems of Innovation

Contrary to the endogenous thrust of the Resource Based View, exogenous theory suggests that the outcomes firms generate are due more to the properties of their systems than to the intentions or actions of individual actors (Cyert and March, 1992, Lundvall, 2007; Sharif, 2006). Mapping national Entrepreneurship and Innovation Policies, Lundstrom, Almerud and Stevenson (2008) propose the study of causal relationships between policy and outcomes in terms of competitiveness, economic progress and growth. Their model (Figure 2-1) articulates the links between entrepreneurship and SME policies in the context of overarching innovation policy along a temporal axis, emphasising integration and the relevance of life course in design and implementation.

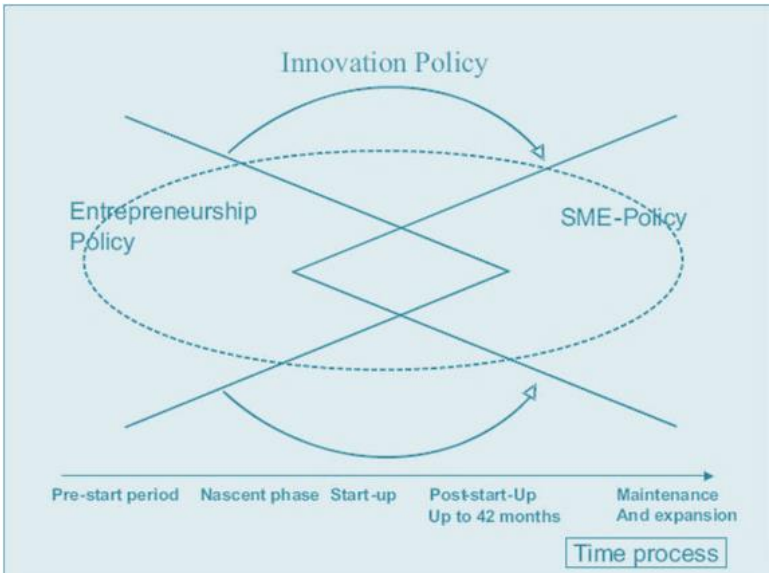

Figure 2-1: Innovation Policy (Lundstrom et al., 2008, p.12)

There are different perspectives on how institutions can be defined and there are several units of analysis to be considered on the firm-context nexus. Linking the entrepreneurship and innovation perspectives of SI, Aldrich and Ruef (2006) observe that entrepreneurship finds limited reference in institutional theory. The next section deals with the institutional aspect of SI.

The institutional and organisational perspectives

The statist perspective perceives environments as institutions (Zucker, 1977) which include 'formal rules (constitutions, statutes, common laws and regulations), informal constraints (conventions, norms of behaviour, and self-imposed codes of conduct) and their enforcement characteristics' (North, 1990, p.2). These elements combine to form a set of institutions involved in making and implementing economic decisions. Viewing the organisation as a nexus of relationships, including those between individuals within the organisation, between individuals and the organisation, and across organisational boundaries, Fichman and Levinthal (1991) assert that the nature and durability of such relations exerts influence on organisational fit and firm mortality.

Internal capabilities and environmental perspectives

Traditional management thinking on innovation has tended to focus almost exclusively on firms' internal capabilities and the processes that create and commercialise technology (Mowery and Nelson, 1999), yet many authors (e.g. Porter and Stern, 2001; Shane and Venkataraman, 2000; Storey, 1994; Ucbasaran, Westhead and Wright, 2011) argue that the external environment for innovation and entrepreneurship is at least as important, given that organisational

transformation occurs within geographical and historical contexts (Aldrich, 1999, Kimberly, 1980, Stuart and Sorenson, 2000). Firms' propensity to innovate presupposes entrepreneurial and strategic dependencies, but also reflects their market positions and operating environments (Roper, 1998).

Contrary to the popular mythology of the lone inventor and the atomistic small firm working independently of the system, the process of innovation is largely systemic, as enterprises innovate in collaboration with other organisations (Von Hippel , 1988) and institutions (Edquist , 2005; Lundvall, 2011). The entrepreneur is not in a 'fixed state' of existence and personal traits, independent of context, fail to explain entrepreneurial achievement (Gartner, 1988) – rather, entrepreneurs are characterised as interactive individuals who depend heavily on the people, resources and opportunities in their particular contexts (Audretsch, Dohse, and Niebuhr , 2010) including upstream suppliers and downstream customers (Jordan and O'Leary, 2011; Malerba and Nelson, 2011). In the context of industries and nations, individual firms play a central role in the development of specific innovations supporting a systems perspective.

Understanding mechanisms of influence across and within firms in contrasting technology domains at different points in their life course is a central focus of this study. Having assessed the impact of the firm and the environment on the potential for innovation through time, the following section examines the influence of technological change in the SI context.

Firms and institutions

'Both the environment and what firms make of that environment matter' (Mowery and Nelson, 1999, p.368) thus, organisations and institutions are seen to orchestrate the system jointly to create the conditions necessary for growth and competitiveness. By prioritising interactive learning and innovation in the analysis of economic growth and development, the NSI concept employs an alternative analytical framework to static standard neo-classical economics (Edquist, 2001; Lundvall, 2007). The framework expands beyond R&D to other types of innovative efforts, encompassing impact on employment and growth. Rather than institutions determining innovation, they constitute the framework within which companies act (Oinas, 2005) by accessing locational strengths and proactively developing the environment for innovation and commercialisation (Porter and Stern, 2001). Organisations are conceptualised as the main actors in innovation processes, although institutions define the rules of the game and both are reciprocally related, firms are seen to act as agents of institutional change (Edquist, 2001). This research sets out to explore how firm age and strategic contingencies impact innovative potential based on SSI fit.

Several factors are associated with firm growth including age, sector, geographic location and strategic selection (Storey, 1994). Cyert and March (1992) posit that firms change by virtue of internal developments and by interacting with their environs, while the environment itself changes through interactions with the firm in conjunction with other firms. This collective effect is important to our understanding of the functioning of SSIs.

2.4.1 Systems Thinking

Understanding innovation as an evolutionary process, the SI approach presents a platform for thinking through and analysing the nature and implications of the collective character of innovation (Edquist et al., 1998). Given that organisations can be constrained by history, culture and their environment in the quest for solutions to new problems (Kimberly, 1980; Sofer, 1972), it is recognised that SIs are so complex that their efficiency cannot be determined in any strict sense (Sloth Andersen, 1997). Indeed Soete et al. suggest that 'innovation policy, just like innovation, is always on the run' (2010, p.1169). Citing the dual importance of internal and external variables in contributing to firm-system fit, Cyert and March (1992) portray the firm as an adaptive system operating with an array of properties while Alchian (1950, p.211) proposes the idea of 'adaptive, imitative, and trial-and-error based behaviour in the pursuit of positive profits rather than maximised profits.'

The purpose of innovation and technology policy is to create the conditions through which ideas, products and processes deliver economic and social benefit. This in turn requires fostering strong knowledge bases, innovative capacities and behaviours within firms, as well as conditions for diffusion and adoption, including production and market knowledge, skills, a functioning distribution system and financial resources (Fagerberg, 2005).

Core to the NSI concept is recognition of innovation as a non-linear process of learning as opposed to a mechanistic, Science-Technology-Innovation (STI)-led process (Mytelka & Smith, 2002). By focusing on diffusion and use beyond market

introduction, policy could be actively crafted around the problems and opportunities faced by entrepreneurs, rather than aggregate input measures such as patents and R&D spend (Wessner, 2005). Despite the assertion that salespeople and customers are as important to the innovation process as scientists and researchers (Bhidé, 2008), Guerrieri and Tylecote (1997) allude to the lesser prestige of sales and marketing compared to scientific and technical roles in some countries. They suggest that sales, marketing and production should work towards mutual respect, and seek to develop cooperation across organisational boundaries and a common language for technology. Citing Wilson's (1968, p.70) history of Unilever, they illustrate the positive mutual regard for scientific and commercial roles in the United States where the social prestige of industry and widespread regard for scientific knowledge are not competitive but complementary. This appears inconsistent with the prevailing view in Europe and represents an important aspect of firm-environmental fit taking into account the significant role of commercialisation.

2.4.2. National Systems of Innovation

Porter asserts that 'the enduring competitive advantages in a global economy lies increasingly in local things – knowledge, relationships, motivations – that distant rivals cannot match' (1998, p.78). On the basis that the national dimension constitutes an abiding feature of SIs, the nation state plays a central role in mobilising resources and establishing competency bases through education (Lundvall et al., 2009). Innovation activity in SMEs responds to different technological and economic drivers than large scale firms and geography has a

defining influence. Although US firms have dominated the market for traded software since its origin, turnover among leading software companies demonstrates competitive strength at the level of the nation rather than the firm. This is in keeping with Mowery's (1999) assertion that 'comparative' advantage is more enduring than 'competitive advantage'(p.133), a noteworthy aspect of system design.

The policies and programs of governments, their laws, common language and shared cultures, define boundaries that largely affect how technical advances occur (Nelson, 1993). Indeed, the international exploitation of innovation developed on a national basis has been identified as the most diffuse form of globalisation (Archibugi, Howells and Michie, 1999). Delineating national-cultural and statist-political dimensions, SIs are described as:

> …. constituted by elements and relationships which interact in the production, diffusion and use of new and economically useful knowledge and that a national system encompasses elements and relationships, either located within or rooted inside the borders of a nation state (Lundvall, 1992, p.2).

The OECD (1999) proposes a model that describes the market and non-market institutions influencing the direction and speed of innovation and technology diffusion, including the connections between components designed to facilitate performance. It articulates the roles of the main actors and the forms and intensity of their interrelations, including the key processes of knowledge generation, diffusion and exploitation shaped by organisational capabilities, and the strength of

their relationships. Supporting these activities are other aspects of the commercial, technological and regulatory environment within which firms operate (Roper & Love, 2006). As depicted in Figure 2-2, the SI focuses on countries' innovative abilities but more specifically, on the relations between company actions and the broader national context, including input providers, customers, government agencies and universities who help define 'maps' for firms' search activities (Sloth Andersen, 1997, p.177). In summary, the model provides a tool for analysing country specificities in the innovation process as well as a guide for policy formulation (OECD, 1999, p.22).

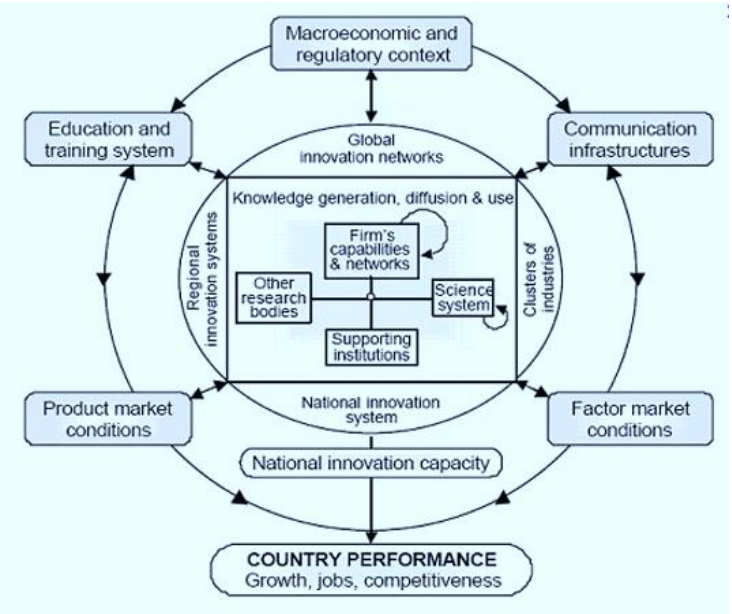

Figure 2-2: Actors and linkages in the Innovation System (OECD, 1999, p.23)

The NSI concept presumes the existence of a nation under the control of a state authority, albeit 'drawing the precise boundaries of an ecosystem is an impossible, and in any case, academic exercise' (Iansiti and Levine , 2004, p.2). Throughout industrial history, entrepreneurial firms located in particular countries have

developed superior product and process technologies, production mechanisms and marketing strategies which have conferred significant advantage on their host nations (Mowery and Nelson, 1999). These factors support the logic of NSI (and its derivations) as a conceptual framework recognising that much innovation relies on resources and interactions outside organisational boundaries (Lundvall, 2007).

At the national level, 'countries and companies vary in respect of their structural adjustment to different starting points in economic evolution, technological and industrial specialisations, institutions, policies and attitudes to change' (OECD, 1998, p.3). Early studies emphasise nation-specific innovation patterns in their historical, political and cultural context (Balzat and Hanusch, 2004), along with a tendency to cluster spatially and temporally (Breschi & Malerba, 1996; Howells, 2005), aspects which have particular resonance for analysis of firm-fit. In order to understand why some countries, and indeed some companies in some countries, are more successful at innovation than others, McKelvey (1993) describes the search for a normative perspective on the SI approach.

Anchored in socio economics, the concept is credited with delivering a holistic perspective on the roles of policy governance and institutions for the analysis and application of technical and social innovation. NSI provide a much broader foundation for policy than the market failure-based approach whereby measures are driven by the identification of failure and parallel justification as to how policy change can bring the system closer to its optimal state. Given the link between innovative know-how and economic performance, the proactive role of the state in developing technological capabilities for economic advantage (Nelson, 1993) is one

of fundamental importance. While the stereotypical image of innovation is one of path breaking endeavour, most firms engage in incremental rather than *pure play* innovation (Danneels, 2002), possibly in the knowledge that innovations with a closer fit to firm competencies tend to be more successful (Autio et al., 2000; Cooper & Kleinschmidt, 1987, 1993; Kleinschmidt & Cooper, 1991). Although most innovations are incremental, many are built on technologies with links to science and engineering principles. Freeman (1992) reflects both scenarios:

> When there is a radical discontinuity in technology systems the role of the Science and Technology network becomes exceptionally important. But when the main direction of technical change is the improvement and diffusion of a familiar technology, the interaction with users becomes more important (p.187).

System hierarchy and intervention

While the SI is commonly applied at macro and meso levels, the firm itself constitutes a system. As firms grow, develop new technologies and become increasingly interdependent, they foster both vertical and lateral relationships (Child and Kieser, 1981). Schilling (2000) describes organisations as systems within the context of an industry, and industries as systems within the context of an economy.

While seen as a framework built from the bottom-up rather than one imposed from above, there are differing views on levels of interventionism within SIs. Rather than creating jobs per se, the role of government is to create and maintain an enabling environment. For example, the drivers of Silicon Valley's ecosystem appear distinctly more entrepreneurial and potentially more democratic than parallel

architectures in Europe (Cooke, 2001). Reflecting on the role of government, Breznitz (2007) contrasts variants of market liberalism in Israel and Taiwan with 'neoliberal interventionism' in Ireland. Cooke (2001) interprets public intervention as a symptom of market failure, suggesting that the innovation gap between Europe and the US is due in part to European entrepreneurs failing to recognise innovation opportunities in marked contrast to their North American counterparts. Whether traits, culture, institutions or resources are at the root of their contrasting fortunes is unclear. This research addresses institutional aspects of fit.

Metcalfe (1995) contrasts two policy perspectives; the first, the enabling stance aimed at building an economic environment which is conducive to technological advance. The second is intervention directed at particular firms, products or technologies leading to policies which support the development of particular sectors. Depending on the technologies or sectors selected, policy is not automatically welfare-improving (Metcalfe, 1999) and it is important to understand the consequences that follow. Policy makers strive to nominate technologies with the potential to offer enhanced returns, but influencing expectations as to winning technologies or 'picking winners' may have far reaching and unintended implications. More broadly, governments need to make careful assessments of the balance between support for high technology sectors and that aimed at innovation and technology diffusion throughout the wider economy (OECD, 1999). The impact of contrasting technologies on system-fit is an underlying theme of this research.

Scientific Research and Education

Incremental and science-based innovations are not opposites - science-based technologies require systemic innovations in both products and processes to be adopted and used by industry (McKelvey, 1993). Supporting the transition from S&T policy towards Innovation policy, the systems approach has helped to shift the perspective from linear to interactive processes with greater emphasis on people, organisations and competence building (Lundvall, 2007). In an assessment of what makes basic research economically viable, Pavitt (1991) notes the indirect contributions made by scientists, who due to their training, can perform a variety of activities within industry. This, he suggests is as important as more typical output measures, such as patents and publications.

Referring to education and training as the 'Achilles' heel' of British Industry for over a century, Freeman (1987) argues that policy responses have been hindered for a range of institutional and political reasons. Organisations and other social systems resist change even when the environment provides strong pressure for it, so change can be frustrated by conflicts and compromises. O'Malley, Hewitt-Dundas and Roper (2008) suggest that education in Ireland acts as a general 'signal' to help secure employment, however the system is seen to lack correlation between educational attainment and required competencies. While recognised disciplines are supported, there is often a failure to integrate commercially-relevant components, such as the ability to understand product-market fit, or to combine business acumen with foreign language fluency in support of export growth, or engineering competence with design capability.

Domain expertise

While incremental innovations in established sectors mainly consist of private initiatives using private funds, more radical technology shifts tend to require government intervention through public R&D funding or through procurement policy. Such interventions demonstrate that policy is not neutral, but rather 'countries should accept the idea of picking winners while avoiding subsidising losers' (Edquist and Hommen, 2008, p.463). Maintaining competitive advantage in high-cost countries relies significantly on innovation driven by policy instruments, facilitated by universities and research institutes (Audretsch and Beckmann, 2007). While the US has the appearance of the most *marketised* SI in the world, federal funding is seen to sustain its scientific leading edge (Cooke, 2002).

The US hardware and software industries illustrate important differences in national patterns of supply and demand. As well as the VC sector providing *smart money*, Mowery and Nelson (1993) describe the importance of Defence Department funded R&D and procurement programs backed by university research and training, in developing a skills pool substantially deeper than Japanese and European equivalents. In Japan, funding was instead focused on a small number of established firms. The development of domain expertise in the US was bolstered by a substantial domestic market for mainframe computers, a sophisticated user base and strong antitrust policy that nurtured the emergence of independent software firms. This position contrasts with the erosion of the US position in the chemical industry, emphasising the differing impacts of national and sectoral policy influences. Prompted by the expected relevance of expanded international

frameworks, Balzat and Hanusch (2004) call into question the appropriateness of the NSI approach suggesting the superiority of regional, technological or sectoral criteria. Sectoral Systems are analysed below including qualification their selection as the conceptual framework on which the research is based.

2.4.3 Sectoral Systems of Innovation

A sector represents 'a set of activities that are unified by some related product group for a given or emerging demand and that share some basic knowledge' (Malerba, 2004, p.10) demonstrating that while firms in sectors demonstrate commonality, they are heterogeneous. Sectoral systems emphasise industry type and the resources, assets and co-operation they rely on for development and diffusion whereas technological systems relate to the specific cluster of firms engaged in generating and diffusing new knowledge within a technology sphere (Malerba & Orsenigo, 1997). For this reason, SSI have been selected as the conceptual framework for this research. The factors that matter for innovation and consequently, the available policy options, vary from one sector to another and among other aspects of SI, the education system, government policy and institutions differ in respect of how they provide structural supports and incentives for different sectors. Research on innovation intensity and success reveals that input-output efficiency has a strong sectoral dependency (Love & Roper, 2001), for example, some sectors rely heavily on interaction with universities whereas others are largely divorced from higher education and while the NSI may set out to support wide-ranging technologies, particular sectors are favoured in many countries.

While national infrastructures set the basic conditions for innovation, companies introduce and commercialise innovations within, and potentially across, sector boundaries. Originally proposed by Breschi and Malerba (1997), SSIs support better understanding of the influence of contextual factors on firm-in-sector performance which they define as:

> '…that system (group) of firms active in developing and making a sector's products and in generating and utilising a sector's technologies; such a system of firms is related in two different ways; through processes of interaction and cooperation in artefact-technology development and though processes of competition and selection in innovative and market activities' (p.131).

Technological capabilities consist of the skills and knowledge necessary to develop, produce and sell products, as distinct from innovativeness, which involves the capacity to generate and commercialise novel or improved products and production processes (Dosi, Pavitt, & Soete, 1990). Innovations are produced by activities in which technology is both an input and an output.

SSI and performance

Entrepreneurship research has established that industry characteristics have a significant impact on venture performance (Baum & Locke, 2004; Bhide, 2000). The sectoral composition of an economy co-determines the institutional setting of the SI, as well as the structure and direction of innovative activities (Balzat & Pyka, 2006). Non-firm organisations generally don't have a direct effect on innovation processes but rather they influence, reinforce or improve the context within which innovating firms operate (Edquist, 2011). Many important elements of government-

provided infrastructures and policy are sector-specific (Nelson and Mowery, 1999) creating a potent *shaping* role, while the national context has a substantial influence on sectoral performance (Archibugi, Howells, & Michie, 1999). Highlighting the importance of SSI, Malerba (2010) argues that entrepreneurial initiatives are shaped by different institutions through specific knowledge and technological domains, heterogeneous agents and interaction with distinct networks.

Consistent with population ecology, the simultaneous action of search and selection sees firms evolve over time, with the condition of the industry in each period bearing seeds in the subsequent period. This holds particular significance for SSI analysis in terms of how respective generations of firms impact those that follow, including effects of positive and negative interactions with institutions. This characterises path dependence, whereby *current* innovative capacity is somewhat conditional on the previous course of events (Carroll and Hannan, 2000), further emphasising the potential inherent in the temporal and lifecycle analysis.

Challenges to sectoral segmentation

In the context of pervasive technologies that span sector boundaries, the notion of SSI and production is broadly encompassing (Malerba, 2002; 2004). Any assessment of sectoral economic development reveals idiosyncrasies at the country level based on indigenous learning, at the product level in terms of portfolio mix, and at the micro level in respect of how firms operate and the markets they serve (Malerba and Nelson , 2011). SSI are principally characterised by the technologies and learning processes they employ – but, just as they represent a disaggregation of

NSI, different systems can coexist within sectors. By way of illustration, the NACE European Industrial Activity Classification system encompasses six broadly based codes for engineering (24 Basic metals, 25 fabricated metal products, except machinery and equipment, 28 Machinery and equipment, 29 Motor vehicles, trailers and semi-trailers, 30 other transport equipment, 33 Repair and installation of machinery and equipment). This presents researchers and policy makers with self-evident challenges in establishing boundaries and to measuring innovative activity. Pertinent to this study, the traditional manufacturing engineering and software sectors both employ pervasive technologies, and are susceptible to broad internal segmentation. Recognition that knowledge bases, actors, networks, inputs, institutions and demand differ from sector to sector, supports discrete system perspectives.

Technologies and applications

Reflecting an evolutionary view of technology, industry structure and supporting institutions, Adams, Brusoni and Malerba (2011) offer a comprehensive interpretation:

> A sectoral system is characterised by a knowledge base and technologies that may cut across conventional industry boundaries. Such systems are composed of heterogeneous organisations or individuals (such as consumers, entrepreneurs, scientists) that may all be sources of knowledge, ideas, and feedback for producers and innovators, but that may not be part of conventionally defined industries in terms of firms (users and suppliers) and other organisations (universities, financial institutions, government agencies, trade unions, or technical associations). These organisations are characterised by specific knowledge bases and learning

> processes… Often their outcome is not adequately captured by existing systems for measuring economic output (pp.169-170).

Agents in sectoral systems are individuals and organisations characterised by specific learning processes, competencies, beliefs, objectives, organisational structures and behaviours, and which interact through communication, exchange, co-operation and competition shaped by institutions. Somewhat contradictory of the idiosyncratic nature of sectors suggested by Malerba and Nelson (2011), DiMaggio and Powell (1983) suggest that highly structured organisational fields can lead to sectoral homogeneity in terms of structure, culture and output. This research addresses the question of whether firm age and strategy confers greater homogeneity in terms of system fit than sectoral affiliation per se.

Sectors and industries differ in how learning and innovation occur within their boundaries (Malerba 2004), and organisational fields are generally characterised by somewhat distinctive governance systems composed of a combination of public and private actors (e.g. trade associations, the education system, intellectual property protection and state agencies) based on regulatory and normative controls (Scott, 2008). The relationship between SSI and NSI is a co-evolutionary one through which sectoral and firm attributes influence the development of knowledge infrastructures, institutions and policies at the national level, while industry characteristics influence the evolution of the national economy (Malerba, 2002). Thus, capacity depends on the strength of linkages between common structures and specific sectors, implying that a given infrastructure results in more innovative output when there are mechanisms or institutions - such as an effective university system or established funding sources - supporting the commercialisation

of technologies in particular sectors (Furman et al., 2002). Given that firms compete for resources within selected environments, organisations in a population exist in a state of competitive interdependence (Aldrich, 1999), which in turn affects the prosperity of the sector, resulting in firms adapting, or perhaps mal-adapting to certain environmental configurations.

By encompassing sectoral characteristics, the SI perspective used in this study not only goes beyond the set of commonly considered variables that seek to capture activities, but also takes account of interdependencies between industry structures and institutional frameworks as evinced by seminal authors in the domain:

- In the early evolution of the NSI framework Freeman, Lundvall and Nelson, became increasingly cognisant of significant differences among innovation systems associated with different sectors (Nelson, 2000)
- Economic growth is often driven by specific sectors - understanding the key sectors of an economy, with their related specificities, advances the understanding of national growth and national patterns of innovation (Malerba, 2005)
- Due to internationalisation, Nelson and Rosenberg and Lundvall argue for a sectoral approach questioning the usefulness of a national perspective (Edquist, 2011).

It is arguable that the SSI framework addresses the criticism that national classifications are too wide-ranging, and that institutions supporting technical advances in one field may not align with the framing conditions required to support innovation in another (Nelson and Rosenberg, 1992; Nelson, 1993; Malerba and

Orsenigo, 1997). This echoes the finding that the most fertile locations for innovation vary across fields (Porter and Stern, 2001).

Sectoral Convergence

Given the increasing ambiguity of industry definitions outlined earlier, partly evidenced by the proliferation of NACE codes within sectors, convergence appears inevitable (Evans, 1987). In the software context, convergence with other technologies has led to the blurring of boundaries within, for example, healthcare and financial services. In the Irish manufacturing sector, Newman (2011) distinguishes between modern and traditional manufacturing, the former covering all high-technology multinational enterprises (e.g. chemicals; computers and instrument engineering; electrical machinery and equipment), and the latter including all other sectors. Manufacturing engineering is also subject to increasingly blurred boundaries, with 'clean tech' emerging as a key sub sector reflecting the revision of the NACE system which has reclassified many manufacturing activities as services. There are parallel illustrations in the software sector, where programming covers enterprise and consumer grade applications, from complex financial platforms to music and gaming.

Adoption of the sectoral lens

Early economic analyses saw comparative advantage residing in differences in the availability of the inputs needed to support different types of economic activity (Mowery and Nelson, 1999). With reference to the dual sector approach adopted by this research, Lundvall et al. (2009) suggest, the SSI approach may facilitate

understanding of interaction not alone within but between different sectors leading to improved understanding of the mechanisms at work.

As systems thinking continues to evolve, historical focus on R&D and the supply side has given way to thinking that such strategies can only be effective if they are accompanied by policies that stimulate output in sectors of comparative competitive advantage (Freeman, 1988). In the context of *differential development*, Rosenberg (1974) articulates the need for careful understanding of the manner in which differences in the state of development of individual industries have a bearing on the composition of inventive activity. This study builds on research that emphasises the role of firms as central actors of SSI (e.g. Breschi and Malerba, 1997; Lundvall, 1992; Wessner, 2000) and, further, that in-sector profiles will be diverse in respect of fitness to context.

The purpose of this study is to explore the effect of firm-level contingencies on SSI fit. Prior to assessing the specifics of age and strategic intent, the literature reviewed in the foregoing section encompassed; the dynamics of firm-system fit, the overarching analytical framework adopted in this thesis, innovation, systems of innovation and most particularly, sectoral systems of innovation. The following section outlines the age/life course context proposed for the research. It examines the influence of age related factors on firms' ability to secure and apply the resources for innovation. Shedding light on the potential impact of SSI via an analysis of age-related liability and viability, the review assesses the influence of variables such as firm newness, and the impact of moral hazard on funding, through to the viability of age and the capacity of mature SMEs to attract and retain talent

based on inferred reputation and stability. Analysing innovation with respect to firm age can make an important contribution to the understanding of firm dynamics.

2.5 Firm age, evolution and development.

The mainstream innovation literature recognises the need for continuous renewal of organisations in dynamic environments, yet limited explicit attention has been given to the question of how firm dynamics affect system fit. It is clear that organisations develop over time and that even standing still does not imply stagnation in terms of policy, structure or behaviour. Given that globalisation, market turbulence and change are not merely routine but gathering pace, questions arise as to how newer, smaller and non-dominant firms confront and negotiate change (Louçã and Mendonça, 2002).

At any particular time in history, firms founded in one era typically rely on different social structures than those formed at another time, creating mixed potential for fit (Stinchcombe, 1965). In the context that any given sector is likely to include some young, some middle aged and some elderly organisations, including them in the same research sample will have the effect of denying potentially important variances (Kimberly, 1980). This poses a parallel question in relation to SSI-fit in line with differing stages of maturity. Linked to that, there have been very few systematic, studies of the relationship between organisational age and the propensity of firms to produce technological innovations (Sorenson and Stuart, 2000). The dynamic quality of firm age is curiously absent from SI research.

Age variables exhibit consistent and significant relationships with performance (Pugh, Hickson, Hinings, & Turner, 1968), although very early stage ventures present weaker evidence of such effects (Baum and Locke, 2004; Low and MacMillan, 1988). While old, small organisations incur a relatively high risk of

failure, successful organisations can outgrow age-based penalties (Ranger-Moore, 1997), an assertion supported by Starbuck's (1965) contention that as organisations get older, they learn more about coping with their environment and with internal problems of communication and coordination. Notwithstanding this, firms are unlikely to be successful if they draw lessons from observing growth in one period and apply these routinely at a later stage (Parker, Storey, & Van Witteloostuijn, 2010). Aldrich and Auster (1986) further argue that formalisation and codification preserve the successes of the past at the potential cost of mortgaging the future.

Empirical research on organisational age refers to tenure within a particular industry cohort or population. Organisations entering a population from an established position in another geographical location or even from another sector, generally display lower failure rates (Carroll and Hannan, 2000) indicating the potential benefits of structure, experience and resources.

Paradoxically, as firms age, their core capabilities have been shown to both enable and impede innovation. While age is frequently associated with increased rates of innovation, the challenge of keeping in step with external developments can cause firm outputs to obsolesce or at least decline in value relative to current demand (Sorensen and Stuart, 2000). As start-ups grow, mature, and develop, their innovation processes frequently lose pace with market developments, with the result that they may become vulnerable to the same problems that gave rise to their initial advantage (Freeman & Engel, 2007). An alternative interpretation suggests that the impact of aging depends on the degree to which gains in competence through experience may be negated by declining performance due to

poor environmental fit (Sorenson and Stuart, 2000). Leonard-Barton labels the growth of core rigidities as the 'dysfunctional flip-side' (1992, p.111) of age, which otherwise demonstrates that activities related to developing and marketing new products expands competencies, in turn enabling further innovations (Danneels, 2002), compared to major new innovations and technologies which are often associated with competence destruction (Tushman & Anderson, 1986). The generation of new technological knowledge generally builds on the previously existing base however the cognitive nature of learning processes and past knowledge can become a constraint (Malerba and Orsenigo, 1997).

These conflicting variables complicate the analysis of enterprise populations, so much so that, observing the near absence of their study from academic and institutional policy-making, Carroll and Hannan (2000) call for the creation of corporate demography as a discipline. Similarly, Kimberly (1980) argues that much organisational theory and research is static and in need of more dynamic theories and models.

Theorists emphasise the need to examine the nature of the relationship between aging and organisational behaviour and, in particular, to study the joint effects of age on innovation outcomes in models of organisational mortality and growth (Sorensen & Stuart, 2000). Given that the relationship between innovation, firm profitability and growth are expected to change over time, the effects of age on critical performance dimensions are insufficiently understood (Davidsson, Steffens, & Fitzsimmons, 2009). Detailed consideration of lifecycle impact on SSI appears merited.

Of particular importance to this study is the distinction between firms, technologies and age. Reinforcing the importance of population dynamics in small firms, Boswell (1973) discounts differentials based on industry classification, instead prioritising firm age, changing industry patterns, and the sociological evolution of the business itself. This leads to the concept of *differential development*, suggesting the need for careful understanding of how variations in the improvement of individual sectors can influence the composition of firms' inventive activities (Rosenberg, 1974).

Evolutionary theory

Evolutionary theory – which aims to explain how particular forms of organisations exist in specific environments (Aldrich, 1999) suggests that organisational environments are rarely if ever static, so firms and the sectors they belong to, transform and change to avoid de-selection (Aldrich and Auster, 1986; Danneels, 2002). While neoclassical theory perceives an economy *at rest* or, at most, undergoing anticipated changes, evolutionary theory sees actors as having the capacity to innovate when they encounter opportunities or when their current behaviour is out of step with a changing context (Nelson, 2011). Growing emphasis on the temporal aspects of firm existence represents a significant trend, as social science seeks to examine the effects and management implications of evolutionary processes within organisations (Aldrich and Auster, 1986; Carroll and Hannan, 1995, 2000; Hamilton, 2011; Phelps, Adams, and Bessant, 2007; Westerman, McFarlan, and Iansiti, 2006) and within sectors (Boswell, 1973; Hanks, Watson, Jansen, and Dean 1993; Huergo and Jaumandreu, 2004; Klepper, 1997; Kotha, Zheng, and George, 2011).

Organisational change has an inevitable impact on learning, behaviour and innovation (Aldrich and Ruef, 2006; Hannan, 1998; Sorenson and Stuart, 2000). Formation, growth, stabilisation, decline, exit and revitalisation mark potential milestones in the firm's life course: virtually all theories about organisations presuppose some process of adjustment over time (Carroll and Hannan, 2000) and consistent with the SI framework, many address adaptation to change in geographic and historical contexts (Aldrich, 1999, 2008). In the context of the specific, differentiated and cumulative nature of technological development, Pavitt (1990) posits that the range of product and process technologies that firms can access depends on their historically accumulated competencies. Change and time resonate closely with innovation in respect of keeping pace with technology trajectories, the science base, industry and economic cycles. As such the impact of time on the firm should be a central feature of the SSI.

Kimberly (1980) asserts that much organisation theory is static and 'ahistorical', suggesting that the revision of research paradigms to accommodate thinking about firms in lifecycle terms is long overdue. There is a significant body of literature on the nature of the technological and organisational capabilities embodied in firms and how these evolve over time (e.g. Aldrich and Auster, 1986; Bruderl and Schussler, 1990; Churchill and Lewis, 1983; Galbraith, 1982; Greiner , 1972, 1998; Kimberly and Miles, 1980; Miller and Friesen, 1984; Ranger-Moore, 1997; Sorenson and Stuart, 2000; Westerman et al., 2006). Market conditions, innovation and diffusion are central to that evolution, as are age, size, productivity, capital intensity, export performance and ownership structure.

2.5.1 Adaptation and Selection

Diverse industrial environments have particular economic and technical characteristics which demand unique competitive strategies (Lawrence & Lorsch, 1986) however; the degree to which strategic adaptation or environmental determinants dominate firm change remains unclear. There has been some criticism of the focus on adaptation to the neglect of selection in analysing organisation-environment relationships (Hannan and Freeman, 1978). Evolutionary approaches to the study of innovation, originated by Schumpeter and pioneered by Nelson and Winter (1982) highlight variety, creation, adaptation, selection and retention, all of which are time and path-dependent. Their suggested approach embodies the principles of biological evolution and natural selection by interpreting the economic system as an adoptive mechanism which chooses among actions generated by firms' adaptive pursuit of success or profits (Alchian, 1950).

At any point in time innovations emerge, but only those that are well adapted to the current selection environment are likely to succeed and form the basis for continuing adaptation and improvement (Alchian, 1950; Fagerberg et al., 2008). While survivors may appear to be those that have adapted best, Alchian (1950) posits that the environment may have actively '*adopted*' them, reducing liability for motivated adaptation *(*p.214). The SI is the selection environment for new entrepreneurial ventures, while path-dependence exerts a significant influence. New ventures that have little in common with strongly embedded sectors may find the system is poorly adapted to their needs. In relation to emerging sectors, Peters (2005) suggests that the SSI and NSI models should be coupled to analyse why some

industries are better supported than others. Equally, government attempts to pick winners may result in selection against established or traditional sectors (Hirsch-Kreinsen, 2008; von Tunzelmann & Acha, 2004) . For this reason, the target research population addresses the low-medium and medium-high technology sectors in parallel.

Developmental and evolutionary theory

Based on the premise that change occurs through a cycle of emergence, growth, maturity and decline, many theories of organisational founding and growth are developmental rather than evolutionary. Contrasting the developmental-stages approach with a focus on configurations of performance outcomes for companies in specific age groups, Steffens et al. (2009) suggest a probabilistic relationship between age and performance. The focus of ecological and institutional researchers is one of analysing common changes within organisational populations over time (Aldrich, 1999; 2008). Penrose (1959) refers to the reinforcement of the firm through the evolutionary lens of an 'unfolding process' based on internal developments leading to new directions and advantageous positions (p.1).

Population Ecology

Population ecology focuses on how groups of organisations are transformed by environmental change. The process of selection and retention, combined with the creation of new organisations, transforms sectors and ultimately renders them better suited to their environments. In biology, the differential survival of mutant organisms best able to exploit the food supply (Aldrich, 2008) is a familiar concept. In SI terms, this might equate to superior ability to access sources of finance, talent

and new markets. Echoing Darwin, Aldrich (2008) credits survival with superior resource-based selection, backed by learning which supports differential reinforcement of valuable processes.

In contrast to Darwin's population adaption, Lamarck promotes the notion of individual adaption, which is typically interpreted as the inheritance of acquired characteristics, yet Darwinism and Lamarckism are not mutually exclusive. While Darwin endorsed Lamarckian inheritance, it is perceived inadequate as a theory, as it fails to explain why dysfunctional characteristics are inherited without invoking selection mechanisms (Aldrich et al., 2008). One expression of Lamarckian thinking is Saxenian's (1994) reference to Silicon Valley as a 'Protean Place' (p.161), based on Proteus' ability to change shape while avoiding commitment to a single form. Cyert and March (1992) interpret Nelson and Winter's (1982, p.19) search based change theory as Lamarckian.

This suggests that a generalisable assessment of SSI fit may be of practical use to firms in search of markers to navigate their environments.

2.5.2 Lifecycle, life course and Stages Models

Economics frequently draws on the natural sciences to illustrate phenomena, the most common application of which is the life cycle metaphor, where firm emergence, growth, decline and exit is perceived as analogous to birth, growth and death in biological organisms (Child & Kieser, 1981; Penrose, 1952; Whetten, 1987). The lifecycle paradigm is well established (Greiner, 1972; Levitt, 1965; Utterback & O'Neill, 1994; Vernon, 1966), with variants spanning organisational age (Boswell,

1973), products (Abernathy and Utterback, 1978) and technology (Klepper, 1996) which renders this particular lens apt for consideration by policymakers.

Theorists point to the importance of size, age, technology and legal form in shaping innovation and growth outcomes for individual firms (Barron, West and Hannan, 1994; Bruderl and Schussler, 1990; 1994; Carroll and Hannan, 1995; Churchill and Lewis, 1983; Fichman and Levinthal, 1991; Greiner, 1972). Distinguishing between age and technological progress (production and output technologies) as sources of growth is challenging. Differentiating between organisational and biological age, Kimberly (1980) adopts a developmental view suggesting that chronology is just one of many dimensions to consider in assessing firm maturity or propensity to grow:

> Chronological age may have very little to do with where an organisation is going or where it has been. Calendar time and organisational time are not necessarily identical. Organisations often have rhythms and cycles that are quite independent of their chronological age (p.6).

Employing similar logic, industrial organisation economists characterise age as young or mature, suggesting that various business and technology iterations occur naturally as industries grow older (Churchill and Lewis, 1983; Greiner, 1972; Nelson, 1995). Other authors use similar nomenclature at the firm level: early-stage new ventures 0–4 years old (Low & MacMillan, 1988); entry, post entry or intermediate and advanced age (Huergo & Jaumandreu, 2004a); infants (0±2 years), adolescents (3±4 years), middle-aged (5±24 years), or old (25 years or more) as a rough approximation for seed, start-up, and later stages (Berger & Udell, 1988). Each of these is suggestive of differential behaviour or economic interaction which requires consideration in regard to temporal adaptation of SI.

The growth literature commonly applies developmental and stage models (e.g. Churchill and Lewis, 1983; Greiner, 1972; Kazanjian and Drazin 1989). The characteristics and challenges of growth stages appear to constitute a more useful mechanism for calibrating the entrepreneurial process than specific timeframes (Hite & Hesterly, 2001b). Promoting a more subtle approach, Phelps, Adams, and Bessant (2007) conclude that lifecycle models are 'linear, unidirectional, sequenced and deterministic' (p.17), calling into question their applicability to the analysis of firm growth over time. In an extensive analysis of growth models, Levie and Lichtenstein (2009) found no consensus on basic constructs and no empirical evidence supporting stages theory. As outlined below, this discord has been addressed by a number of authors, extending the menu of evolutionary diagnostics which might be applied to assess system fit within chosen sectors.

Start-ups and Lifecycles

Liabilities of newness and smallness combined appear to dilute the usefulness of the lifecycle description of organisational change in that most organisations don't grow and, high mortality rates among start-ups mean that most new firms face short term dissolution (Aldrich and Auster, 1986). The US Small Business Administration as cited in Berger and Udell (1998, p.627) estimates that about 23.7% of small businesses disappear within 2 years and 52.7% disappear within 4 years due to failure, bankruptcy, owner retirement, ill health, or a desire to embark on a more profitable endeavour. Given the instability of the start-up population, entrepreneurship policy, rather than the system of innovation, may offer a better route to resolving market-failure.

Firm Age and Growth

Gibrat's Law predicts discontinuous growth patterns driven by independent random variables (Hamilton, 2011) however Parker et al. (2010) contend that this is incompatible with evidence that consistently explains firm growth. Employing growth as a proxy for innovation, the literature presents supporting and conflicting evidence of the age-growth relationship. Citing high-technology start-ups as an exception to generally accepted business growth stages, Churchill and Lewis (1983) suggest that the entrepreneurs and investors who start them, do so with the intention of growing them quite rapidly, often with a view to a successful exit (e.g. IPO or trade sale). While there is some evidence that rapidly growing enterprises are more concentrated in technologically sophisticated sectors, empirical data increasingly points to a lack of concentration in the high tech sector (Mason & Brown, 2013; Parker et al., 2010). Exit patterns and growth potential in high tech sectors should be a key consideration in SSI design; both from the perspective of qualifying expectations for job-related growth and the consequences of firm exit/acquisition for a small open economy.

Once established, organisations benefit from patterns of relationships that ultimately coalesce into a social structure that enhances their survival prospects. Beyond the minimum efficient level, however, this study focuses on firm age in combination with the distinction between technologies and industry lifecycles. Several aspects of the SI are thought to be prominent in influencing the ultimate success of innovation as businesses mature from start-up through intermediate and advanced ages. In the developmental tradition, Churchill and Lewis (1983) argue

that small businesses experience common challenges at similar stages of development - so while each firm is unique, they all face similar problems and are subject to the vagaries of changing conditions - and that categorising problems and growth patterns could help entrepreneurs to navigate them. They highlight pivotal components as:

> Financial resources, including cash and borrowing power; Personnel resources, depth and quality of people at management and staff levels; Systems resources, in terms of the degree of sophistication of information and planning and control systems; Business resources, including customer relations, market share, supplier relations, manufacturing and distribution processes, technology and reputation, all of which give the company a position in its industry and its market (P.40).

By way of illustration, emergent markets are challenging for many young firms as the timing of market adoption is difficult to predict, and difficulties are often compounded by straitened capital and human resources, so that the firm is too drained to bridge the chasm (Moore, 1991). Clearly, an active presence in growing markets where customer needs and awareness are established can offer young firms significant advantage (Eisenhardt & Schoonhoven, 1990).

Lifecycles and system contingency

Adopting a growth perspective, Adizes (1979) portrays lifecycles themselves as contingency models, suggesting that they provide frameworks for prescribing the actions and decisions likely to be most effective at particular organisational stages. Employing stages theory, it appears reasonable to assume that development takes place in identifiable stages during the life course of most firms (Foss, 1997). The growth and maturity phases merit focus in terms of potential to scale and diversify.

Models further suggest the potential for firms to foresee problems associated with growth over time, and to gain insights for effective action (Adizes, 1979).

Articulating parallel factors that condition sector-specific patterns, Klepper (1997) describes how firms could exploit regularities in evolution, including insights offered by industry lifecycles. This is supported by La Rocca, La Rocca, and Cariola (2011) who propose a financial lifecycle model that is homogenous for different industries and consistent over time.

Child and Kieser (1981) are critical of efforts to support managerial decision-making by attempting to typify development paths. They suggest that lifecycle models offer only limited help to those seeking to navigate development, compounded by the absence of information about potential time lags. Route 128's minicomputer firms and Silicon Valley's semiconductor firms, followed lifecycle organisational and location logics closely during the 1980s, but competition based on continuous - and especially radical - innovations undermined the industrial maturity logic implicit in those models, creating shortened lifecycles. However, Silicon Valley with its capacity for experimentation, learning and pursuit of multiple technology trajectories (Saxenian, 1994) privileged the companies involved in that system.

Life course

Child and Kieser (1981) outline the challenge of drawing a sharp distinction, conceptually or empirically, between development brought about by strategic choice and that caused by unplanned forces. They suggest that 'the distinction between development as a function of strategy and development as a function of ageing is a highly academic one' (p.46) and propose that ex post rationalisation by

managers and researchers risks producing spurious analyses of organisational development. This notwithstanding, Aldrich and Auster (1986) suggest that research on strategy and context would benefit from investigations which simultaneously consider both levels of analysis and how they are connected.

Aldrich (1999) suggests substituting the life cycle concept with 'life course' (p.196) as a means of avoiding implied determinism. Borrowing from population demography, Aldrich and Ruef (2006) employ history rather than time as the central attribute of firm evolution, suggesting a framework (Table 2-1) incorporating age, period and cohort effects.

Age effect	Changes produced by processes inherently associated with duration of existence – e.g., decay of a founder's initial enthusiasm
Period effect	Changes produced by historical events and forces that have similar effects on all organisations, regardless of age (e.g., deregulation of financial markets). Organisations founded in the same year make up a group that moves together through time, experiencing historical periods and events while they are all the same age.
Cohort effect	Changes produced by historical events and forces that have different effects on organisations of different ages - for example, shortages of essential resources may weaken younger organisations but have little effect on older ones.

Table 2-1: Attributes of firm evolution (Aldrich and Ruef, 2006, p.164).

Many young organisations display drive, flexibility and dynamism derived largely from the characteristics of their founders and the relative newness of their ideas, assets and markets, while other young firms may make investments in people, technology, and assets that they are unable to change subsequently because they are blinkered or resource-poor (Eisenhardt & Schoonhoven, 1996). In a meta-analysis of literature on SME age and growth in the US and the UK, Storey (1994) finds that younger firms grow more rapidly than their more mature counterparts, and consistent with this, Robson and Bennett (2000) in a 1997 study of 2474 British

SMEs find that as firms age, they are less likely to drive growth in employment and turnover. In accord with Storey's findings on the negative age-employment relationship, they contend that this is due to owner-managers having achieved the objectives they formulated at founding, and also that older firms are more likely to have surpassed the minimum efficient scale of production giving them reasonably secure position in their markets. One aspect of the aging process is goal-change, including adjustment to meet broader and/or more achievable targets, and maintaining the organisation once established (Child and Kieser, 1981). Growth has been found to decrease with age when firm size is held constant (Evans, 1987). This suggests that improved understanding of firm dynamics is critical to SSI governance.

Although a large body of literature charts the evolution of market structures, industries and firms, including theories attempting to predict patterns of growth over time (Evans, 1987; Klepper, 1997; Phelps et al., 2007), the implications of age, stage, life course and lifecycle for SSI fit have received limited attention. Sorenson and Stuart (2000) contend that there have been very few systematic studies of the relationship between organisational age and firms' propensity to innovate. Similarly, Metcalfe (1997) observes wide differences in firms' abilities to sense relevant innovation opportunities and to manage technology creation processes. Echoing that, Phelps et al. (2007) propose a typology of maturity stages of absorptive capacity, assessing organisations' abilities to engage with and use new knowledge. The methodology employed in the current research offers an opportunity to gain insight into firms' absorptive capacity.

2.5.3 Stages of development

Transitioning from the theories and frameworks that support our understanding of ages and stages of development, there is scope for overlap and confusion. Klepper (1997) delineates three stages of evolution; exploratory or embryonic, intermediate or growth and maturity. The stages-of-development tradition promoted by Churchill and Lewis (1983), Greiner (1972) and Kazanjian and Drazin (1989) presents a stage-based map of founder and firm characteristics evolving over a timeline. In a bid to provide management with a roadmap for the future, Greiner (1972) articulates the developmental phases of organisational growth as five interconnecting dimensions; age, size, stages of evolution, stages of revolution and the industry growth rate, defining evolution as 'prolonged periods of growth where no major upheaval occurs' and revolution as 'periods of substantial turmoil in organisational life' (p.398).

Arguing against the idea of predetermined stages of firm development as a function of age, Penrose reasons that:

> to abandon firm development to the laws of nature diverts attention from the importance of human decisions and motives, and from problems of ethics and public policy, and surrounds the whole question of the growth of the firm with an aura of naturalness and even inevitability (1952, p.809).

Penrose (1952) further derides the concept of stages as a bare, undeveloped hypothesis lacking consistent theory and with insufficient substance to make it useful. In a comparable analysis of the S-curve as a management tool, Schilling (2010) cautions that while it is useful for gaining a deeper understanding of rates of improvement or limitations when mapping technology trajectories, its use as a

predictive tool is limited. Aldrich and Ruef (2006) similarly advise that 'cross-field borrowing' (p.160) can generate helpful insights but that facile equations of organisational development could be misleading. In a comprehensive review of stages models and life-cycle theories of business and entrepreneurial growth, Levie and Lichtenstein (2009) argue that they do not offer an accurate representation of entrepreneurial firm growth and development, describing stages models as being 'similar to clear but misleading roadmaps that create an illusion of certainty about the path ahead' (p.336).

Contending that lifecycle models are overly deterministic, Churchill and Lewis' (1983) own findings suggest that while some companies may be at a given stage of development, many are at one stage with regard to one growth dimension and at another on an alternative dimension. This aligns with the argument that many organisations survive at an arrested stage of organic development, while most attain maturity and avoid transitioning to decline and death (Child & Kieser, 1981). In conclusion, Levie and Lichtenstein (2009) resolve that scholars should no longer use stages models, claiming that they act as a barrier to the advancement of research on the growth of entrepreneurial organisations.

Taking account of the conflicting observations expressed by scholars of stage and age-related models, empirical research on age-related system fit appears warranted. This mixed method study explores SSI fit in respect of the research population. While the findings may not be significant in terms of innovation output, firms' demands for innovation related resources such as external funding and

access to R&D should be indicative of the opportunities and constraints associated with age.

2.5.4 Age-related Liabilities

Two factors present at the foundation of an organisation are said to influence its subsequent development: the personality of the founder and societal conditions at the point of the firm's foundation (Storey, 1994). It is reasonable to assume that the characteristics and aspirations of founders initially drive their firms, but the necessity for survival dictates the need for growth in newly established businesses (Gartner, 1988). Entrepreneurs' beliefs and preferences have been shown to frame organisations, both at the outset and thereafter (Child and Kieser, 1981), but growth in small firms (where it occurs) is rarely a continuous and sustained process, so firm age is rarely a predictor of growth prospects (Aldrich and Auster, 1986; Smallbone and Wyer, 2012). In the context of founding conditions, additions to a firm's knowledge base depends on what it already knows and how it processes or assimilates new knowledge (Autio et al., 2000), which brings into question the learning and unlearning of routines, 'competency traps' and firms being 'locked-out' of types of knowledge if they don't acquire or cannot access them at an early stage (Cohen & Levinthal, 1990, p.136-137).

Extending the earlier reference to cohort effects (Aldrich and Ruef, 2006), the economic era in which a particular type of organisation is founded may have a residual effect on its structure (Stinchcombe, 1965) and growth prospects. Boswell (1973) describes infancy – i.e., the first five years of existence - as a distinctive period in a firm's history, associated with boot strapping, high risk, modest capital

expenditure and personal sacrifice by the owner. He finds that the link between founder-ship and management was strongest in young firms, albeit founder entrepreneurs normally have long periods of involvement with firms in the manufacturing sector – over 25 years in some cases. Such firms are characterised by founders' drive and ambition for growth which can be matched by a reluctance to adopt formal planning and control, opting instead to deal with issues on an intuitive basis diminishing potential for scale - impetus can decline, and the changes that success brings such as the need to delegate, may be at variance with the style of the founder (Child and Kieser, 1981).

Liability of newness

In the context of conditions that affect comparative mortality rates among new and old organisations, Stinchcombe (1965) coined the term 'liability of newness' based on evidence of the higher risk of failure among new firms compared with older counterparts. In a study of growth oriented founders, Baum and Locke (2004, p.588) similarly identify characteristics of the entrepreneur's situation as: (a) extreme uncertainty (newness of products, markets, and organisations; lack of information), (b) resource shortages (financing, knowledge, operating assets, and legitimacy), (c) surprises, and (d) rapid change. The inexperience of start-ups contrasts with the established routines of more mature firms including succession structures, skills transfer, decision criteria, mechanisms for dealing with conflict, known liabilities in routine procedures and general loyalty to the firm (Bruderl and Schussler, 1990, p.530; Stinchcombe, 1965, p.148). While conditions associated with newness are partially addressed through provision for start-ups, the other dynamics enumerated are given limited consideration in the SI literature.

Two of the main problems in starting new organisations are the concentration of sufficient resources in the hands of the 'innovating elite' and the capacity to recruit, train, motivate and organise personnel effectively' (Stinchcombe, 1965, p.160). The liability of newness theory has become part of the conventional wisdom of organisational sociology, in which reliability and accountability are seen to increase with age (Barron, West and Hannan , 1994). However more recent findings indicate that mortality rates do not decline monotonically from firm foundation, as implied or empirically observed (e.g. Freeman , Carroll and Hannan, 1983), but rather they sometimes rise during the early part of a firm's life when initial resource stocks are exhausted before declining over a typical lifespan. It is posited that these patterns have been overlooked due to reliance on parametric representations that assume monotonic changes in hazard rates over time (Fichman and Levinthal, 1991).

Huergo and Jaumandreu (2004a) show that entrant firms are more likely to be innovative than older firms however, Malerba and Orsenigo (1997) find that a large proportion of new innovators can be classed as 'occasional' with many ceasing to innovate soon after entry. They also show that the oldest and youngest cohorts held a far larger share of patents than the intermediate or adolescent cohorts, and that entry and exit processes mean the age distribution of innovators appears strongly skewed towards youth.

Extending the analysis, Eisenhardt and Schoonhoven (1990) argue that liability of newness fails to deal with two common observations; firstly that leaders can and do influence the performance of firms, particularly young and small ones, and secondly, that there can be enormous differences in the quality of life of surviving

ventures. Exploring contrasting perspectives on age-related liabilities, Autio et al. (2000) advance the notion that the generation of new organisational knowledge is greater in proximity to domains of existing knowledge. This suggests that emerging firms have few organisational routines to unlearn, meaning that learning, assimilation and retrieval occurs in a persistent fashion conferring advantages on young firms, which are generally more flexible and enjoy 'discovery advantage', whereas established firms enjoy 'exploitation advantage' based on their ability to leverage resources and experience (Steffens, Davidson and Fitzsimmons, 2009, p.125). Similarly, Autio et al. (2000) introduce the concept of the 'learning advantages of newness' (p.919) in conjunction with knowledge based competition in SMEs. Entrepreneurial firms lacking traditional 'hard' sources of power - such as scale, deep pockets and a strong customer base – can nevertheless use 'soft' sources of power that reduce ambiguity and create influence (Santos & Eisenhardt, 2009, p.667), echoing the potential *viability of newness* (Levie and Lichtenstein, 2009). The strengths of larger, older organisations show up the weaknesses of smaller, newer organisations and vice versa (Aldrich and Auster, 1986), these paradoxes warrant further study in respect of implications for SSI configuration.

Liability of adolescence

A number of authors (Adizes, 1979; Bruderl and Schussler, 1990; and Ranger-Moore, 1997) define adolescence as the mid-point of firms' age range, with distribution subject to sectoral and industry lifecycles. Between 20-40 per cent of new entrants in a given cohort fail within their first two years, and although failure rates decline with age, only 40-50 per cent survive beyond the seventh year (Bartelsman et al., 2005). Research indicates a higher probability of fast growth for

surviving firms as the accumulation of experience and assets fortifies their position and reduces the likelihood of failure as they adjust to environmental change (Ahn, 2002; Mason and Brown, 2010). More time is spent on planning and co-ordination, and on establishing policies, so a somewhat contradictory style emerges where the administrative orientation seeks stability while the entrepreneurial orientation seeks variation (Adizes, 1979). This supports the proposition that failure rates peak during adolescence, as found by Bruderl and Schussler (1990) in their work on the mortality hazard of Bavarian businesses. They refute Stinchcombe's hypothesis of higher risk for young firms, introducing the concept of 'liability of adolescence' (p.530), proposing an inverted U-shaped risk pattern indicating that mortality, depending on firms' initial resource endowments, peaks between one and fifteen years after founding. In adolescence, death risks are seen to be low because monitoring is high and judgment about success or failure is postponed: later, however, monitoring reduces and organisations are more vulnerable to the usual risks of failure (Bruderl and Schussler, 1990). Because organisations tend to be most vulnerable to survival hazards early on in life, any factors that result in a buffer period making them less susceptible would have a significant effect on persistence: Fichman and Levinthal (1991) refer to this as the firm equivalent of a honeymoon period, in which age effects and initial endowments shield relationships to varying degrees, 'even if they are, in some sense, less fit than other possible relationships or organisations' (p.447). Even so, proponents of the idea of adolescent liability continue to assume that mortality hazard declines with age over the majority of organisational lifespans (Carroll and Hannan, 2000) although Fichman and Levinthal

(1991) suggest that initial endowments can mask difficulties up to a point in the lifecycle, resulting in greater challenges for adolescent firms.

In keeping with emergent thinking on business model innovation (Osterwalder and Pigneur, 2009), it might be suggested that adolescent organisations are liable to iterate or change direction based on shifts in their environment or in technology. Hannan and Freeman (1984, p.160) propose that such change renews their liability of newness by diluting the value of the organisation's history of survival, making established routines and competencies obsolete, and disrupting relations with the market. This is consistent with the theory on competence-enhancing and competence-destroying innovations and also with structural inertia theory, which suggests that organisations might fail as a direct result of their attempts to survive (Baum, 1996). Considering governmental interest in job-rich growth, the challenges and opportunities inherent in adolescent companies merits closer consideration in the SSI context.

Liability of age

Older technology firms are generally presumed to have perfected the routines and structures needed to develop new technologies and bring them to market, but they may also be prone to obsolescence or senescence (Stuart & Sorenson, 2000) if employee behaviour becomes ossified (Aldrich and Auster, 1986). Unlearning established practices becomes more difficult as firms develop 'self-reinforcing patterns' (Autio et al., 2000, p.911) where existing knowledge is most likely to be exploited and new knowledge may injudiciously be assimilated based on dominant logic (Bettis & Prahalad, 1995). Although knowledge-intensive firms suffer greater

downside risks of technological obsolescence, they are more likely to be able to contend with knowledge obsolescence than firms with less developed knowledge regenerating capacities. Given the inevitability of environmental change, firms and policy makers must be alert to the risk that organisational policies can become locked into strategic frames of reference formulated for an outdated context (Child and Kieser, 1981), a phenomenon that may offer some explanation for the difficulty businesses experience in sustaining growth over time.

A popular theme in the literature is that larger organisations are likely to generate incremental innovations whereas smaller ones are the more likely springs of radical innovation, albeit a small minority of them (Roper, 1997). On the other hand, Winter (1984) suggests that small firms face an obvious disadvantage in developing incremental innovations due to the absence of necessary complementary assets in their portfolios, whereas established firms may suffer opposing constraints, imposed by incumbency (products, assets and customer/supplier commitments). As organisations age, they gain a history and routines that limit their flexibility by restricting their range of potential action, compounded by external commitments that create pressure to continue business as usual (Ranger-Moore, 1997; Stuart & Sorenson, 2000). Together with the necessity to continue serving existing customers, this may hamper the perception and pursuit of emerging market opportunities (Rosenbloom & Christensen, 1994).

In research on the combined attributes of age and size, Barron, West and Hannan (1994) suggest that larger and older organisations gain increasing dominance over their environment, enjoying lower failure rates and higher growth through

competence-enhancing change which Ranger-Moore (1997, p.903) and Anderson and Tushman (1986, p.445) liken to the 'the rich getting richer while the poor get poorer' as liabilities of newness plague recent entrants. By extension, Starbuck (1983) claims that older, larger firms may hold sufficient resources to buffer themselves from adverse changes in the environment while Aldrich and Auster (1986) argue that organisational inertia may be a product of external selection, rather than assuming it is a primary cause. External mediators such as funding agencies, suppliers and customers may select more established organisations on the basis of seeking accountability and reliability in their dealings (Hannan and Freeman, 1984).

A number of studies point to increasing bureaucratisation as a function of time, sometimes independent of organisational size. Among the characteristics and strengths of innovative culture, Pavitt (1991) cites flexibility, short lines of communication, close customer relations, management and labour force motivation, reduced bureaucracy and strong interest in product development and technological change. Starbuck (1965) suggests that process formalisation is fundamentally adaptive, and Child and Kieser (1981) add that only when organisations treat a discontinuous environment as continuous, do repeatability and formalisation become sources of inflexibility or weakness, countering the assumption that maturity inevitably leads to sclerosis.

Obsolescence and senescence

The fate of older, larger firms is presented as one of diminished capacity to respond to new challenges which is framed alternately as the 'liability of obsolescence' and

the ‘liability of senescence’ (Barron, West and Hannan, 1994, p.387; Stuart and Sorenson, 2000). In the case of obsolescence, causal significance cannot be attributed to aging per se, as mortality rates are independent of age in stable environments. Senescence connotes disadvantage among older firms in dynamic environments where accumulated routines and structures impede the firm’s ability to react in a timely fashion, or simply impose excessive overhead costs that undermine efficiency, even in a stable environment. Models of the drivers of innovation, productivity and firm growth for manufacturing plants in Ireland and Northern Ireland show that plant age has a uniformly negative effect on product and process innovation (Roper, Du, & Love, 2008). However, an earlier study by Roper and Hewitt-Dundas (2001) revealed positive effects on productivity for older plants with consistently negative growth effects.

The liability of obsolescence corresponds with Schumpeter’s thesis on ‘creative destruction’ whereby aging organisations become vulnerable to competition from new, unencumbered entrants. Among the constraints mature organisations face which limit their potential to make changes are ‘retention of control by founders long after such control is effective, a tendency towards internal consistency and homogeneity, and the hardening of vested interests opposing changes’ (Aldrich and Auster, 1986, p.172).

One impact of firm maturity has been interpreted as a lack of innovative decision-making, combined with avoidance of risk, leaving established firms vulnerable to emerging competitors more sensitive to environmental change. Within the SI framework, this may constitute an inability on the firm’s part to access the physical

and social assets needed to modify production processes, recognise the need for diversification or to implement strategic or functional change. In most instances, managerial rather than material interventions may be needed.

Liability of Smallness/Size

Most organisations are small and suffer from attendant liabilities. Freeman, Carroll and Hannan (1983) lament what they perceive as unquestioning acceptance of Stinchcombe's 'liability of newness' argument. They reason that firms may instead suffer 'liability of smallness' in so far as the smallest organisations suffer the highest death rates, and that overall cohort death rates decline with age as small firms exit the population. Significant to this is that the Small Business Administration in the US was created with a specific mandate to protect and preserve firms burdened with size-related inefficiencies (Audretsch & Beckmann, 2007). Studies reporting size distributions usually do not control simultaneously for size and age, thus inferences drawn about the effects of organisational age in such models may be spurious (Aldrich and Auster 1986; Barron, West and Hannan, 1994).

Liability of smallness indicates the tendency among larger organisations to have lower and later mortality peaks than their smaller counterparts (Bruderl and Schussler, 1990; Freeman, Carroll and Hannan, 1983). Birch (1987) showed that non-survival rates for small firms were very high regardless of age, despite some evidence that smallness does not necessarily make survival problematic (Aldrich and Auster, 1986). Firm size measured by employee numbers is frequently used as a proxy for the amount of resources available, allied to the importance attributed

to the economic and innovative contributions of large firms (e.g. Schumpeter, 1947; Nelson and Winter, 1982 and Penrose, 1969).

Viability and liability of size

There is little question that in general, larger, older firms have certain advantages over smaller, newer firms, given the reduced managerial effort required for routine operations. Larger organisations enjoy advantages over their smaller counterparts in respect of raising capital, managing taxes and government regulations, as well as being better positioned to compete for labour (Bruderl and Schussler, 1990). Size can legitimate organisations to the extent that their scope may be interpreted as an outcome of prior success and an indicator of future dependability. Pertinent to SIs, Pavitt (1990) points to the strategic decisions of large firms having a bearing on sectoral patterns, technical activity and economic competitiveness within an industry. Thus larger organisations may be better positioned to influence their environments by monopolising resources or by exerting control over institutions, while conferring greater fitness in a broader range of environments (Ranger-Moore, 1997). This offers a parallel with the benefits of advanced age including the ability to compound favourable conditions.

The size-age relationship is the subject of much debate, with a number of studies implying that firm growth is independent of size (e.g. Evans, 1987; Jovanovic, 1982). Assessing the impact of efficiency on growth and survival, Jovanovic (1982) posits that firms differ in size, not because of the supply of capital but because some are more efficient than others at bringing about a range of outcomes from growth and steady-state through to exit. However, efficient organisations take time to build,

requiring the creation of roles and routines, gaining an understanding of the environment and developing relationships with relevant organisations and institutions (Barron, West and Hannan, 1994; Stinchcombe, 1965). In contrast, large firms may have a tendency to avoid risky innovation by substituting minor product improvements which are sufficient to defend and extend market positions (Child and Kieser, 1981), potentially undermining long term viability. Senescence may result in dated market vision, with the result that the size-age related advantage of established firms reduces in growth markets (Eisenhardt and Schoonhoven, 1990).

The literature review on age/life course and the preceding review of systems of innovation touch on a number of factors which research suggests may have an impact on firm-system fit - collectively or independently.

The next section addresses strategic aspiration and how strategic contingencies might affect potential fit. Strategic aspiration emerged from the semi-structured interview phase of the research as a potentially important determinant of SSI-fit.

2.6 Strategic Context

Porter (1991) defines strategy as the act of aligning a company and its environment while noting that the environment and the company's capabilities are likely to change over time. Firm strategies in any period are thus related to the market position of the business, the characteristics of the entrepreneur, the aspirations of the company and the operating environment. For the most part, organisational outcomes are a product of the intentions and consequent actions of the individuals who run them, influenced by environmental and institutional conditions (Roper,

1998). While venture growth is assumed to be the essence of entrepreneurship, divergence in growth paths is common as small firms mature (Tan, Fischer, Mitchell, & Phan, 2009), highlighting the need to understand the relative importance of firms' strategic motives in order to craft SSI which align entrepreneurial and policy aspirations.

Ventures that match their technological choices with their external environment are better positioned to achieve superior performance (Zahra and Bogner, 2000). In the SME context, this is broadly in line with the perception that external factors dominate internal influences, consistent with industrial organisation theory that strategy and performance are primarily determined by the firm's sector, while economic competence or the ability to identify and exploit business opportunities is unevenly distributed (Carlsson, 1994). Carlsson and Jacobsson (1997) argue that rationality around these assumptions is not alone limited but quite different among firms. These opposing perspectives are led by institutional and strategic choice theorists; clearly both schools of thought have a significant bearing on SSI analysis and fit. While institutional theorists stress organisational inertia and dependence, strategic choice theorists give primacy to managerial autonomy and adaptability (Aldrich and Ruef, 2006; Aldrich, 2008). Lundvall (1992) cites strategy as fundamental to firm learning, second only to consideration of economic structure. Expressing a contrarian view, Child and Kieser (1981) observe the tendency to interpret organisational development in terms of strategy but raise the possibility that development takes place independently of strategic moves, merely 'as a function of time' (p.44).

One defining characteristic is that no two firms innovate identically. Lundvall (1992) asserts that taking advantage of the environment for innovation is not routine given that companies based in the same location demonstrate significant variations in output, as they are shown to navigate the same environment with very different strategies (Miles & Snow, 1978; Miller & Friesen, 1984; Miller & Toulouse, 1986) This view is particularly pertinent to the comparative study of SSIs and the influence and impact of aspiration.

2.6.1 Economic Motivation

In the mainstream economic literature, the supremacy of economic motive is often taken for granted with the assumption that firms act in ways to maximise profits. However, in the context of privately owned SMEs, a more diverse view may be relevant. Setting aside the close association between growth and development, growth does not represent the only organisational development strategy, indicating that researchers might dispense with profit maximisation as a first approximation (Alchian, 1950). People start and operate firms for a variety of reasons other than maximising economic returns (Davidsson, 1989a; Delmar, 1996; Gundry & Welsch, 2001; Nelson, 1984; Storey, 1994). In terms of strategic orientation, not all owner-managers can be described as Schumpeterian or Kirznerian entrepreneurs. Most entrepreneurs articulate modest growth ambitions (Levie and Lichtenstein, 2009) however, little is known about why some identify and pursue more opportunities than others (Ucbasaran, Westhead, & Wright, 2008) . This runs somewhat counter to the idea that similar organisations experience comparable social expectations and are inclined to conform to the same strategies and structures.

New technology based firms are frequently founded by engineers with limited knowledge of markets, or experience in managing and growing businesses. Those founded with the objective of exploiting a technology proposition, rather than a recognised strategy or market opportunity, frequently regard the functions needed to drive commercialisation as secondary (Ganotakis & Love, 2011). Explicit enthusiasm for commercialisation in policy discussions is uncommon, a deficit which the SSI has the potential to address in an integrated, developmental fashion. This leads to the key question of how the system might support firm level strategy, embodying commercialisation and diffusion. It also presumes knowledge of and access to the human, capital, market and other resources needed to create deliver and capture value.

2.6.2 Strategic Planning and Small Firms

The aggregate economic and social impact of SMEs indicates that societal interest would be served by research that delivers an improved understanding of their strategies (Robinson & Pearce, 1984) and how that might inform system design. Bell et al. (2004), drawing on theories of strategy-making in SMEs, observe that strategic planning undertaken by CEOs is a key factor in firm expansion. As small firms mature, planning routines reflect a combination of the dynamics associated with start-ups and the need for bureaucracy and discipline (Storey, 1994). In accord with the view that strategic planning becomes more advanced over the business life cycle, Bell et al. (2004) note that, strategy formulation is a top-down process and that the absence of an explicit strategy should not necessarily be interpreted as a lack of strategic vision. By comparison with larger organisations characterised by

broader managerial participation in strategy making (Miller & Toulouse, 1986) , small organisations tend to have inexplicit, intuitively derived strategies that reside mainly in the mind of the CEO (Mintzberg, 1993; Oakey, 2012).

Reflecting the paucity of strategic planning among small firms, Robinson and Pearce (1984) document the gap on the basis of four themes; lack of time, lack of knowledge of the process, absence of specialist expertise and sensitivity about sharing business decisions with employees and outsiders. This underscores the difficulty in measuring the strategy construct whereby strategy-making is often reactive, ad-hoc or simply opportunistic, leading to calls for alternative approaches in the context of widely documented financial and human resource constraints which often arise due to formal planning deficits (Carson, Cromie, McGowan, & Hill, 1995; Welsh & White, 1981). For the purpose of this thesis, the strategic orientation construct developed by Autio et al. (2000) is employed as an indicator of strategic intent on the part of the firm.

2.6.3 Strategic Orientation

In the context of developing strategy constructs, Hambrick (1980) counsels researchers to view strategy as a predictor, mediator, or criterion variable arguing that strategy is too situational to be usefully measured and that attempts at measurement often lose sight of context and internal logic. Making a similar argument against researchers' attempts to build contingency models sophisticated enough to account for all possible variants of strategy, Bailey, Johnson, and Daniels (2000) propose following archetypes or configurations of strategy development.

Baum and Locke (2004) suggest that the aspirations of CEOs, regardless of whether they are entrepreneurs, span profitability, survival, career satisfaction and innovation. In a similar vein, Autio et al. (2000) articulate five strategic orientations with the underlying intent of maximising growth, profit, technology leadership, exit conditions or firm longevity. In regard to how this might translate to SME behaviour, Roper (1997) finds that UK and Irish firms adopt a balanced approach to innovation with increases in both productivity and employment while German strategies produce sharp increases in productivity with a concomitant reduction in employment. Thus, while differing aspirations do not preclude value creation, they may fall short of the economic and social outcomes sought by governments and policy makers, job-rich growth in particular.

2.6.4 Growth orientation

Originating in the work of Storey (1994) there is a growing body of empirical evidence to support the proposition that only a small proportion of firms create the majority of jobs in any cohort (Anyadike-Danes, Bonner, Hart, & Mason, 2009; Birch, 1987; Henrekson & Johansson, 2010; Stangler, 2010). Some small firms are 'mom and pop' type enterprises that are not designed to pursue a high growth strategy; others are `life-style ventures' with the primary objective of protecting autonomy (Berger and Udell, 1998, p. 627). In a UK survey of over 18,000 respondents' two-year growth objectives, Vos, Yeh, Carter, and Tagg (2007) found that less than one-tenth of SMEs opt for rapid growth. The majority reported an objective of moderate expansion (49.1%) or to remain the same size (24.7%) while fewer than 10% wanted to either sell (6.9%) or transfer (1.9%) their businesses.

Rapid growth was cited as the main objective by just 8.3% of the total sample (p.2655). Vos et al. (2007) also found that rapid growth aspirations decrease with time, while ambitions for closure, exit, succession or maintaining the status quo increase incrementally with age.

Pertinent to SSI design, Child and Kieser (1981) question whether social structures should be adjusted to fit strategy (strategic choice/adaptation) or whether they should be employed to constrain strategic activity (evolutionary/determinist view). This reflects the adaptive-adoptive character of the environment and warrants research into the potential for firms to achieve better fit through adaption while policy makers might analyse potential to harness growth potential among aspirant firms.

2.7 Summary

This review set out to achieve three broad objectives. The first was to document and organise the body of literature on innovation systems, including a specific focus on SSI. The second was to examine the related phenomena of firm age and industry life course and their potential impact on SSI-fit. The third was to identify the ways in which system-fit may be diluted or enhanced by firms' strategic intent.

It is argued that the role of endogenous change and managerial discretion has been overshadowed by equilibrium and static methods of analysis (Foss, 1997) and while much of the research on innovation and productivity has integrated industry and firm level perspectives (Pianta and Vaona, 2006), age- and strategy-contingent effects on SSI fit have not been examined heretofore. Among key drivers of

innovation in small firms are culture, leadership, process innovation and notably, strategic orientation (Laforet & Tann, 2006). While contexts present a variety of constraints and opportunities, the literature suggests that firm age and strategic aspiration are likely to exert influence on system-fit, as firm-specific factors are known to have greater impact than industry-related features (Hawawini, Subramanian, & Verdin, 2005).

Sectoral Systems of Innovation

SSIs address the need to explore innovation dynamics in leading economic sectors to analyse the interaction between firms and the institutional infrastructure and also to understand whether some industries are supported (Peters, 2005) while others may be subject to de-selection (von Tunzelmann and Acha 2004). The literature reveals a gap in regard to firm-level contingencies with significant impact on innovation output, insofar as the SSI may expose firms to unknown positive or detrimental effects.

Given that most countries concentrate activities in selected industries, a sectoral perspective facilitates more nuanced understanding of the interactive processes at work. It also offers potential for greater impact in respect of learning about the potential for adaptation and adoption. This responds to criticisms that SME research is not sufficiently sector or industry-specific, and that findings are too general to be instructive for managers and policy makers (Fagerberg, Mowery, & Verspagen, 2009; Laforet & Tann, 2006).

Age

The literature conceives of stages in organisational development spanning progression from the emergent firm to mature organisations marked by greater financial security, complex operations and potential to scale. The start-up usually has less capital, fewer scientists and engineers, less legitimacy, limited brand presence, fewer strategic alliances, evolving organisational structures, and incomplete or even non-existent processes. At a more abstract level, young firms suffer liabilities of newness and smallness, failing at higher rates than their larger and older competitors.

Analysis of the temporal aspects of firm existence represents a significant trend in social science as researchers seek to examine the effects and management implications of evolutionary processes within organisations and sectors. The literature reveals organisational age as an appropriate contingent variable given that its impact on innovation and firm behaviour is multifaceted and unresolved (Stuart and Sorenson, 2000). If youth signals vulnerability, twinned with dynamism, and aging suggests exploitation advantage coupled with underlying rigidity (Aldrich & Ruef, 2006; Barron et al., 1994; Leonard-Barton, 1992; McGahan & Silverman, 2001), questions arise as to how systems and firms can best respond to age in terms of preserving productivity in an institutional context. The assessment of corresponding system-fit is necessarily complex, given the micro-level, meso-level and institutional factors involved (Aldrich, 1999; Ucbasaran, Westhead, & Wright, 2001) as well as the interactions between them, each of which plays a decisive role in shaping technological innovation.

Strategic Intent

Strategic intent was selected as a secondary contingency based on exploratory research in relation to SSI fit. In the context of exploitation advantage, among the most robust outcomes of strategy research is that firm-level drivers have the greatest impact on explaining variations in performance including the finding that firms in the mid performance range demonstrate a lesser facility in navigating their environments than their more successful counterparts (Hawawini et al., 2005). Firms may not respond to environmental change either because they are unwilling or unable, or because they fail before delivering an adequate response (Baum, 1996). Given that innovation is shown to be a firm- rather than a country-level phenomenon (Covin and Slevin, 1991; Wessner, 2005), an in-depth understanding of how company strategy guides the initiation, resourcing and management of innovation is critical to the design and implementation of SSI policies.

The theoretical framework derived from the foregoing review forms the basis of the research questions outlined below.

Research Questions

For software and traditional engineering firms:

- Question 1: What are the positive and negative associations between firm age and sectoral system (SSI) dimensions?
- Question 2: What are the positive and negative associations between firms' strategic intent and sectoral system (SSI) dimensions?
- Question 3: What are the contrasting associations between age, strategic intent and dimension fit in the respective sectoral systems?

The propositions align with the overarching objectives of the research outlined in Chapter 4.

Chapter 3 describes the software and engineering sector systems in the context of the economy of the Republic of Ireland.

Chapter Three

Research Context

Irish Economy - Software Sector - Manufacturing Engineering Sector.

3 Research Context

This thesis analyses the dynamics of sectoral system of innovation (SSI) fit using Ireland (the Republic of Ireland), as the research setting. This chapter reviews the Irish economy as the context within which the research takes place. Initially, it examines the framework conditions for innovation in the broader economy including economic history and policy evolution. To support the objective of assessing SSI-fit, the chapter later focuses on the software and manufacturing engineering sectors encompassing sectoral characteristics, industry profiles and system dimensions.

Underpinning the SSI focus of this research, analysis of economic performance in small economies demonstrates that growth is positively related to the sectoral structure of the economy allied to the influence of location (Read, 2008). In the context of Ireland's dependence on international trade, firms are known to be more likely to export in sectors in which host countries offer comparative advantage (Bleaney and Wakelin, 2008).

The origins of Ireland's NIS were laid in the late 1950s with employment policy based on attracting multinational corporations through financial incentives and a parallel emphasis on achieving growth through export-oriented indigenous enterprise (Cunningham & Golden, 2014). This combination has brought about Ireland's so-called *dual economy* (Collins & Pontikakis, 2006; O'Riain, 2008) characterised by the uneven development of the country's productive system between indigenous enterprise and Foreign Direct Investment (FDI) (Ramirez, Love, & Vahter, 2013). FDI generates approximately 49 per cent of private sector output

(CSO, 2013b) and 72 percent of exports (Industrial Development Authority, 2013). OECD, EU and US government initiatives to reform the global tax regime render the FDI proposition fluid, reinforcing the need to examine the indigenous sector.

Population and Employment

The 4.59 million population of the Republic of Ireland is set to exceed 5 million by 2016 (CSO, 2013). Of the 1.85m people in employment at the end of 2012, 75.7 per cent were in full-time employment, 83.5 per cent were employees, 36 per cent were under the age of 35, 46.6 per cent were third level graduates and 85 per cent were Irish nationals (Forfás, 2013a). Emigration, a perennial economic safety valve, rose to almost ninety thousand in 2011 and 2012; however immigration was also significant, at over 50,000 in each of the two years (CSO, 2013).

A National Economic and Social Council (NESC) report (Mjøset, 1992) which set out to analyse Ireland's historically poor economic performance by comparison with other European economies, concluded that the country had a very weak system of innovation. Beyond assessing technical system dimensions and firms' capacity to initiate and manage change, the NESC study determined that the country's demography and emigration constituted twin engines of underdevelopment. Mjoset argued that reduced emigration would create sufficient pressure to challenge the country's economic inheritance rather than accepting its constraints. This argument has not been developed in the literature however emigration patterns have persisted in the intervening years.

3.1 Republic of Ireland - Economy

This section analyses the evolution of the Irish economy over the last century. It concludes with a chronology of policy documents that have been important in shaping thinking on Ireland's exports, the innovation system and labour market development. Ministries with core responsibility for driving innovation policy are the Department of Jobs, Enterprise and Innovation (DJEI) and the Department of Education and Skills. Oversight of research and innovation investment is led by the cabinet sub-committee on Economic Recovery and Jobs.

Exports as the sole driver of economic growth

Ireland's budgetary and debt crises rooted in the 2008 recession established exports as the only significant medium term driver of growth (Barry & Bergin, 2012; Forfás, 2014). The domestic economy was supressed though a combination of austerity measures and a high debt burden. While there was little evidence of permanent damage to Ireland's tradable sector as a result of the global recession (McHale, 2012), credit rationing coupled with the increased cost of capital had a dampening effect during the reference period.

Output drivers include growth within target export economies, especially the US and the EU, coupled with the competitiveness of the Irish economy vis-à-vis its peers (FitzGerald, 2012). 2011 brought a turnaround in productivity and exports, including rising levels of FDI however the need to diversify the export base was underlined as Ireland's global market share remained at pre-recession levels (Forfás, 2014).

Historical perspective

While firms depend heavily on current resources and investments, economic history exerts an inevitable influence (Pavitt, 1990; Rowen, 2007) as current output is rooted in the fabric of industry legacy (Carlsson, 1995). Development and structural change in western economies is generally characterised by a transition from agriculture accounting for the bulk of GDP and employment, to industrialisation through the growth of the manufacturing sector to the more recent dominance of the service sector. Ireland is seen to have vaulted to a post-modern high-tech economy without experiencing the intervening phase of industrialisation (Donovan & Murphy, 2013), possibly raising questions about the robustness of its structural foundations.

Ireland is not renowned for its 'entrepreneurial expertise and risk-taking ethos' with business failure readily criticised and success often regarded with antipathy (Heavin, Fitzgerald, & Trauth, 2003, p.245). One policy report found that the organisational and management capability of Irish firms was insufficient to deliver success in the absence of hands-on industrial policy (Telesis, 1992). The near absence of a managerial class prior to the 1970s may have some bearing on this (Begley et al., 2005). By contrast, Cunningham and Golden (2010) perceive strong cultural drivers supporting the evolution of the NIS including increasing levels of entrepreneurship and positive interaction between policy-makers, private industry and the third level sector . This view points to contention in the assessment of the country's structural supports for economic growth. Economic output data will qualify this perspective in the medium to long term.

Globalisation

Ireland is recognised as one of the most globalised economies in the world with more than half of its manufacturing and financial sectors in foreign ownership and export values in excess of Gross National Product (Honohan & Walsh, 2002). As a small open, trade-dependent economy growth is, as already referenced, highly dependent on external markets. Output of internationally traded goods and services in 2012 was equivalent to 191 per cent of GDP, totalling €164 billion (Duffy & Timoney, 2013).

As one of the world's largest beneficiaries of FDI, the profile of subsidiary employment has transitioned from low-skilled, low-cost manufacturing and assembly in the 1970s, to higher skilled localisation, advanced manufacturing and services in the twenty first century. By way of illustration, 2013 saw the celebrated launch of Intel's first Irish-designed chip in the twenty four year history of the subsidiary. Heretofore, the FDI base has largely been focussed on process-related innovation. The sustainability of FDI is generally attributed (e.g. Buckley & Ruane, 2006; Devereux, Lockwood & Redoano, 2008) to a combination of factors: corporation tax (12.5% since 2003) with effective rates reportedly as low as 2.5 per cent, financial inducements (e.g. capital grants – though these have been subject to constraint by the EU), the European market gateway, stable macro-economic policies and the flexible, educated, English-speaking workforce.

Despite FDI having sustained Ireland's economic wellbeing since the 1990s, persistent questions about the viability of an economic model that is so heavily dependent on the foreign-owned sector (Andreosso-O'Callaghan & Lenihan, 2011;

Lenihan, Hynes, & Hart, 2010) have led to a stated shift in policy emphasis to internal entrepreneurship, with indigenous export cited as the engine of future economic growth (DJEI, 2011). In this context, the indigenous software and manufacturing sectors are perceived as central to building scale in value-added exports (Forfás, 2012b).

Boom and Recession

Unlike Ireland's FDI export-led economic surge in the 1990s (Celtic Tiger era) with average growth rates of 9.2 per cent (Begley et al., 2005), growth from 2002 to 2007 was driven by construction and domestic consumption fuelled by a supply of credit based largely on foreign capital. Characterised as a period of speculation rather than enterprise, the traded sector was crowded out by construction and growth in the public service sector (Barry and Bergin, 2012). The 2007 slowdown that foreshadowed the global financial crisis of 2008 exposed vulnerabilities in the economy and its institutions, notably the failure of banking regulation and inappropriate fiscal policies (Kennelly, Thornton, Aronson, & Munley, 2012).

Irish GDP and GNP grew by 5.7 per cent and 5.0 per cent respectively between 2000 and 2007 however the combined collapse of the construction and banking sectors and the onset of the financial crisis saw GDP and GNP declining by 5.4 and 10.1 per cent through 2011 (ESRI, 2013). Unemployment climbed from 4.8 to 14.8 per cent between 2008 and 2010 and personal consumption contracted by 21.4 per cent between 2007 and 2011 (Lawless, McCann, & McIndoe-Calder, 2012).

Indigenous firm landscape

In 2011, micro, small and medium enterprises accounted for 99.8 per cent of all companies in Ireland, 68.6 per cent of private sector employment, 51 per cent of turnover and 46 percent of Gross Value Added (GVA) representing almost seven in ten jobs with just over nine in ten firms employing less than ten people (CSO, 2013). In the European Union, SMEs account for over 98 per cent of all enterprises, 67 per cent of employment and 58 per cent of GVA (Ecorys, 2012).

Indigenous exports contribute approximately 15 per cent of the nation's total output year-on-year with SMEs delivering approximately 7 per cent of that volume (Lawless et al., 2012). Coupled with significant differences in productivity (some tax-driven), foreign-owned firms are more export intensive. The statistics point to productivity challenges suggesting the need for improved understanding of how SSI can better support indigenous SME potential.

Large scale enterprises account for 0.2 per cent of active businesses, employing 31.4 per cent of the workforce (CSO, 2013) and are mainly in foreign-ownership. Irish-owned multinationals employed approximately 246,000 people in overseas affiliates in 2011 generating €73bn turnover however according to the report of the Forum on Small Business (Forfás, 2006b), indigenous companies tend to start small and stay small for an array of reasons :

> *Difficulty in accessing finance, weak management capability, lack of innovation, both technological and non-technological, under exploitation of Information and Communications Technology, burdensome and costly administrative regulations, rising local charges, poor access to information*

and advice, inadequate infrastructure and the lack of a systematic approach to entrepreneurship for start-ups (p.x).

Expectations of international scaling, through *born globals* or adapted versions of locally developed offerings have not borne fruit. The employment intensity of Irish SMEs coupled with their reliance on internal demand (64 per cent of all employees work in indigenous, non-exporting firms) and domestically provided credit renders them extremely vulnerable to the fate of the domestic economy (Lawless et al., 2012). Further, policy tends to prioritise job-rich growth – driving labour intensity.

FDI Landscape

Ireland hosts a significant number of companies such as Apple, DePuy, Ericsson, Glaxo Smith Kline, Google, IBM, PayPal and Pfizer. IDA Ireland lists a total of 1,033 overseas companies, employing 152,785 people, generating €122 billion in exports. The sector created over 12,722 new jobs in 2012 while inward investor job losses were the lowest for a decade (Industrial Development Authority, 2013). Other attributes aside, retention of the 12.5 per cent corporation tax rate is central to maintaining attractiveness as an FDI hub (Godart, Görg, & Hanley, 2012).

FDI Spill-over and Embeddedness

In parallel with export volume, FDI is seen as a potentially important contributor to technology transfer and absorption while enhancing human capital (Read, 2008). Despite some evidence of industry spill over e.g. in the medical device and engineering sectors (Giblin & Ryan, 2012; IEEF, 2014) there is scant indication of significant spill over in the software sector. This is consistent with multinationals generally sourcing fewer inputs in the host country than domestic firms; the

foreign-owned sector is not strongly embedded in the innovation system (Godart et al., 2012, Love, Roper & Du, 2009; Wrynn, 1997). US-owned subsidiaries appear to depend heavily on innovative capacity developed at home and collaborative relations with Irish firms tend to be formed on the basis of outsourcing rather than local collaborative networks (Kirby, 2008). In a study of innovation, ownership and profitability among Irish and foreign-owned plants in Ireland and Northern Ireland, Love, Roper & Du (2009) concluded that while 'innovation is a competitive weapon for indigenous plants, it is simply a fact of life for externally-owned plants'(p.16). They further observed that externally owned plants in the Republic of Ireland do not draw strongly on the Irish Innovation System.

Having provided an overview of the current landscape for innovation and entrepreneurship among indigenous and foreign-owned firms, to follow is an outline of how industrial policy and development has evolved since the 1950s.

3.2 Industrial Policy

Programme for Economic Expansion

Ireland's Economic Development Plan (1958), the country's first programme for economic expansion and industrialisation, spurred a policy based on export oriented industrial growth (Smith, 2005). The Industrial Development act signalled the intent to engage foreign participation in the economy including rejection of previous protectionist mechanisms embodied in the Control of Manufactures Acts, 1932 to 1934 (Donnelly, 2012). It was anticipated that domestic firms, protected by high tariff barriers, would prosper in export markets however the policy had a much greater impact in attracting the establishment of foreign enterprise export bases

(Kirby, 2008). The transition from inward looking protectionism to external openness is commonly described as *industrialisation by invitation*. By 1973, FDI accounted for almost one-third of all manufacturing jobs and by 1983 some 1,000 overseas firms were established in the state (Kirby, 2009). Consistent policies in the interim have resulted in Ireland becoming the most FDI-intensive economy in the EU (OECD, 2013).

Telesis Report

With the near collapse of the Irish economy in the early 1980s, the Telesis Consultancy Group was contracted to conduct a study of industrial development policy. Published in 1982, the study was critical of over-reliance on foreign-owned firms, suggesting that economic growth should have a *double engine* in the form of strategic FDI industries and Irish owned companies (O'Riain, 2004). The report proposed the selection of *national industry champions*; however Telesis failed to offer any specific guidance on selection (Breznitz, 2007).

Culliton Report

Telesis was succeeded by the Industrial Policy Review Group's Culliton Report (1992) *'A Time for Change'* which suggested that the state should work to mitigate financial market failure by supporting companies in sectors deemed too risky by conservative financial institutions (Breznitz, 2007). Culliton also called for a transition from attracting FDI to the promotion of export oriented indigenous enterprise through the systematic improvement of social structures and public utilities coupled with tax reforms to promote employment. The report highlighted software as a potentially fertile sector.

Enterprise Strategy Group Report

Culliton was succeeded by the Enterprise Strategy Group (ESG) report '*Ahead of the Curve*' (Forfás, 2004), commissioned to chart economic development for the ensuing decade. The report recorded Culliton's 'influence on policy in a range of areas including increased investment in infrastructure and human capital under the national development plans 1994-1999 and 2000-2006' (p.5). It further outlined sources of competitive advantage along with supporting conditions as articulated in Figure 3-1. It underlined the need to balance calls for greater R&D commitment with emphasis on market understanding and expertise in customer engagement.

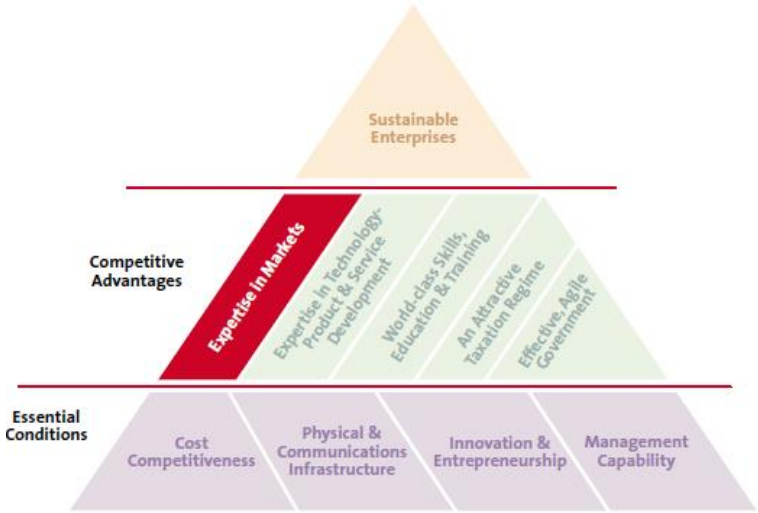

Figure 3-1: Conditions for competitive advantage (ESG, 2004, p.59)

ESG (2004) reflected critically on the Celtic Tiger economy (mid 1990s to mid-2000s) suggesting that it was built on shallow, externally driven foundations.

> *Ireland's principal enterprise strengths have been in the operational aspects of manufacturing and services, rather than in markets and product development. This is particularly true of the foreign-owned sector, which*

> *accounts for most of our exports and which, for the most part, produces goods that were designed elsewhere, to satisfy market requirements that were specified elsewhere, and sold by other people to customers with whom the Irish operation has little contact and over whom it has little influence (p.XII).*

Originally designed to serve as a strategy blueprint for enterprise growth and employment, the report, despite its apparent accessibility to enterprise, government and the education sector, has seen limited implementation.

Strategy for Science, Technology and Innovation

The Strategy for Science, Technology and Innovation (SSTI, 2006) 2006-2013, had the objective of enhancing Ireland's position as a *knowledge-based-economy* and bringing R&D performance into line with leading economies through continuation of the Programme for Research in Third Level Institutions and Science Foundation Ireland. SSTI (2006) set forth the vision that:

> *Ireland by 2013 will be institutionally renowned for the excellence of its research, and will be to the forefront in generating and using new knowledge for economic and social progress, within an innovation-driven culture (SSTI, 2006, p.8).*

While evidence of achievement is mixed, the strategy is seen as the first wide-ranging attempt to develop science, technology and innovation through a whole-of-government approach encompassing; The Interdepartmental Committee on Science, Technology and Innovation, The advisory council for Science, Technology and Innovation, Forfás (the policy advisory board for Enterprise, Trade, Science and Innovation), Science Foundation Ireland and the Office of the Chief Science Advisor (subsequently abolished).

The ensuing National Skills Strategy (2007), produced by the Expert Group on Future Skills Needs, set out a number of objectives aimed at building a competitive, innovation-driven, knowledge-based economy, including: Up-skilling 500,000 people in employment, increasing the participation rate in upper secondary education to 90 percent; and increasing the progression rate to third level from 55 to 70 percent. In recognition of systemic gaps in applied skills development, the government has since announced efforts to review apprenticeship policy.

The Innovation Taskforce

SSTI (2006) was succeeded by the Innovation Taskforce Report (ITF) (2010) titled *Building Ireland's Smart Economy* with an overarching and ambitious aim that:

> *By 2020 Ireland will have a significant number of large, world leading, innovation-intensive companies, each having a global footprint, many of which are Irish headquartered and owned (p.3).*

The Taskforce proposed a framework spanning an ecosystem with five pillars aimed at enhancing productivity and promoting sustainable economic growth for entrepreneurs and enterprises (indigenous and foreign-owned) by leveraging innovation in its broadest sense as outlined in figure 3-2.

Figure 3-2: Main elements of the National Innovation System (ITF, 2010, p.21)

Critics suggest that the report placed too much emphasis on university-led innovation through a focus on STI and spin-outs. With a new government taking office in the year subsequent to its publication, there is limited likelihood that the Taskforce report will be adopted.

Development and Policy landscape

Reflecting on the overall role of government, Breznitz (2007) contrasts 'neoliberal interventionism' in Ireland with variants of market liberalism in countries such as Israel and Taiwan, suggesting that Irish economic and industrial policy has been based on two conflicting principles since 1958 - on the one hand, a strong free market ideology and on the other a major role for government in enhancing competitiveness and managing growth.

Many of the development reports and policy documents outlined have strong merit and the nation's capacity and infrastructure to deliver innovation-led growth have been advanced as a result. Pointedly, the imbalance between indigenous and foreign-owned export output highlighted in a number of policy documents has not been redressed. In 2012, 90 per cent of total industrial export sales were attributable to foreign-owned firms, the figure in 2003 was 91 per cent (Forfás, ABSEI, 2014) so the balance has not changed in the last decade. This reinforces the need to gain greater insight into the enablers and constraints affecting indigenous firms' ability to contribute to the export-led economy.

3.3 Institutional Structure

The Department of Jobs, Enterprise and Innovation (DJEI) directs government efforts in relation to enterprise, employment protection, science, technology and

innovation policy through IDA Ireland, Enterprise Ireland, Forfás (absorbed by DJEI in 2013) and Science Foundation Ireland. Cunningham and Golden (2010, p.433) perceive the 'responsiveness of policy initiatives through Forfás and its ability to organise specialised taskforces combining social and economic institutions' as a strong driver supporting the evolution of the NIS. The Department of Education and Skills oversees the Higher Education Authority and the research council. Figure 3-3 summarises the institutions involved in the public, enterprise and higher education sectors and the linkages between them.

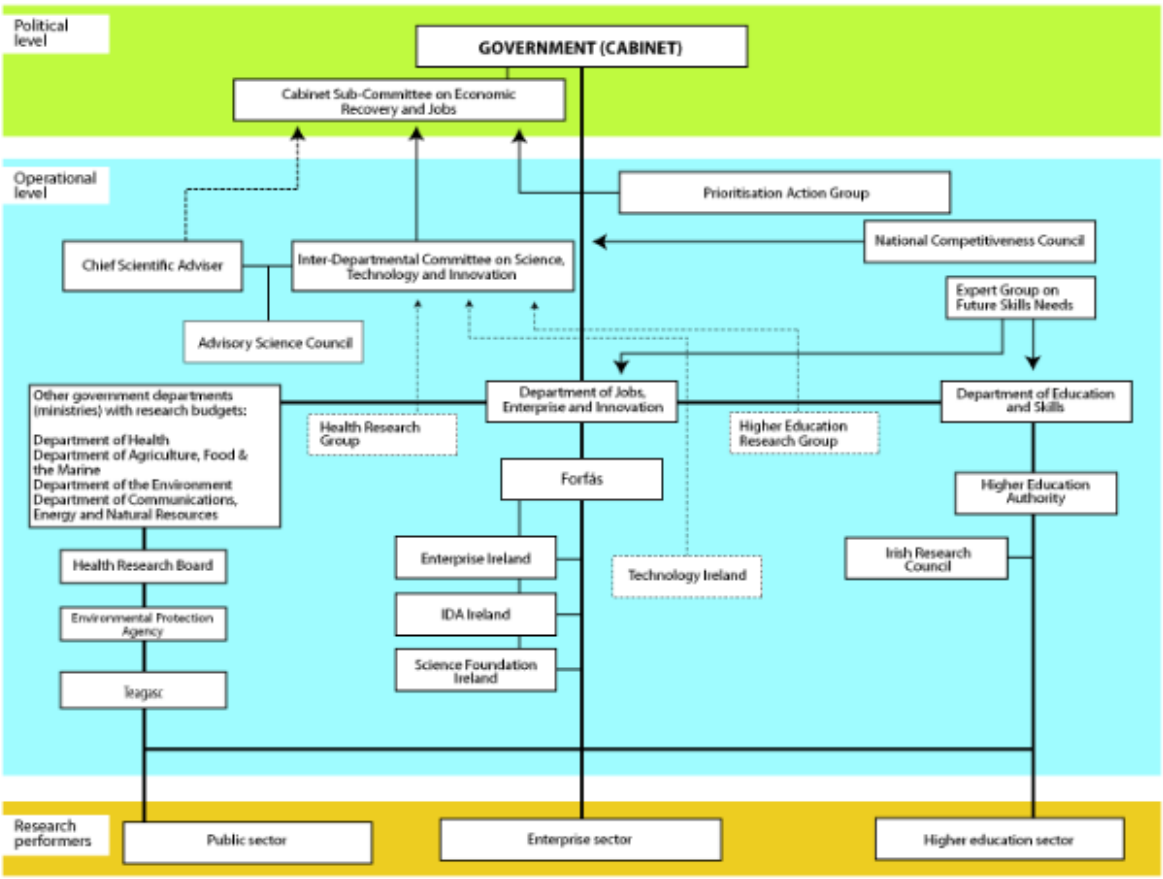

Figure 3-3: Irish Innovation and Research Sector Structure (Erawatch, 2013)

The remit, function, budget and key outputs of core entities in the system are outlined in table 3-2 overleaf.

Public Institutions

In addition to the central roles played by the IDA and EI in the system, support is provided by Local Enterprise development Offices, SFI, Forfás and Solas with a national training and development remit. Under the direction of the Higher Education Authority (HEA) the third level sector comprises 7 universities and 13 institutes of technology along with a number of teacher training colleges.

Agency	**Remit**	**Core Objectives**
Enterprise Ireland [EI]	EI provides direct supports to Irish and overseas SMEs at all stages of development to foster job creation and export growth.	- Exploring new opportunities - including feasibility studies and trade missions - Capability Building - including management development, R&D grants and lean programmes - High Potential Start Ups - Seed and Venture Capital Programmes, and - Research collaboration and commercialisation
Funding/ Impact	In 2010, client companies created 8,193 new jobs, bringing the total number employed to 137,241. The DJEI budget allocation was €307m, supplemented by €37m from the Department of Agriculture, Fisheries and Food and the National Training Fund. In 2012, client companies generated €16.2bn exports up from 15.2bn in 2011(Enterprise Ireland, 2013).	
Industrial Development Authority- IDA Ireland	The IDA aims to attract high quality FDI projects while embedding existing companies in the economy, generating as many new jobs as possible while maintaining the existing stock. The agency provides grants to client companies to support capital investment, R&D, training and employment.	- Improve company-wide competitiveness - Enhance the use of new technologies - Grow the skills of the business - Engage in R&D and innovation - Develop new business processes - Make company operations more energy efficient.
Funding/ Impact	The IDA supports 1,033 client companies with approximately 153,000 employees who created 6,570 jobs and generated €122bn exports equating to 72 per cent of the total output for 2012 (IDA Ireland, 2013). The 2011 budget was €93M.	
Shannon Development	Supports foreign and indigenous firms in the Shannon Free Zone.	- Similar to IDA and EI offering.
Funding/ impact	Companies supported by Shannon Development created 362 new jobs in 2010. The agency's budget for 2011 was €3.6 million.	
County and City Enterprise Boards	35 boards deliver supports to micro-enterprises. Replaced by Local Enterprise Development Offices (LEO) in 2014	- Assist existing micro-enterprises in survival and growth initiatives - Assist new start-ups - Focus on the stimulation of entrepreneurship locally.

Funding/ impact	Provision of grants for start-up, business expansion and feasibility testing. Provision of Mentoring and Start-Up Programmes, General Business Training and Management Development. The DJEI budget allocation in 2011 was €27.24m. 4,433 new jobs were created in supported companies in 2010. There were 32,910 people employed full time in supported companies in 2010, with 11,462 in a part time capacity.	
Science Foundation Ireland(SFI)	Founded in 2000 to encourage research in science and engineering. Invests in academic researchers and research teams most likely to generate new knowledge, leading edge technologies and competitive enterprises. Its remit expanded in 2013 to include applied research as well as oriented basic research.	Underpins the activities of Enterprise Ireland and the IDA in three areas: - Biotechnology - Information & Communications Technology (ICT) - Sustainable Energy & Energy Efficient Technologies (Energy).
Funding/ impact	The 2011 budget allocation was €161m. In 2013, more than 45% of IDA job announcements were in companies with links to SFI research teams. Five new Research centres of major scale, involve Government investment of over €150 million with an industry contribution of over 30%.	
IRC Irish Research Council	The IRC mission is to enable and sustain a vibrant and creative research community in Ireland. Launched in 2012, the council represents a merger between the Irish Research Council for the Humanities and Social Sciences (IRCHSS) and the Research Council for Science, Engineering and Technology (IRCSET).	- Focus on human capital development from postgraduate, early postdoctoral and senior researcher project based awards - Encourages exploratory research in the sciences, engineering, technology, humanities, social sciences, business and law.
	The research budget for 2011 was €33M.	
Forfás	Policy and Advisory Board for enterprise, trade, science, technology and innovation – established 1994. Provides research, advice and support in the areas of enterprise and science policy. Supports DJEI and wider Government. Works with IDA Ireland, Enterprise Ireland and Science Foundation Ireland to ensure the coherence of policies across the development agencies. Absorbed into DJEI as of 2013.	Manages the work of: - Advisory Council for Science, Technology and Innovation - Expert Group on Future Skills Needs - National Competitiveness Council - National awareness programme, Discover Science and Engineering - Accreditation services of the Irish National Accreditation Board and - Hosts the Office of the Chief Scientific Adviser to Government.
An Foras Áiseanna Saothair (FÁS)	Labour market agency responsible for promoting job opportunities, training and labour market programmes for school leavers, post graduates and professionals	As of October 2013 SOLAS is the Irish Further Education and Training Authority with responsibility for funding, planning and co-ordinating training and further education programmes.
Higher	The HEA, reporting to the Minister	- Funding body for the Universities,

Education Authority (HEA)	for Education and Skills, is accountable for the planning and policy development of higher education and research.	Institutes of Technology and other institutions designated under the HEA Act. - Administers Program for Research at Third Level Institutions (PRTLI) (€866M 99-2010), 7th Framework Programme (FP7) and Horizon 2020

Table 3-1: Overview of Enterprise Support Agencies

Having described the policy and public institutional landscape for innovation, to follow is an overview of Ireland's innovation performance followed by an analysis of the Software and Manufacturing Engineering industries reflecting both industry characteristics and the Irish SSI context.

3.4 Innovation Performance in Ireland

By international standards, Ireland boasts high levels of innovation despite a history of relatively low levels of R&D expenditure (O'Malley, Hewitt-Dundas & Roper, 2008) however there are reservations about the degree to which this reflects both parties to the dual economy. FDI is seen to skew the rankings as Irish output represents just one step in an international value chain including tax related intercompany accounting (Begley, Delany, & O'Gorman, 2005) while Irish indigenous enterprise is generally characterised by low productivity (OECD, 2013).

Describing R&D in Irish SMEs as flexible, responsive and informal - consistent with the tendency to root innovation in more predictable near-market opportunities, Roper (1997) contrasts this with the more formal R&D-driven planned technology innovation in Germany. Similarly, Irish firms are described as having a creative attitude to software development in contrast to other nationalities that tend to adopt a more mathematical approach (Heavin et al., 2003). Even though the FDI

sector engages in fewer innovations than indigenously owned firms, these are typically more successful; due potentially to higher quality output and superior commercialisation practices (Love and Roper, 2001). Edquist and Hommen (2008) assert a link between countries specialising in high-tech, R&D intensive sectors and the achievement of high economic growth rates, including Ireland in that class by dint of its foreign-owned firm stock. Results from the 2010 - 2012 Community Innovation Survey (CSO, 2014) indicate that Irish owned enterprises (79% of all enterprises in the survey), spent €1.36bn on innovation related activities in 2012, while foreign owned enterprises (21% of those surveyed), spent €2.3bn, just over two-thirds of all innovation-related expenditure. The €3.6bn investment level in 2012 represents an increase of almost 7% on R&D spend registered in 2010.

The Innovation Union Scoreboard (EU, 2014) (Figure 3-0), ranks Ireland as a follower with performance close to the EU27 average but lagging behind leaders such as Sweden, Denmark, Germany and the UK. Ireland is highly ranked in international scientific co-publications, license and patent revenues from abroad, engagement in tertiary education and knowledge-intensive services employment and exports. In regard to the human resources dimension of the SI, Ireland closely follows top performing Finland and Sweden while the 'economic effects' dimension ranks the country as the top performer (EU, 2014), this ranking is likely to reflect the 'dual economy' effect discussed earlier.

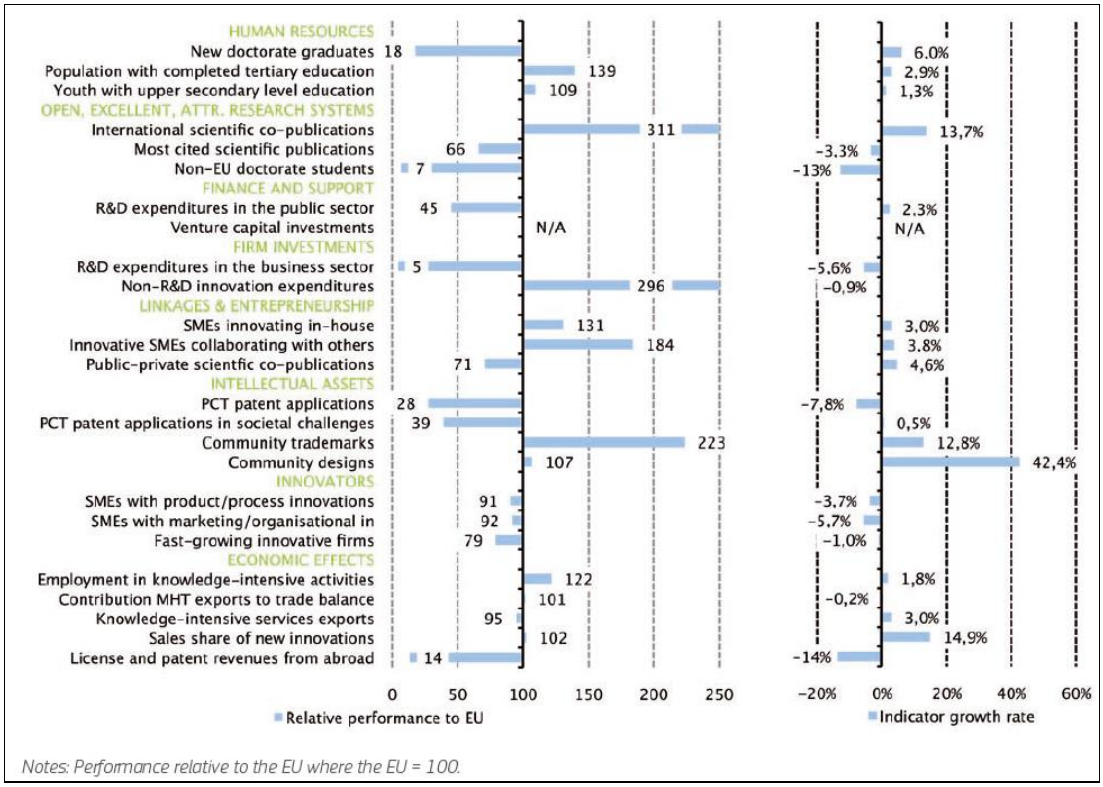

Figure 3-0: Innovation Union Scoreboard (EU, 2014, p.49)

In terms of scope for improvement, the scoreboard (EU, 2014) notes relative weaknesses in Community designs and Non-R&D innovation expenditure. Performance is also below average in SME product/process innovations, marketing/organisational innovations and innovative SMEs collaborating with others category. The OECD Economic Survey of Ireland (2013) observes that the innovation capacity of SMEs could be boosted by improved linkages between firms and higher education. In respect of the workforce, the report advocates reducing mismatches between supply and demand for skills and better alignment of education and training schemes to meet the needs of expanding sectors. The Economic Survey (OECD, 2013) further indicates that the innovation supports offered by state agencies are potentially too complicated for firms to access.

Figure 3-1 below indicates that Ireland's innovation performance relative to the EU has been in decline since 2006, although levels have trended upward since 2010. The contrasting performance of aspects of Ireland's SI dimensions noted here, in combination with the mixed outcomes of Ireland's innovation policy to date, have played a significant role in motivating this thesis.

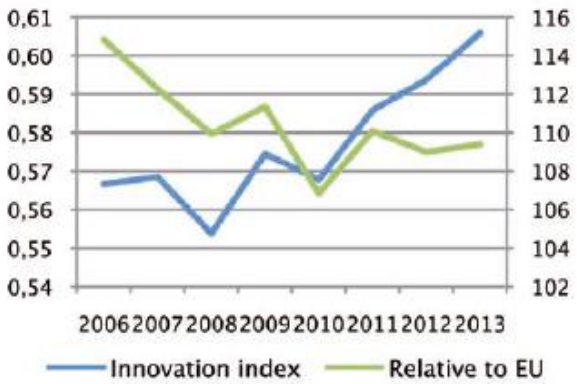

Figure 3-1: Innovation Union Scoreboard (EU, 2015, p.49)

Expenditure on R&D

Appreciation for the role of R&D in economic development is relatively recent in the case of Ireland (Kirby, 2009; Ramirez et al., 2013). National Development Plan (NDP) funding has devoted increasing levels of support to STI – NDP (1994-1999) €0.5 billion, NDP (2000-2006) (Department of Finance, 2000) €2.5 billion and NDP (2007-2013) (Department of Finance, 2007) €8.2 billion. A 1998 survey of industry, academic and government leaders pinpointed biotechnology and Information Communication Technology (ICT) as global engines of industry concluding that 'world class research capability in selected niches of these two enabling technologies is an essential foundation for future growth' (ICSTI, 1999, p.7). In response, the Government initiated the Technology Foresight Fund with a budget of €646 million and established Science Foundation Ireland to administer it (SFI,

2013). Sustainable and energy efficient technologies, including nanotechnology have since been added as priority areas.

R&D spending as a percentage of GNP, increased from 0.93 per cent in 2003 to 1.46 per cent in 2011 and 1.47 per cent in 2012 (Forfás, 2013). Table 3-1 presents a summary of aggregate BERD in 2011/12.

BERD 2011 2012 est.	Firms across all business sectors spent €1.86 billion on in-house R&D activities in 2011, a 1.3 per cent increase over 2010. Enterprises active in R&D in 2011 estimated R&D spend of 1.96 billion in 2012 (+ 5.5%).
Business R&D intensity	BERD as a percentage of GDP reached 1.17% in 2011 (1.46% of GNP) against an average EU of 1.26% of Gross Domestic Product (GDP). This compares to Finland with the highest BERD intensity at 2.67% of GDP.
FDI leads	FDI accounted for 71% of total business R&D spend in 2011.
Current and Capital expenditure	The majority of BERD (86 per cent) in 2011 was current expenditure (wages of R&D staff etc.) with the remainder on capital (buildings, equipment, licence payments etc.)
Service sector	In 2011, 61 per cent of BERD was generated in the service sector.
Medium/large firms lead	Medium and large enterprises (> 50 employees) accounted for almost three quarters of BERD in 2011.
Self-funding predominates	89% of BERD funding was from company funds in 2011, down from 92 per cent in 2009.

Table 3-2: Aggregate R&D data adapted from BERD 2011/12 (Forfas, 2013, p.3)

Highlighting the importance of understanding the fabric of the NIS, foreign owned enterprises account for €1.3bn of the total R&D spend or 71% of BERD which appears out of proportion in light of FDI turnover at 55 per cent of industrial output and business sector employment at 22 per cent (CSO, 2011).

Government Expenditure on R&D

Government expenditure on R&D (GERD) across all sectors of the economy reached a historical high of €3.8 billion in 2013, equating to 2.4 percent of GNP[2], about half of which is targeted at 14 priority areas identified as offering high potential returns

[2] Irish GDP is inflated by the inclusion of profits of inter-firm activities of multinational firms; GNP excludes these profits giving a truer measure of economic activity.

(Research Prioritisation Steering Group, 2012). Among the priority areas relevant to the current research are: Future networks and communications; data analytics management and security; digital platforms, content and applications and manufacturing competitiveness.

Higher Education Expenditure on R&D

Higher Education sector Expenditure on R&D (HERD) was estimated at €829 million in 2009, the intensity ratio, as a proportion of GNP, was 0.63 per cent which exceeded the OECD average (0.4 per cent) and the EU 27 average (0.46 per cent). Business expenditure on R&D (BERD) is low by international standards.

The foregoing analysis addressed the framing conditions for Ireland's NIS. The section to follow focuses on the sectoral systems of innovation supporting the software and engineering and engineering industries.

3.5 Sectoral Context

The sectors selected for this research are identified as growth industries in national policy documents (E.g. Enterprise Strategy Group, 2004; Forfás-ICSTI, 1999; Forfás, 2006a, 2008, 2013a, 2013b). A report on the Changing Nature of Manufacturing and Services in Ireland (Forfás, 2006a) observes significant structural change in the selected sectors. The software sector has been cited as a pillar of growth since the nomination of ICT in the government's 1998 technology foresight exercise (Forfás-ICSTI, 1999). Growth in software technology and services is mirrored across developed and catch-up economies. The Innovation Taskforce (Forfás, 2010) envisaged Ireland as a European Innovation Hub encompassing SMEs in services and manufacturing across the domestic and internationally traded sectors.

Cross-sectoral approach

While analysis of single sectors allows for control of industry effects, such a perspective risks lacking balance - as *knowledge-intensive* and *traditional* firms are known to respond differently to opportunity (Bell, Crick & Young, 2004). Additionally, Robertson, Smith, and von Tunzelmann (2009) argue that the roles of the high tech and low-to-medium tech (LMT) sectors should not be analysed in isolation arguing it is their very interaction that drives growth and development.

Liagouras (2010) cites a high-technology preoccupation at EU level, suggesting this undervalues the importance of business organisation and broader level economic structures. In the context of widespread expectations for the potential of the high technology sector, it is estimated that approximately 6.2% of workers in Ireland are engaged in high-tech employment (European Commission, 2009). While manufacturing firms are automating processes through adoption of advanced technologies, some software offerings may be considered low-tech based on low-level functionality or minimal engagement in R&D. Perhaps more importantly, increasing focus on high technology sectors risks isolating the bulk of fast growth firms (Acs & Mueller, 2008) which populate almost every sector, irrespective of industry performance (Parker et al., 2010). High-growth firms are neither unique to nor concentrated in the high tech sector, one UK study showed that all major sectors contained between 4 and 10 percent of high growth firms (Anyadike-Danes et al., 2009). Further, the suggestion that only 7 per cent of high-growth firms in the UK are classified as high-tech (Bishop, Mason, & Robinson, 2009) supports the selection of manufacturing engineering and software in parallel. The dual approach

allows assessment of age and strategic contingency against similar and contrasting dimensions of the respective SSIs.

Given that the interaction between NSI and SSI constitutes an independent source of variability, this analysis encompassed national development strategy, human capital, R&D expenditure, production and human capital development. To follow is an analysis of the engineering and software SSIs. Since sectoral systems transcend and sit within national borders at the same time, the sectoral perspective briefly addresses global and macro perspectives.

3.6 Sector Overview

3.6.1 Manufacturing Engineering Sector

The complexity that characterises business globally is reflected in the manufacturing engineering[3] sector spanning intensified competition, technology adoption, product diversification, productivity improvement and related skills. The LMT sector, measured by capital investment and employment, dominates the economies of developed nations providing more than 90 per cent of output in the EU (Robertson et al., 2009). In the early twentieth century, mechanical engineering SMEs were at the forefront of small scale industrialisation.

Relevant NACE codes for the engineering sector comprise: [25] Fabricated metal products, except machinery and equipment, [28] Machinery and equipment, [29]

[3] The terms engineering industries and metalworking industries are used interchangeably (Carlsson, 1989)

Motor vehicles, trailers and semi-trailers, [30] other transport equipment, [33] Repair and installation of machinery and equipment).

Only 3 per cent of Irish SMEs are active in manufacturing compared to an EU average of 10% (European Commission, 2012) however Carlsson (1989) advises caution in interpreting the decline of manufacturing and the related growth in services suggesting that outsourced manufacturers often *show up* as services establishments rather than manufacturing entities. While average firm size has been in decline since the 1970s, firm numbers have grown due to 'flexible specialisation' as manufacturing is divested or outsourced to smaller suppliers (Carlsson, 1989, p.27).

It is estimated that SMEs contribute between 25 and 35 per cent of world manufactured direct exports concentrated around relatively few larger SMEs, however the bulk of export growth is generated by smaller firms (OECD, 1997).

Innovativeness

The manufacturing engineering sector spanning mechanical technologies with R&D expenditure at less than five per cent of revenue are generally classed as being engaged in evolutionary rather than revolutionary technology (Eisenhardt & Schoonhoven, 1990). Research-driven innovation in the mechanical engineering sector is secondary to customer-supplier relationships in generating innovation – which is predominantly incremental (Wengel and Shapira, 2004). However many firms that are traditionally considered 'low tech' are in fact highly innovative (Leiponen & Drejer, 2007). This is echoed by an Irish Government report citing a negative perception of contemporary manufacturing which is increasingly complex

and cutting-edge (Forfás, 2013a). In their seminal work on technical innovation and national systems, Nelson and Rosenberg (1993) note that the effectiveness of a nation's schooling and training systems not only determine the supply of skills but also influence attitudes towards technical advance. The increasing use of science and informatics and the formalisation of R&D pose a challenge to traditional learning processes in the sector which are predominantly in-house and tacit in nature (Wengel and Shapira, 2004). Furthermore, manufacturing engineering firms make a significant contribution to their own process technology in contrast with low tech firms who rely largely on upstream suppliers (Pavitt, 1984; Terziovski, 2010).

Firm Age-Ownership

The indigenous engineering sector is characterised by family firms where links between ownership and management are strong and intergenerational involvement appear significant. Family ownership facilitates lengthy tenure (field data indicates periods of up to fifty years) creating 'parsimonious stewards' (Breton-Miller & Miller, 2011, p.1173) who seek to avoid short term actions that jeopardise viability. Among the research population, succession, progression and strategic challenges are met by an array of responses, some driven internally, others supported by state agencies.

Output, export and employment profile

The Irish engineering sector has an aggregate turnover of over €14.2 billion, equating to 9.5 per cent of manufacturing output, it employs approximately 53,000 people and represents 22.4 per cent of manufacturing employment (IEEF, 2011).

The sector has suffered shortfalls in qualified labour leading to concerns of inhibited growth (Wengel & Shapira, 2004), this is proving problematic in a number of markets including Germany and the United Kingdom.

The indigenous sector comprises approximately 600 companies employing 16,000 people operating across domestic and export markets. Indigenous firms generate sales of €2.7 billion with exports of €802 million (Enterprise Ireland, 2010). Export levels, potentially masked by domestic sub-supply, have been slated for policy support. As noted earlier, the engineering sector is significantly embedded in the Irish economy as foreign owned and indigenous firms source a large proportion of their inputs and services domestically (IEEF, 2014).

The manufacturing engineering cohort accounts for 17 per cent of total sector exports and approximately one quarter of the payroll and value-added generated by indigenous manufacturing (IEEF, 2011). Although increasingly populated by graduate engineers, the sector is characterised by apprentice-based recruitment with local employees who are not mobile (Wengel and Shapira, 2004).

Trading Profile

Trade is concentrated within the EU, primarily in the UK, Germany and France (IEEF, 2011) with growing reach into Eastern Europe and Asia among the research population. The sector is diverse with identifiable sub-sectors spanning original equipment manufacturers, Tier 1 and 2 sub component or assembly suppliers also called 'producer's goods' (Pavitt, 1990, p.43). Product design and development is gaining traction among original-equipment companies and also among sub-suppliers seeking to optimise output for their clients (intellectual property owners)

or those seeking to diversify their portfolios in order to reduce reliance on sub-supply contracts.

While the sector is diverse, dominant sub-sectors include: agricultural machinery, materials handling, precision and process engineering, automotive and aerospace, metal fabrication and processing. Table 3-3 presents an overview included selected company listings in each of the sub-sectors.

Agricultural Machinery	A strong sub-sector generating exports of over €100 million. Irish agricultural machinery tends to be more rugged and built to a higher specification than machinery from some other countries due to the mixed quality of Irish land.
	E.g. Dairymaster, Dromone, Keenan Systems and Mc Hale Engineering.
Materials Handling	Sub-sector dominated by a small number of companies delivering exports of over €150 million. Companies service a wide range of sectors including manufacturing, transportation, retail, construction and quarries.
	E.g. Combilift, Dennison Trailers and Instant Upright.
Precision Engineering	Sub-sector largely comprised of companies manufacturing a range of precision sub-components for large multinational manufacturers. A number of niche manufacturers have been highly successful. A significant number of these companies have developed their own product ranges.
	E.g. Bellurgan Precision Engineering, Mincon International and Pressco Ltd.
Process Engineering	Sub-sector comprises companies manufacturing process equipment including high value-added modular skid units used by the world's leading pharmaceutical, chemical and bio-pharmaceutical companies, and large bulk storage tanks for a range of applications including mining and food.
	E.g. BCD Group, Grant Engineering and Suretank Ltd.
Automotive and Aerospace	Sub-sector has a small number of successful niche sub-component manufacturers supplying the automotive and aviation industries. Companies in precision engineering, tool making, plastics and metal fabrication are active in these sectors.
	E.g. C & F Automotive Ltd (Iralco), M J Quinn Ltd and Romaquip Ltd.
Fabrication and processing	There are a large number of companies fabricating a range of metal products for the construction, agriculture, industrial, marine and transit industries. Also a source of highly innovative own-products.
	E.g. Crowley Engineering, LMH Engineering Ltd and McAree Engineering Works Ltd.

Table 3-3: Engineering Sector Profile & Sample Companies (EI, 2010, p.1)

The foregoing section provides a brief analysis of key dimensions of the manufacturing engineering sector in a global and Irish context. The next section addresses these dimensions in the Software sector.

3.6.2 Software Sector

The computer software and services sector originated in the US in the 1950s and has since expanded to serve multiple product and service niches. The sector is dominated by global brands such as Microsoft, SAP and IBM at one level and Independent Software Vendors (ISVs) at the other. The former provide generic solutions with minimal customisation, the latter more commonly deliver niche oriented and custom built solutions. Two million workers or at least 1.35 per cent of the EU labour force are directly engaged in software production (Steinmueller, 2004).

As a sector within the ICT industry, software has grown at about 10 per cent per annum over the last 25 years representing about 4 per cent of total world output (Rowen, 2007). As technology has evolved, the separation of applications from infrastructure reduced barriers to entry for small firms and led to the emergence of niche opportunities in formerly peripheral markets (Messerschmitt & Szyperski, 2005; Saxenian, 2006) of which Ireland is a prime example. Pertinent to the focus of this research, Mowery (1999) suggests that 'low physical capital intensity and high human capital intensity has enabled national influences rather than the industry-specific effects commonly associated with mass-production technologies, to affect the software industry's development (p.156)'. The industry is characterised by

clustering, geographic concentration and a high volume of innovators (Breschi & Malerba, 1996).

Software firms vary significantly because of the wide array of markets in which they compete and their differentiated knowledge and resource bases (Zahra & Bogner, 2000). The sector delivers a variety of application and infrastructure solutions throughout business and consumer markets. Application developers target the needs of specific segments in a way that maximises market share by servicing multiple end-users, often allied to the delivery of technical and project management skills.

Innovativeness

The seeds of Ireland's high tech cluster emerged in the 1990s underpinned by growing competencies in software design and production (O'Riain, 2004). Firms pursued niche export markets employing a *low-end* disruptive approach, rather than competing directly with established players. Contrasting Israel with Ireland, Niosi, Athreye, and Tschang (2012)suggest that Israel has gained advantage through comparatively higher absorptive capabilities whereas software innovation in Ireland is largely path-dependent on the FDI sector however the impact of technology transfer is much less evident than the emergence of born globals on the sector's expansion.

Output, export and employment profile

The ICT sector employed 43,280 people in Ireland in 2012; an additional 25,000 were employed across other sectors in the economy. The sector is dominated by FDI, Irish firms are typically small; employ less than 25 people and turnover less

than €2M per annum (Enterprise Ireland, 2008). In 2013, 40 companies or 8 per cent of firms in the sector achieved turnover in excess of €10M. Indigenous software firms are highly export intensive with export volumes at 73 per cent compared to an average of forty five per cent across the EI client base.

Referring to the sector's 30 year history, EI's strategy for 2009-2013 (Enterprise Ireland, 2008, p.3) states that 'the New Software Economy is an environment in which Irish companies are uniquely well-placed to prosper'. The report noted that the sector comprises 500 companies, employing over 10,000 people, with combined sales of €1.4 billion. A profile of the broader ICT sector (Table 3-4) depicts its significant role in the economy.

	Information Communications Technology Sector
Output	- Constitutes approximately 25% of Ireland's total turnover - Second largest exporter of computer and IT services worldwide
Export value 2009	- One third of the country's exports by value - Five of the top 10 exporters in Ireland are technology companies - Computer services exports €24,223 million (€3,951M UK exports)
Employment	- 75,000
Enterprises	- 5,400
Ownership	- 233 foreign owned including the top 10 global ICT companies - 1,277 indigenous firms generating output of over €1 billion annually
Growth	● net employment growth rate of 6% in 2009 and 4% in 2010

Table 3-4: ICT Sector Profile (ICT Action Plan 2012, ICT Ireland, 2013)

Trading Profile

Computer software embedded in hardware or carried via other physical media are classified as merchandise while the sale and purchase of software transmitted electronically as well as exports of software licences are classified as computer services (CSO, 2013a). Services account for an increasing proportion of total value added and commercial software services represent a growing proportion of that.

Domain expertise developed in a number of specialist areas including telecoms, finance, public sector, digital media entertainment and e-learning (Enterprise Ireland, 2009) while next generation internet, location based services, mobile ICT and social networking have been a more recent source of innovation and new revenue (ICT Action Plan, 2012). Table 3-5 presents an overview including selected companies within the sub-sectors.

eLearning	Content solutions, Learning Technologies, eLearning Services, Supplementary Tools – online books, portals, manuals, Job aids and workbooks.
	Akari Software, Enovation Solutions and Intuition Publishing,
Digital media entertainment	Mobile content, Interactive TV, Animation, Digital Games, Film/ TV.
	Brown Bag Films, Jam Media and Kavaleer Productions.
Travel technology	Distribution and reservation technologies, payment solution providers, business process and enterprise management solutions, CRM, mobile technologies and digital marketing
	Datalex, Open Jaw Technologies and Mobile Travel Technologies.
Public Sector	Hub, Enterprise solutions, Security & privacy solutions. Business process management, Collaboration & productivity tools
	Careworks, Keelvar Ltd and Quest Computing.
Telecommunications	Applications: Messaging, content, security. Mobility solutions: Mobile payments, personalisation. Middleware: billing and revenue assurance. Infrastructure: integrated communications and quality assurance.
	E.g. Accuris Networks, IQuate and Openet.
Financial and Enterprise	Global sourcing and security management. Claims software for the insurance industry.
	Cylon Controls, Vizor Ltd and Zarion.

Table 3-5: Software Sector Profile and Sample Companies (EI, 2008, p.2)

Irish firms generate a high proportion of revenue through professional services in support of integration and implementation efforts in the client environment. Software products are highly replicable however professional services delivering client-specific solutions are labour intensive placing additional demands on a constrained talent base while dampening potential for scalability.

Age-Ownership

Although the Irish Software sector emerged in the late 1960s (Heavin et al., 2003) the indigenous sector is relatively young with firm age averaging less than ten years. Founder entrepreneurs populate CEO roles, the majority of them being from technical backgrounds with less than 25 percent being sales, marketing and financial professionals (Enterprise Ireland, 2008). Appointment of career managers to replace founder entrepreneurs is a frequent response to failure to adopt formalised approaches to scale (Child & Kieser, 1981), often at the behest of board members and investors. In contrast to the engineering sector, displacement is more common than succession in software firms. The sector employs a high proportion of professional staff and demonstrates more limited levels of family involvement than in manufacturing engineering.

The following section on IPOs is specific to the indigenous software sector (having no parallel in the engineering sector). It is included here based on its significance as an indicator of *investor sentiment* and a signal of the potential inherent in the sector.

Initial Public Offerings

Initial public offerings (IPOs) are a key barometer of the health of the technology sector. In the Irish context, the historical success of companies such as Iona in middleware, Smartforce and Riverdeep in education and Trintech and Baltimore in data security, reinforced by public listings on NASDAQ in the 1990s, resulted in software becoming the first industry in Ireland's history to sow the seeds of a virtuous cycle of entrepreneurship (Breznitz, 2007). The subsequent delisting of

each of the firms depicts something of a vicious cycle (Table 3-6), largely based on failing to meet the challenge of aggressive growth. Through a combination of entry, acquisition and dissolution, sectoral revenues have remained relatively static over the last ten years. As acquiring firms are largely foreign-owned, they absorb the revenues overseas while acquired firms are reported as *dissolutions* (Evans, 1987).

Firm	Nasdaq IPO Listing	Exit from Nasdaq
Iona	1997	Acquired by Progress Software (US) in 2008
Smartforce	1995 (CBT Systems)	Merged with Skillsoft. Acquired by SSI Investments (US) in 2010
Riverdeep	1999	Delisted in 2002 when the stock price fell below $2
Trintech	1999	Acquired by Spectrum Equity Investors (US) in 2012

Table 3-6: Record of Irish Software Company NASDAQ Listings

In 2012, Fleetmatics, a provider of cloud-based fleet management solutions became the first Irish Software company to launch an IPO (New York Stock Exchange) in ten years. Fleetmatics is one of the indigenous sector's top earners with revenues of $177.4M (€129M) in 2013, Globoforce with 2012 earnings of approximately $187m (€136M) postponed a planned Nasdaq listing in March 2014 (the first by an Irish firm in 14 years) stating the intention to await more favourable market conditions.

While praising Ireland's policy of encouraging high-tech export businesses, Cusumano (2005) suggests that many Irish entrepreneurs are interested in growing their companies but, not at the expense of maintaining their lifestyles including:

> *independence from large outside investors, from the pressures of public stock markets and independence from the syndrome that many US software companies face; hectic work schedules, frenetic product launches, aggressive attempts at expansion and then bankruptcy or market failure more often than we care to admit (p.27).*

A meta-analysis of the growth patterns of gazelles found that firms who introduce new-to-market products are significantly less likely to survive – they are also less likely to be acquired than to be liquidated (Parker et al., 2010). This diagnosis appears representative of the indigenous sector, perhaps explaining why few software companies have scaled beyond €20m and why overall revenues have plateaued over the last decade.

3.7 Conclusion

Assessment of firm-system fit relies on a contextualised understanding of educational and skills provision, the fiscal environment, the technology infrastructure, legislation, intellectual property protection, the institutional landscape and the relationships between them (Feldman & Kogler, 2010). This chapter provides an overview of the economic and policy landscape in the Republic of Ireland and documents the significance of the software and manufacturing engineering sectors in the global and Irish context. In light of the recession prevailing during the primary research phase of this thesis, it can be argued that the characteristics and challenges associated with innovating in such circumstances present a more useful mechanism for identifying environmental fit than in the boom times that preceded it.

Primary analysis of system dimensions is presented in the analysis chapters (5&6) with emphasis on significant associations between firm contingencies and perceived fit.

Chapter Four

Methodology

Dialectical pragmatism.

4.0 Methodology

This chapter describes the methodology and methods employed to answer the research question. It provides an overview of the research orientation including pertinent philosophical and epistemological issues. It offers the rationale for the approach adopted to address the research problem followed by an outline of the research design used and the methods of analysis adopted in respect of firm contingencies (age and strategic intent), and the corresponding fit of key SSI dimensions.

Details of sampling frames, sample selection, the interview guide, survey development and administration, data coding and analysis are described within the research framework. The mixed methods pragmatic framework is exploratory, without a priori hypotheses. To be clear about the boundaries of the research, the concern is to establish significant associations between SSI dimensions and firm contingencies and as such, it does not consider fit for non-correlated dimensions.

4.1 Research Problem

Extant research suggests conflicting hypotheses based on the proposition that system-fit is likely to be contingent upon firm age (e.g. Autio et al., 2000; Aldrich and Ruef, 2006; Klepper, 1997; Ranger-Moore, 1997; Stinchcombe, 1965) and strategic intent (e.g. Baum and Locke, 2004; Berger and Udell, 1998; Levie and Lichtenstein, 2009; Lundvall, 1992) among other firm-specific dependencies. The critical intersect between age, strategic intent and SSI dimensions, (Carlsson, Jacobsson, Holmén and Rickne, 2002; Sorensen and Stuart, 2000) has not been tested heretofore.

Promoting the utility of cross cutting analysis of SSIs, Malerba (2002) finds that most studies focus on a single dimension, ask different research questions, employ different methodologies and different units of analysis, reducing the potential for analytical consistency. Further, it is suggested that comparative analysis of different systems across similar dimensions should help illuminate disparities such that policy and practice can be better informed (Lundvall et al., 2009). This study addresses a number of these gaps by analysing two distinct sectors, employing parallel dimensions and methods within a single national territory to uncover contingency based fit. The research seeks to analyse the degree to which firm age and strategic contingencies moderate system fit with a view to informing system design and improving firms' innovative capacity.

The overarching objective of the research is to:

- Investigate the perceived fit of the sectoral system of innovation (SSI) to the needs of indigenous manufacturing engineering firms contingent on age and strategic intent

- Investigate the perceived fit of the sectoral system of innovation (SSI) to the needs of indigenous software firms contingent on age and strategic intent

- Analyse the extent to which contingency-based fit is homogenous across the manufacturing engineering and software SSIs.

Figure 4-0 depicts the research schema which was derived from the literature and extant research, in particular, the Community Innovation Survey (CIS).

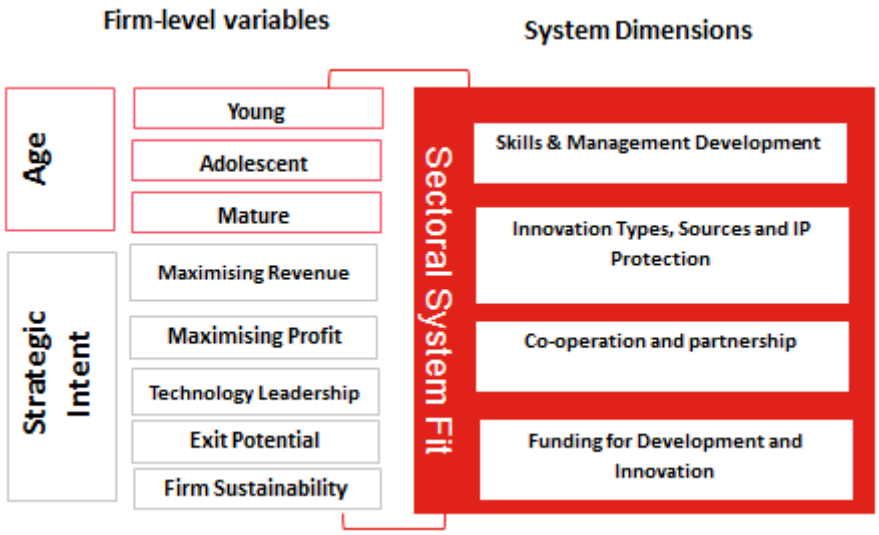

Figure 4-0: Sectoral System of Innovation Dimensions

To follow is an explanation of the research paradigms considered and the methods used to gather and analyse the data for this study.

4.2 Research Process

Before undertaking research it is important to have an appreciation of the paradigms and general theory underpinning alternative methodologies and the tools and techniques that are most suited to it. The choice of paradigm has implications for research design, data collection and analysis. Alternative paradigms are framed within positivism, post-positivism, critical theory, constructivism and pragmatism.

Methodology refers to the theory or philosophy of how research should be undertaken supported by methods - the technical procedures used in data gathering and analysis. There is broad familiarity with the notions of 'quantitative research (numerical analysis and measurements)' and 'qualitative research (feelings, perceptions and meanings)' (McGregor and Murnane, 2010, p.421) as well as with their more general characterisation as methods and procedures. In

determining a research design, it is recommended that researchers choose a single paradigm (Creswell, 2009). Table 4-1 outlines the array of worldviews considered for application in the study. Each is discussed concluding with the approach adopted in this study.

Philosophical Worldviews	
Positivism	Interpretivism
- Observable social reality - Highly structured methodology - Validity - Generalisation	- Understanding - Multiple participant meanings - Social and historical construction - Theory generation
Postpositivism	Pragmatism
- Determination - Empowerment issue-orientated - Collaborative - Change-oriented	- Consequences of actions - Problem-centred - Pluralistic - Real-world practice oriented

Table 4-1: Philosophical Worldviews (Cresswell, 2009, p.6)

4.3 Philosophical Background

Paradigms/Theoretical Perspectives

Paradigms comprise sets of assumptions concerning reality (ontology), knowledge of that reality (epistemology), and the ways of knowing that reality or the process of research (methodology). In essence, they govern the way we think and act or the *worldview* we adopt in carrying out research. The two research paradigms most widely discussed in business and management are positivism from which post-positivism has evolved and interpretivism which is used interchangeably with constructivism and phenomenology. Over the last twenty years, pragmatism has grown in status. It is not committed to any one system of philosophy (Creswell, 2009), but rather employs mixed-methods drawing on both the quantitative and qualitative domains.

Positivism

Empirical research in business was historically governed by the positivist paradigm which views the world as external and objective. Positivism sees social science as an 'organised method for combining deductive logic with precise empirical observations of individual behaviour in order to discover and confirm a set of probabilistic causal laws that can be used to predict general patters of human activity' (Neuman, 2003, p.71). Ontologically, positivists view the social world in much the same way as natural scientists view the physical world. The positivist objectivist approach imposes scientific meanings on individuals to explain singular, 'presumed-to-be true' realities by coding, counting and quantifying phenomena in an effort to represent concepts (Gephart, 2004, p.455). Associated with the quantitative tradition, the positivist paradigm makes the epistemological argument that the researcher and that which is being researched, must be separate from each other and that the researcher much be independent and objective. Despite criticism from a variety of rival orientations, positivism remains the dominant epistemological orientation in management disciplines (Denzin & Lincoln, 1994).

Due to a focus on variable analysis, positivism is perceived to ignore the processual character of human sociation (Hammersley, 2008) and therefore fails to take account of the underlying mechanisms of social behaviour and how these change over time. In a review of research modes, Corbetta (2003) refers to the increasing acceptance among quantitatively oriented social scientists that the addition of qualitative techniques can yield worthwhile outputs. He ascribes this to the neo-positivist or post positivist paradigm.

Postpositivism

In the context that one cannot be *positive* about claims of knowledge when studying human actions and behaviour, post-positivism challenges the notion of absolute truth (Creswell, 2009). This is akin to failure to reject a hypothesis as opposed to proving it. Non-positivistic studies occur in small scale groups where the intent is to search for meanings in select contexts rather than for generally applicable laws, while positivism seeks validity and reliability as benchmarks of rigour, post-positivism strives for trustworthiness rather than unbiased measures (McGregor & Murnane, 2010). According to Lin (1998), postpositivism strives 'to uncover the conscious and unconscious explanations people have for what they do or believe, or to capture and reproduce a particular time, culture, or place so that actions people take become intelligible' (p. 162). This is an important feature of the current study.

Post-positivism lays claim to a single reality but we may not be able to understand what it is or how to arrive at it because of the hidden variables and lack of absolutes in nature, therefore reality can never be fully captured but rather, approximated through interpretive methodologies (Creswell, 2009; Guba & Lincoln, 1994). The next stage of paradigmatic evolution witnessed the emergence of constructivism and interpretivism which saw theorists adding new dimensions to post-positivism.

Interpretivism

Interpretivists refute positivistic claims about the logic of science, suggesting that theory does not generally precede research but follows it (Cohen, Manion and

Morrison, 2007). The research process is qualitative and largely inductive with meaning generated from field data. The interpretivist paradigm is concerned with the way that humans make sense of the world; seeking the insider view. Just as reality is understood to be perceived, different individual and group perspectives reflect multiple realities which may change over time (Hudson & Ozanne, 1988) seeing 'people and their interpretations, perceptions, meanings and understandings as the primary data sources' (Mason, 2002, p.56).

Among criticisms of the interpretive approach is the inability to experience others' thoughts, the absence of validation and the idea that sharing an experience does not equate to understanding it (Hudson and Ozanne, 1988). Some argue that anti-positivists abandon scientific procedures of verification, weakening the prospect of making useful generalisations (Cohen, Manion, & Morrison, 2007). Responding to criticisms of ambiguity, Jick (1996) suggests that qualitative research does not aim to present unequivocal, quantifiable meanings but rather to describe meanings that are potentially contradictory and ambiguous.

4.4 Pragmatism, Mixed Methods and This Study.

Determining an appropriate research design

From a methodological perspective, policy makers and practitioners require multiple forms of evidence to document and inform research problems (Creswell and Plano Clark, 2007). This is exemplified by Rush, Bessant, and Lees (2004) who suggest that the body of knowledge about how to evaluate policy on innovation is well established and moreover that it should employ both qualitative and quantitative methods. 'Surveys maximise population generalisability but are low on

realism of context and measurement' (Scandura and Williams, 2000, p.1250), whereas interviews are high on realism but lower on measurement precision of behavioural variables and generalisability. Denzin and Lincoln (2000) propose that 'clarity can be gained by contrasting qualitative research with quantitative research that emphasises measurement and analysis of causal relations among variables' (p.8). The use of contradictory methodological arguments allows researchers to mobilise the post positivist paradigm in quantitative data collection and the interpretivist in qualitative data collection and then to put the two in conversation with each other to allow for deeper understanding based on convergence and dissonances uncovered (Mertens, 2012) since knowledge is not simply data but is rooted in human experience and social context (Lemon and Sahota, 2004).

This section describes the philosophy underpinning the approach to the current research and the methods adopted. Pragmatism counters the idea of epistemological incompatibility and offers support for the logic of mixed methods to address system fit. Given the complexity of the innovation landscape and related evidence on the role of the entrepreneur, management of, and interaction with the system (Carlsson, 2006; Rush, Bessant and Lees, 2004), a mixed methods approach appears fit for the purpose of this research.

An important value of mixed methods research and one which deemed the approach suitable to the current study is the clarity offered by integrating qualitative and quantitative research along with measurement and analysis of associations among variables. Recognising that 'social life is a contingent and even emergent process' rather than a repetition of law-like patterns (Hammersley, 2008,

p.23), quantitative research alone would not provide adequate insight into executives' perspectives on the SSI however qualitative data lacks robustness in terms of generalisability. Mixed methodology seeks to achieve that generalisability and statistical significance in reporting findings while capturing the nuances and understanding of each firm's context.

The current study interprets mixed methods as the integration of two approaches to research, rather than the collection and analysis of two types of data. Stressing the integrative nature of mixed methods, Tashakkori and Creswell (2007) see the approach as 'research in which the investigator collects and analyses data, integrates findings, and draws inferences using both qualitative and quantitative approaches and methods in a single study' (p.4). The term 'dialectical pragmatism' (Mitroff & Mason, 1981, p.20) has been proposed to describe the integration of qualitative and quantitative research to develop synthesis.

Theorists and researchers are increasingly moving towards paradigm relativism (Morse & Niehaus, 2009; Tashakkori & Teddlie, 1998). The idea of holding a dual view of paradigms has gained currency over the last twenty years with many researchers adopting a pragmatic viewpoint. Instead of focusing on methods, pragmatism emphasizes the research problem and the use of appropriate approaches to solving it (Creswell, 2009). As a world view, pragmatism is based on an evolutionary perspective typically associated with mixed methods. As a form of research strategy, it is also known as convergent or multi-method (Jick, 1979), focusing on the primary importance of the question asked and the consequences of the research, rather than the methods of data collection (Creswell and Plano Clark,

2007; Saldana, 2009). Observing that mixed methods research is a design with philosophical assumptions as well as methods of enquiry, Creswell and Plano Clark (2007) encapsulate the approach:

> As a methodology, it involves philosophical assumptions that guide the direction of the collection and analysis of data and the mixture of qualitative and quantitative approaches in many phases in the research process. As a method, it focuses on collecting, analysing and mixing both quantitative and qualitative data in a single study or series of studies. Its central premise is that the use of quantitative and qualitative approaches in combination provides a better understanding of research problems than either approach alone (p.5).

Howe (1988) coined the term 'incompatibility thesis' to describe the stance of those who view the rapprochement of methods as resting on the 'epistemologically suspect criterion of what works' (p.10), however Wengraf (2001) advocates 'fitness for purpose' (p.14) as the criterion by which instruments and procedures for social research should be chosen.

Marrying the requirement to explore and explain and to ascertain how as well as how many, mixed method research has become known as the third methodological movement (Creswell and Plano Clark, 2007; Tashakkori and Teddlie 2009). Johnson and Onwuegbuzie (2004) advocate use of a method and philosophy that integrate the insights provided into a workable solution. Along these lines, they advocate consideration of the method of the classical pragmatists (e.g. Charles Sanders Peirce, William James, and John Dewey) as a way for researchers to think about the traditional dualisms debated by the purists. Among characteristics cited are that it 'replaces the historically popular epistemic distinction between subject and

external object with the naturalistic and process oriented organism-environment perspective and that it endorses practical theory to inform effective practice' (Johnson and Onwuegbuzie, 2004, p.18).

These characteristics bear particular relevance to the current research where there is a need to gain understanding of the influence of both organisational and contextual factors to analyse system fit. In the absence of more holistic, context theorising on both the macro and micro levels, Bamberger (2008) posits that we are unlikely to yield research dividends if we fail to introduce a broader range of paradigms and perspectives with the tools to create new theories explaining the relationships between structures, environments and timeframes on the one hand, and attitudes, cognition and behaviour on the other. In line with the objectives of the current research, Creswell (2003) proposes that a mixed method design is warranted when the researcher wishes to generalise the findings to a population while developing a detailed view of the meaning of a phenomenon or concept among individuals.

Critical of the argument that combining qualitative and quantitative data might be regarded as a paradigm case of triangulation, Hammersley (2008) suggests that the term has come to refer loosely to drawing on different sorts of data within the same study, irrespective of how they are used. Flick (1998) notes that triangulation, rather than validating results in mixed methods, is in danger of being interpreted as an alternative to validation.

Triangulation

Whilst allowing a researcher to use different methods for different purposes in the context of one study, mixed methods offer the potential for triangulation. The use of a variety of methods to examine a topic is seen as producing more robust and generalisable findings resulting in higher external validity (Scandura & Williams, 2000). Management researchers put forward an argument for mixed methods as having the potential to provide more perspectives on the phenomena being investigated leading to extensive debate on the benefits and drawbacks of triangulation. For this research, a mixed method approach is used not only to examine the same phenomenon from different perspectives but also to enrich understanding by allowing new and deeper dimensions to emerge (Jick, 1979). Offering a critical perspective, Bryman (2007) argues that 'the metaphor of triangulation has sometimes hindered this process by concentrating on the degree to which findings are mutually reinforcing or irreconcilable' (p.21). He advises against the tendency to use the outcomes from one method as a 'support act' to the other, rather than investing in integration arguing that researchers should provide justification as to why for example, survey evidence justifies claims that a particular theorization has been supported or disconfirmed by interview evidence. This logic has been employed in the analysis (chapters 6&7).

4.4.1 Qualitative Research

Context-relevant analysis is increasing as economic interactions are in many ways embedded in the structures of social relations (Bamberger, 2008; Granovetter, 1985) typified by systems thinking. In employing participants' meanings to

understand the phenomena of interest (Denzin & Lincoln, 1994; Neergaard & Ulhoi, 2007), qualitative data can be 'particularly difficult to pin down' because of their 'flexibility and emergent character' requiring 'highly contextualized individual judgements' (Van Maanen, 1998: xi). In a similar vein, Alvesson (2003) refers to the argument that language constructs, rather than mirrors phenomena – both perspectives underline the need for caution in interpreting participant data. In support of the qualitative approach, Gephart notes that 'it can provide thick, detailed descriptions of actual actions in real-life contexts' (2004, p.455). Qualitative research adopts a perspective of 'situated, contextual' knowledge where the interviewer's role is to ensure that the relevant context is set such that situated knowledge can be produced (Mason, 2002, p.62).

Interviews

Broadly described as a conversation with a structure and a purpose (Kvale, 1996), interviews in semi-structured in-depth and loosely structured forms are the most commonly used method in qualitative research. Mason (2002) describes 'unstructured interviewing' as a misnomer (p.62) suggesting no research interview can be completely lacking in structure or configuration as time and resource constraints would make it impracticable. Structured interviews are aligned with a neo-positivist perspective whereby the interview is construed as a scientific enquiry and the interviewer extracts information based on a rigid script. In depth semi-structured interviews are planned and flexible exchanges conducted with the purpose of obtaining descriptions of the world of the informant (Kvale and Brinkmann, 2009) in order to shed light on their experience of the research

phenomenon. Within the current study, semi-structured interviews achieve a balance between controlling the topics covered and remaining open to the informant's mode of response including the scope to improvise in a careful and theorised way (Flick, 1998; Wengraf, 2001) by employing freeform discussions to gather additional information for analysis and interpretation (Autio et al., 2000). Alvesson (2003) describes a researcher applying this approach as a 'localist' (p.13) who sees the interview process as an opportunity to explore the meaning of the research topic for both the interviewer and the respondent with the interplay between the two participants producing a situated account of the phenomenon in question.

According to Rogers (2003) the very meaning of innovation is worked out through a process of social construction. It is crucial for a researcher to know the context of a behaviour or event because social beings construct reality and give it meaning based on context (Hudson and Ozanne, 1988). Adding to the debate that qualitative interviewing tends to be under-theorised, Wengraf (2001) posits that when interview data is used as evidence, it tends to be supported by extra-interview data and contextual knowledge. This adds to the motivation for the use of interview and survey tools in answering the current research question.

4.4.2 Quantitative Research

Research concerned with social facts tends to favour quantitative methodologies. Formalised procedures of quantification and categorisation present means of ordering and structuring the social world (Jick, 1996). Quantitative researchers craft concepts into the language of variables and, more particularly, relationships

between variables. Due to the settings and limited number of cases used in qualitative research, quantitative methods and surveys in particular, are considered superior in respect of generalizability (Johnson and Duberley, 2000).

Surveys

In studies seeking to model or predict the behaviour of larger groups in society, surveys are addressed to large, appropriately targeted, samples of the population. A survey design provides a quantitative or numeric description of a population by studying a sample with the intent to generalise characteristics, attitudes and behaviours from the sample to the population (Creswell, 2009). Employing survey or correlational design, data relating to all variables are collected simultaneously (Bryman & Cramer, 2011). The approach prescribed in the literature was adopted in the current research as outlined below.

4.5 Research Design Framework

Research designs are procedures for collecting, analysing, interpreting and reporting data. Rigorous designs are important because they guide the choice of method and set the logic for analysis and interpretation (Creswell and Plano Clark, 2007). Practical issues such as time, availability of resources and access are clearly important considerations.

Design has implications for a study's ability to have clear practical significance (Scandura and Williams, 2000). Addressing the age and strategy contingent effects of the SSI on firms' innovative capacity required both qualitative and quantitative approaches to reflect the role of the firm, the importance and impact of system dimensions and the challenges associated with resource acquisition and

exploitation. The sequential approach facilitated use of information from prior phases to inform later stages (Creswell & Plano Clark, 2007) as well as analysis in respect of how the qualitative data help to explain quantitative results and vice versa. To that end, the mixed method, sequential framework addressed the trade-off between the realism of context in the interview phase with the generalizability of the survey as advocated by Scandura and Williams (2000).

Knowledge generation in this context is guided by the need to explore, explain and generalise the effects of age and strategic contingency on the engineering and software SSI fit. Poole, Van de Ven, Dooley and Holmes (2000, p. 120-121) propose that the design of age-related research should reflect three sources of temporal change:

1. Age - The age or temporal duration of the organisation at the time of measurement
2. Cohort - The set of characteristics of all organisations incorporated at the same time representing the common historical conditions shaping the development of a given cohort
3. Transient - All the temporary or immediate noncumulative factors that influence outcomes or dependent variables at the time of measurement.

Following the exploratory research recommendation of Remenyi (1998), data gathering was first broad-based and then more in-depth and specific. A three-phase mixed method analysis was employed. Based on a convenience sample, Phase 1 of the study consisted of exploratory dual-sector system analysis including data collection and inference based on in-depth interviews supported by a loosely structured topic guide in the form of a mind map. This involved re-conceptualizing the SSI in the participant perspective. Employing an aged-based stratified sample,

Phase 2 consisted of semi-structured interviews based on gaps in the literature in combination with inferences from the preceding phase. Employing dual sector, single stage, self-administered e-surveys, Phase 3 informed by the prior phases, provided the basis for the generation of new data. Final meta-inferences were made on the basis of the confirmatory or dis-confirmatory age and strategic contingencies determined through the survey – supported by the interview data.

4.5.1 Research Process

The approach used is summarised in Table 4-2 which articulates a progression from early stage exploration of the sectors, to age based analysis of enabling and constraining SSI dimensions, concluding with a wide-ranging survey.

Phase	Inputs	Outputs
Literature/ Secondary data	- Review of academic/policy research on SI firm age and life-course - Engineering and software and sector profiles, agencies and industry bodies.	- Documented preliminary understanding pertinent to innovative capacity.
Schedule	September – December 2008	January 2009
Phase 1 Loosely-structured interviews	- Exploratory interviews n=10 - SMEs (n=4), Agencies (n=2), Industry bodies (n=2) and Venture Capital Companies (n=2) based on convenience sample.	- Qualify system perception - Inform semi-structured interview phase 2
Schedule	Pilot: January 2009	February 2009
Phase 2 Semi-Structured Interviews	- Develop and pilot interview guide - In-depth, face-to-face interviews engineering (n=9) and software firms (n=9) based on stratified sample	- Perceived system fit by firm, sector and maturity
Schedule	Pilot: May 2009	May - July 2009
Phase 3 Sector Surveys	- Development and testing of questionnaire - Expert panel review and cognitive interviews.	Survey of both sectors (n=676)
Schedule	Pilot: October-November 2010.	Survey: Jan – Mar 2011

Table 4-2: Research Process and Timeframes

4.5.1.2 Phase 1: Exploratory research - loosely structured interviews

Bamberger (2008) promotes the use of qualitative methods in the early stages of research as a means to better understand the situational and temporal contingencies potentially shaping the phenomena of interest, contending that 'pre-research' (2008, p.843) may help inform the inclusion of new context-related constructs and the exclusion of others. Distinguishing between mapping and modelling, Wengraf (2001) describes the process of moving from exploratory research where a phenomenon is given preliminary 'mapping', to theory-testing where the provisional map is analysed against reality (p.51), he advocates moving from lightly structured to semi-structured *prior theory* interviewing in a planned sequence.

Having generated information about aspects of the phenomenon and provided a broader understanding of the research problem, inductive, lightly structured interviews were designed to gain an understanding of how executives perceive and articulate the SSI. This provided a measure of how provisional the researcher's understanding was (vis-a-vis the conceptual framework) in advance of operationalising the more advanced elements of the design. This phase involved preliminary interviews with cross industry organisations including SME chief executives from within the respective sectors, sectoral specialists from EI and IBEC and, given the emphasis on funding constraints in the literature, two venture capitalists. The phase was designed to obtain executive's views on the dimensions of the SI and the firm-system interplay.

The phase 1 purposive sample involved a relatively small number of organisations because they could provide particularly valuable information related to the research question (Teddlie & Tashakkori, 2009). While the common innovation infrastructure sets the general context for innovation in an economy, it is ultimately firms, influenced by their microeconomic environment, that develop and commercialise innovation (Furman et al., 2002). See Phase 1 overview of interview sites at Appendix 1.

Phase 1 - Operationalisation

A review of the literature and policy documents was undertaken to facilitate the creation of a mind map (tentative SSI model – Figure 4-1), to depict the respective software and engineering innovation systems. Innovation systems (Carlsson et al., 2002; Sharif, 2006) and Ireland's innovation system have been well documented e.g. (Acs, O'Gorman, Szerb, & Terjesen, 2007; Forfás, 2004a; O'Malley, Hewitt-Dundas, & Roper, 2008), as have SSI (e.g. Malerba, 2002, 2005; Hirsch-Kreinsen, 2008). Policy documents include reviews of the software (IDC, 2008; Enterprise Ireland; 2009) and the engineering sectors (IEEF, 2011) along with the Forfás Annual Business Survey of Economic output (Forfás, 2009, 2010) and the Oslo Manual (OECD, 2005).

Appropriate to the application of mixed methods to achieve a comprehensive and nuanced understanding of SSI fit, collection and analysis calls for effective operationalisation, a term widely used in quantitative research but commonly underplayed in qualitative work (Wengraf, 2001). The patterns and pace of innovation were discussed and the relationship between resource availability and

innovative activity were explored within the broader context of the strategy of the firm. A mind map charted system components identified in the literature and policy reports. Mind mapping pioneered by Buzan and Buzan (2000) enables the rapid expansion and exploration of ideas because it utilises the skills commonly associated with creative thinking including idea association (Roffe, 1999). The concept is similar to the model of knowledge management developed by Nonaka and Takeuchi (1995) and specifically, their identification of the processes permitting tacit-explicit knowledge conversion.

Based on informant input, both sector maps enabled adaptation of the approach to phase 2 interviews based on sector specific components and vocabulary. An image of the engineering system map is included below (Figure 4-1).

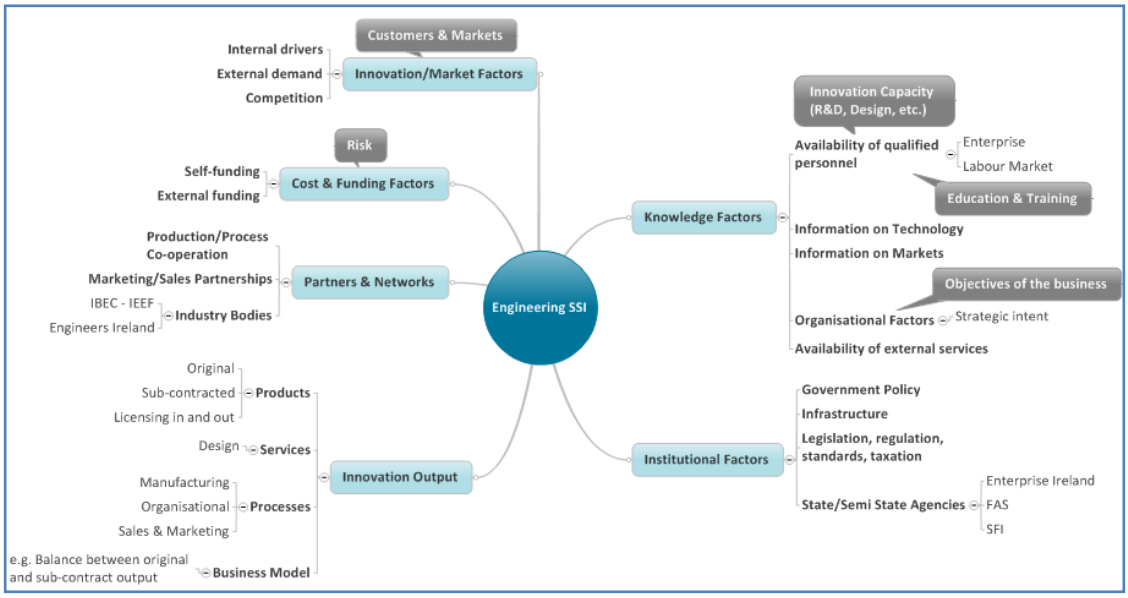

Figure 4-1: Preliminary Engineering SSI Review (Phase 1)

A brief description of the respective dimensions is included in Table 4-3 below.

System Dimensions	Components
Management	Managerial structure of the enterprise. Ability to devote staff to innovation activity versus operational/production requirements
Knowledge Factors: Labour Market: Education, training and development	Innovation potential (R&D, design, etc.). Availability of qualified personnel within the enterprise and the labour market. Primary, secondary, tertiary and fourth level education. Sources of knowledge on technology and on markets. Availability of external support services.
Representative and Industry bodies	Irish Business and Employers' Confederation (Irish Engineering Enterprises Federation). Engineers Ireland.
Institutional factors/ State Agencies	Infrastructure. Property rights, Legislation, regulation, standards, taxation. Agencies: EI, FAS, Enterprise Boards, Science Foundation Ireland.
Cost/Funding factors	Funds within the enterprise: Owner's starting capital/equity (incl. friends and family), owner's loans and retained earnings. External Finance: Debt, equity finance, public/agency funding, Business Expansion Scheme.
Partnering/ Networks	Supply-side co-operation: product & process development (suppliers, universities, consultants and research institutions) and demand-side partnerships (customers and marketing/sales channels)
Growth Trajectory Strategic Intent	Strategic Orientation: Scale or customised offering. Export orientation. Organisational posture. Demand for innovative goods and services. Competitive landscape.
Innovation Output	Products, Services, Processes and Business Model change.

Table 4-3: Engineering SSI Components

4.5.2.2 Phase 2: Semi Structured Interviews

In-depth semi structured interviews were conducted with CEOs and director-level informants during June and July 2009. As qualitative sampling is determined by the representativeness of the phenomenon under study (Morse and Niehaus, 2009), stratified sampling was employed to identify the sub groups in the engineering and software populations representative of sectoral age distribution. The eighteen firms were selected by stratified quota derived from the preliminary population database (detailed below) developed in support of this research (table 4.4). Sampling is an important aspect of qualitative research in terms of implications for subsequent generalisation (Mason, 2004; Wengraf, 2001). Nine engineering and nine software companies were sampled from the young, adolescent and mature strata.

	Engineering	Software
Young – 25th percentile	11	6
Adolescent – 50th percentile	21	9
Mature – 75th percentile	28	13

Table 4-4: Research Population – Age Quartiles

Aside from practical reasons such as costs and time, decisions on the number of interviews to undertake are driven by the data that is needed for comparison and the extent to which the sample enables that. Distinct from sampling for quantitative analysis, the intent here is to enable replication to build theory. The method and number adopted allows for the comparison and contrast of specific perceptions that could not readily be encapsulated in the idea of a stereotypical company. Firms were selected to provide coherence and cross-comparison without excessive variation, providing for literal replication. Multiple informants enabled greater confidence in theory building as idiosyncratic observations could be weighed against the data of others, until no new information was revealed. Nine interviews per sector provided scope for theoretical saturation (Eisenhardt & Graebner).

Interview Population

Interviews were conducted primarily at Chief Executive Officer (CEO) level within the selected firms. A summary of the interview sites is included at Appendix 2. In the case of relatively small companies such as those in the current study, the CEO tends to have direct influence on all aspects of the business with the result that s/he tends to have a much greater effect on organisational outcomes than in the case of larger organisations. Bartholomew and Smith refer to the 'CEO effect' (2006, p.85) on the basis that s/he may be the sole individual with authority to

participate based on their knowledge of firm background, strategy and key activities including institutional interactions. This informed selection on the basis of CEO, MD or director level positions.

Interview Administration

Companies were contacted and interviews were arranged subject to confirmation of age, employee numbers and agreement to participate. The Phase 2 interviews were conducted according to an interview schedule (Appendix: 3) based on extant theory and the themes that emerged from Phase 1.

A pilot was carried out in May 2009 which resulted in minor refinements to the interview protocol. Interviews ranged from 60 to 90 minutes duration. In the engineering sector, time on site was generally extended to include a tour of production facilities. Based on the interview guide, data were collected about founding history, turnover, employees, the main activity of the enterprise, sources of differentiation, innovation activities, strategic intent, categorisation of the technology and sector growth, markets, innovation funding, protection of IP and key competitors alongside perceptions about dimensions of the SSI. An expanded version of the Phase 1 mind map was drawn up to illustrate participant perspectives (figure 4-2) in support of analysis. A more structured aspect of the interview concentrated on the fit of five key system dimensions (listed below) over the preceding three year period (2006-2008):

1. Quality and skills of workforce over the period [availability and impact]
2. Capability development/staff progression [availability and impact]
3. Availability of funding over the period. [availability and impact]
4. Innovation partnerships and co-operation [access and impact]

5. Technological Innovation [e.g. products, services, processes]
6. Non-technological innovation [e.g. business model, organisational].

Figure 4-2 articulates aspects of the SSI dimensions that emerged from Phase two

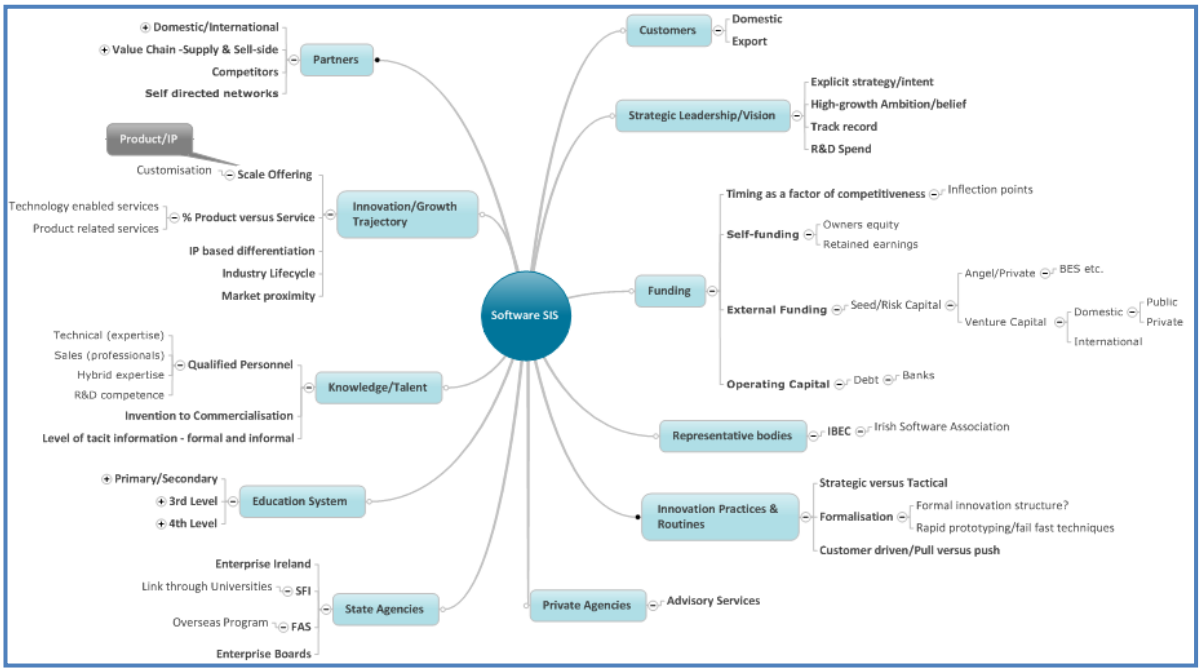

Figure 4-2: Software SSI Map (Phase 2)

All interviews were transcribed and analysed iteratively using manual coding of responses to increase the analytical potential of the data. Following a priori theoretical orientation (Creswell, 2007), the extant theory used to frame the research influenced the data collection and the thematic coding in parallel. The qualitative data were later refined and used to support analysis of the Phase 3 statistical results based on in-depth perspectives on significant dimensions. Consistent with mixed methods, the approach allowed the researcher to establish to what extent and in what ways the semi-structured interviews could contribute to a more nuanced understanding of the SSI as operationalised and reported in the survey.

Interview Coding

Consistent with qualitative research, data collection and data analysis are not overly delineated. The researcher moves back and forth from capturing the data, immersing themselves in it, coding, categorising, and identifying themes, assessing new data as it is presented to test for fit to the emerging theory (Green, et al., 2007). A code is generally a word or short phrase that assigns a 'summative, salient, essence-capturing attribute' (Saldaña, 2009, p.3) to a portion of the interview transcript. The coding filters were based on SSI themes and sub-themes from the literature. Interview transcripts were condensed into more succinct forms within sectoral and age categories. Firms' strategic intent was established in Phase 3 as outlined below.

4.5.3.2 Phase 3 – Sector Surveys

Phase 3 was designed to achieve a quantitative description of perceptions and attitudes to the SSI by studying the dual populations with a view to generalising from the respective samples. Consistent with the chosen methodology and existing research in the domain, the survey was deployed as the final element of the primary research. (See Appendix 5 for copies of the survey). The cross-sectional design provides a quantitative description of the sample population using self-reporting measures. The output was analysed using cross tabulation in SPSS.

Survey Population

In order to ensure adequate data analysis within both sectors, a large sample was required. The intention was that every engineering and software SME (excluding those firms incorporated within the previous three years in line with the reference

period) in the Republic of Ireland should be included in the study. Consistent with the European Community Innovation Survey (CIS) instrument, the target population for the research comprised companies with ten or more employees. Following the European Commission definition (2003/361/EC), SMEs comprise firms employing fewer than 250 persons and which have an annual turnover not exceeding 50 million euro, and/or an annual balance sheet total not exceeding 43 million euro.

Researchers in the area of small, privately held firms can experience difficulty in respect of the limited obligation to declare information coupled with state agency reluctance to share company data in light of risks to client confidentiality. Access to individual firm information is generally problematic for researchers working outside government agencies and public custodians of data (Mairesse & Mohnen, 2010). More widely, primary research among entrepreneurs and small businesses is confronted by a dearth of publicly available data. As small firms and new ventures tend not to be publicly traded, there is a lack of published information (e.g. shareholder reports, commercial analyses) which is compounded by reluctance among small business managers to divulge commercial information.

Efforts to establish detail on the respective populations of both sectors included obtaining data from Forfás (2007) and the FAME database. Neither was adequate in terms of completeness and accessibility of company-specific detail. A population database of all engineering and software companies operating in the State was created by combining lists from EI and Data Ireland. Data Ireland is a commercial provider of business listings linked to the national postal service (providing mailing

lists for over eighty business sectors from a pool of 200,000 business contacts). The two sources were combined to build a robust population database for Phase 3.

Based on a confidentiality agreement, access was gained to EI's 2008 client database (engineering and software divisions) with data confined to company name, sector classification and date of incorporation. This included 333 software companies (media entertainment firms were excluded) and 590 engineering companies at the time of receipt on March 15th 2009. For reasons of client confidentiality, contact details were not provided.

Examination of the databases uncovered significant gaps. Within the EI database, a number of companies had ceased trading or been acquired by overseas entities. Others had fewer than 10 employees and in some cases the date of incorporation did not match that provided by the Central Registrations Office (www.cro.ie). The commercial database contained more complete information including contact names and details. After exclusion of erroneous items, Data Ireland indicated respective populations of 454 software firms and 529 engineering companies employing ten or more people. All companies were contacted by phone to confirm willingness to participate and secure e-mail addresses. Table 4-5 below, summarises the survey population.

Survey Population	Engineering	Software	Total
Enterprise Ireland Client list (firm, age, sector)	590	333	923
Data Ireland database (firm, CEO, contact details)	529	454	983
≥10 employees/≥3 years since incorporation Agreed to participate	362	314	676

Table 4-5: Survey Population

Population Age and Response Rates

Empirical research on organisational age refers to tenure within a particular industry cohort or population. In the case of the population of interest, organisational age and tenure are the same (de novo foundation) for all firms. Firm age is defined as the number of years since incorporation, in effect; the length of time the firm has been in operation.

As age is a key control variable for the research, multiple sources were used to verify the founding year. The Companies Registration Office was the definitive source of the firms' date of incorporation. Company websites were also checked to ensure that they were indigenously owned and engaged in primary production as opposed to marketing, consulting or distribution. Companies in each sector were divided as follows: Young (25th percentile), Adolescent/median (50th percentile) and Mature (75th percentile). The population strata derived from the original EI database alongside those represented in the survey are indicated in Table 4-6 below.

Strata	**Engineering**		**Software**	
	EI client database	Survey based percentile	EI client database	Survey based percentile
Young – 25th percentile	11	17	6	5
Adolescent – 50th percentile	21	24	9	10
Mature – 75th percentile	28	32	13	14

Table 4-6: Survey Age Strata – Survey Population and Response Profile

Questionnaire development

To minimise content and construct validity issues, the questionnaire items were largely derived from a review of previous instruments and established constructs used by researchers in the fields of innovation and firm growth. Thirty dimensions

of system-fit were selected. Sources included the Community Innovation Survey, an instrument developed by the European Commission under the Lisbon Strategy to provide a comparative assessment of the innovation performance of EU Member States (Hollanders & van Cruysen, 2008) and the third edition of the Oslo Manual (OECD, 2005) which is generally described as the foremost source of guidelines for the collection and use of data examining the nature and impact of innovation activities in industry. Product, process, organisational and marketing innovations are defined in line with other surveys of business-level innovation such as those devised by Roper (2001), Jordan and O'Leary (2011) and the EU Community Innovation Survey 2008-2010 (Forfás, 2012a).

The survey aimed to assess fit based on SI dimensions prominent within the literature but which lack evidence of combined utility in the context of firm age and strategic intent. The questionnaire design was further informed by the phase one and two interviews which reflected firm and sector contexts, for example the absence of venture capital as a component of the engineering SSI.

Among substantive constructs over and above those included in the CIS were:

- Employee disciplines and qualifications
- Scale for strategic intent adapted from Autio, Sapienza and Almeida (2000)
- Importance of technical and commercial disciplines to innovation performance
- Ease of filling staff vacancies in senior management, technical and commercial disciplines
- Effectiveness of internally and externally provided training and development
- Effects of FDI/multinational presence on the skills base
- Output of patents copyrights and trademarks
- Ease of securing intellectual property protection
- Funding sources for innovation in the reference period (sector specific)
- Importance of funding sources to innovation
- Distinguished between spend on R&D and broader, non-R&D spending

Following the approach of Bailey, Johnson and Daniels (2000), item development comprised three stages: Generation of a pool of items which reflected the context-specific characteristics of each dimension and which were suitable for use in a self-completion questionnaire; The evaluation of the item pool by a panel of academics experienced in the method; The evaluation of the item pool by five practising senior executives based on cognitive interviews to establish the face validity of the instrument. The panel make-up and the feedback provided are listed in Appendix 4.

The experienced managers who participated in cognitive interviews were asked to complete the survey to establish the validity of questions, appropriateness of wording, format, etc. This type of interview is important in survey design as it allows the researcher to craft constructs in ways that enable target respondents to understand the questions (Dillman, 2007). The exercise measured the time required for completion in addition to collecting feedback. The process resulted in a number of refinements and pilot surveys produced a final selection of 31 items. The survey questionnaires for engineering and software are included at Appendix 5.

Scales

To ensure a consistent frame of reference in rating, respondents were informed that the items were designed to assess current conditions for innovation among Irish-owned engineering/software companies noting the requirement for access to employee talent, customers, suppliers, information, funding and other resources. The survey employed rating and ranking scales with emphasis on the former. Dillman (2000) advises that the same order of response categories is preserved across categories to avoid confusing respondents and questions included both

positive and negative statements to keep respondents engaged. With the exception of categorical responses and two ranking questions, items were rated on a five point scale. The scale was anchored only at the extremes based on two categories:

Importance of the dimension (1) 'Not at all' and (5) 'To a significant extent'

Firm access to the dimension (1) 'Difficult' and (5) 'Easy'

Survey Administration

Planned use of a dual mode survey encompassing web and postal formats was revised based on pilot survey feedback. It was envisaged that that dual-mode administration would help to overcome non-availability of e-mail addresses while accommodating individual preferences for completion online or in hard copy. The use of two or more survey modes in a single data collection effort raises the possibility of increased response rates however it also raises the likelihood of obtaining different answers to each mode (Dillman et al., 2009). Software pilot respondents strongly advocated web-only administration pointing out that they would regard hard-copy surveys as somewhat archaic and too time consuming. The feedback from engineering pilot respondents was less categorical but a decision was taken to check preferences in the telephone survey which was required to confirm respondent identity, establish willingness to participate and secure e-mail addresses. Dillman (2007) advocates the use of the phone to determine to whom a questionnaire should be sent and to establish eligibility, followed by a mail contact to help establish credibility and legitimacy. Only one engineering CEO respondent requested a hard copy version of the survey. This facilitated personalisation of all e-mails. A commercial communications platform (www.newsweaver.com) was used

to facilitate personalised messages as well as to verify which mails had been opened and which respondents had clicked on the survey link. As the survey offered anonymity, the platform allowed for the automation of reminder e-mails which would otherwise have required global renewal of the survey request. It is the policy of some firms not to do questionnaires; others declared that they did not have time to engage.

Survey sponsorship influences how a questionnaire is viewed by the recipient and the likelihood of responding (Dillman, 2007). University sponsorship is used as a form of external endorsement in almost all studies published in academic journals (Bartholomew & Smith, 2006) and Dublin Institute of Technology was clearly identified as the researcher's employer. Based on cognitive interview feedback relating to survey fatigue and concerns about use of public funds, email requests emphasised that the survey was self-funded.

Operationalisation of variables

The constructs selected represent the outcome of several iterations based on discussions with an expert panel (Appendix 4), agency representatives and executives in the sample population. Careful consideration was needed in the interests of achieving a balance between the response rate and the time and level of detail required to complete the survey. Asking people to check records makes it more difficult to obtain responses as unavailability becomes an important reason for non-response. While precise numbers are preferable, some questions (e.g. R&D as a percentage of turnover or proportion of sales revenue generated by products/services developed in the last three years) were categorised in ranges.

A web-based survey was published using a commercial provider of internet surveys (Survey Monkey). This was active for 90 days (Jan–March 2011) during which time the URL and background details were circulated (and recirculated) by email to 676 senior executives in the Engineering and Software sectors - 362 Engineering and 314 Software firms had agreed to participate. Dillman (2007) recommends that varied procedures have a substantial effect on response rates including contact procedures, token financial incentives, telephone follow-up and addressing target individuals. The procedures outlined in Table 4-7 (overleaf) were applied.

Stage	Survey procedures
1	Initial telephone contact
2	Personalised e-mail containing e-survey link, suggested completion date and the commitment to make a charity donation for each response
3	Reminder e-mail to identified non-respondents two weeks later
4	Final reminder e-mail.

Table 4-7: Survey Procedures

Survey response

The initial sample of 983 (529 Engineering and 454 Software) firms was drawn from the Data Ireland database. Based on a telephone campaign to request participation in the survey, close to 70% of companies in the respective sectors (362 Engineering and 314 Software) agreed to participate. The survey yielded 200 usable responses as outlined in Table 4-8. Response rates of 15 per cent for Engineering (80 responses) and 26 per cent for Software (120 responses) were achieved.

Population	Engineering	Software	Total
Data Ireland database	529	454	983
Agreed to participate	362	314	676
Response Rates	80 (15%)	120 (26%)	200 (20%)

Table 4-8: Survey Response Rates

Bartholomew and Smith (2006) in a review of survey response rates in small business research reveal that (mail) surveys published in Entrepreneurship Theory and Practice and the Journal of Small Business Management over the period 1998-2004 indicate an average response rate of 27%. They contrasted this with higher response rates achieved in surveys of large business citing the resource constraint and reliance on the CEO in smaller firms.

Selected survey variables - Descriptive statistics.

The average age of software respondents was 10 compared with 24 years for the engineering sector. Software businesses were two thirds the size of engineering firms with almost triple the number of employees having undertaken tertiary education. The primary strategic intent expressed by software respondents was revenue growth while engineering sector respondents prioritised profitability.

Employment and skills profile:

The 120 software respondents had an average of 36 employees in 2010, 85% of whom had a third-level degree (62% Science-Engineering, 25% other degree and 13% non-degree). Employee numbers had increased by 21% in the 2008 to 2010 reference period. The 80 engineering respondent firms had an average of 47 employees, 27% of whom had undertaken tertiary education (17% Science-Engineering, 10% other degree and 73% non-degree). Average employment remained flat over the reference period.

Innovation Output:

To achieve stated growth objectives, software respondents engaged primarily in product and service innovation, followed by marketing and sales process

innovation. Engineering firm innovation in the reference period was similarly oriented to product, marketing and sales process innovation. As might be anticipated, production process innovation was more important than service innovation.

Impact of Foreign Direct Investment

Respondents in both sectors cited competition for talent as a by-product of the presence of foreign multinationals in the economy. This was countered by FDI firms' positive impact on the overall skills base. With respect to spill over, respondents cited minimal impact on domestic demand due to the presence of FDI.

Perceived obstacles to Software and Engineering Sector innovation

Survey respondents indicated the degree to which SSI dimensions (e.g. Financial and Human Capital, tax incentives and Intellectual Property protection) were perceived to have constrained innovation in the reference period (Figure 4-3 overleaf provides a summary for both sectors). In line with D'Este et al. (2012), funding is indicated as the most significant constraint for the software sector followed by labour costs. For the engineering sector, labour costs were perceived to be marginally more constraining than funding for innovation, perhaps significant of higher concentration on cost-based competition.

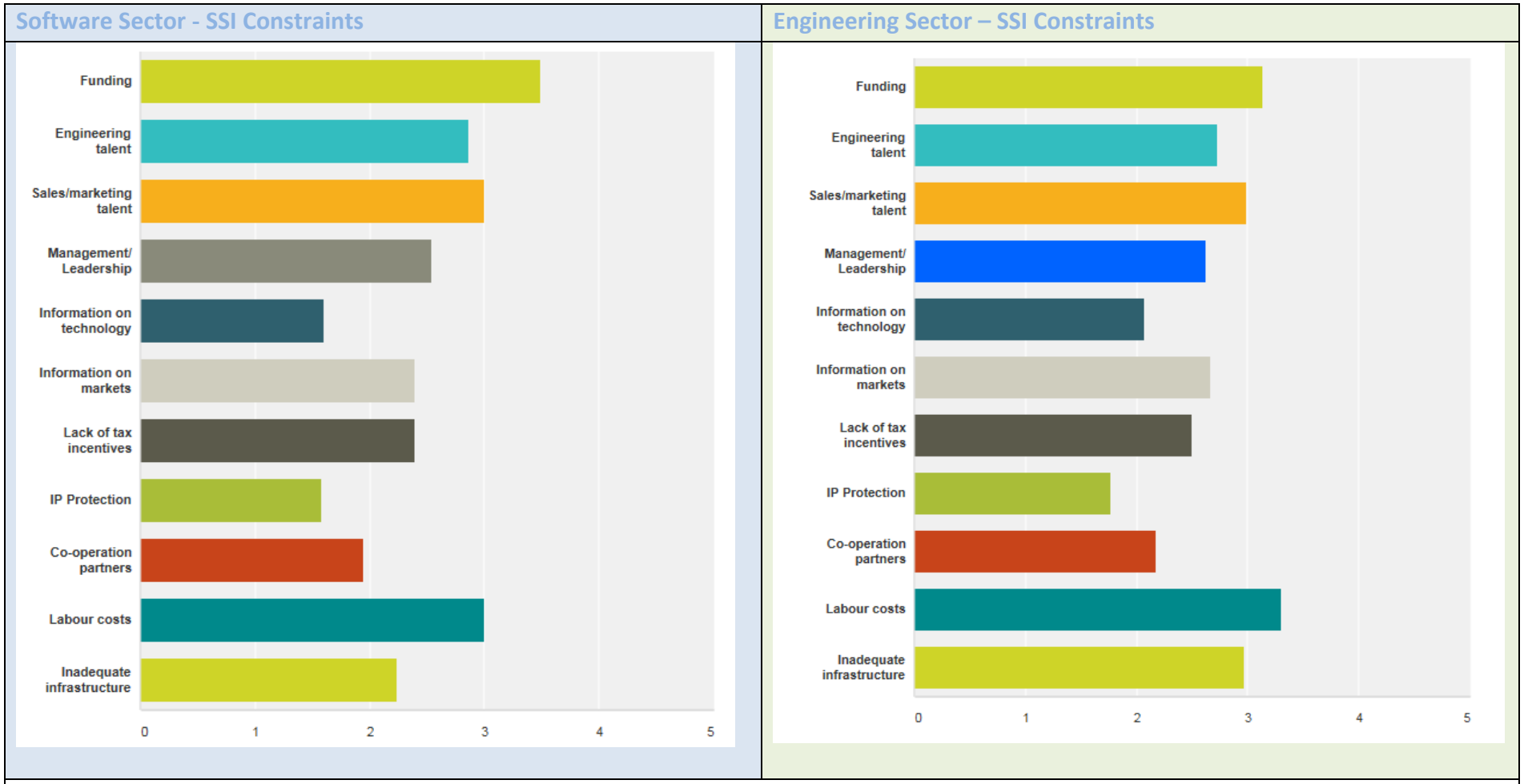

Figure 4-3: Key obstacles to innovation in the Software and Engineering Sectors

Data Analysis

Having outlined selected variables from the dual sector surveys, the following paragraphs chart the steps taken to analyse the quantitative and qualitative data employing the pragmatic philosophy to guide the research process.

Survey Analysis and Convergent Validation

In keeping with Jick's (1979) convergent validation, Bryman (2007) recommends that outputs should talk to each other, much like a debate in order to construct a negotiated account of what they mean together. To develop generalisable findings built on accepted theoretical constructs, the quantitative findings led to repeated examination of the qualitative data, resulting in the identification of contingencies which were compared with existing literature.

Chi-square

The model was tested using the standard chi-square test frequently associated with analysis of contingency tables. Chi-square is used in two ways. As a descriptive statistic, it measures the strength of association between variables, as an inferential statistic chi square weighs the probability that any association found is likely to be due to chance factors (Neuman, 2003).

A chi-square test was performed to test the null hypothesis of no association between SSI dimension fit, firm age and strategic intent in both sectors using the Pearson chi-square test of independence at the 0.05 significance level. The validity of the test depends on both the sample size and the number of cells (Elliott & Woodward, 2007). Employing Cochran's measure for goodness-of-fit, the approximation was deemed adequate if none of the expected cell frequencies is

less than one, and no more than 20% are less than five. Unlike many other tests, the finding of a significant result in contingency analysis does not explain why the results are significant so examination of the differences between observed and expected counts were undertaken in conjunction with the relevant qualitative analyses.

The qualitative data were used largely to supplement the quantitative results (Jick, 1979) for fit, the survey output became more meaningful when interpreted in that light. The integrated analysis employed Jick's (1996) guidelines for reporting interview data, key among which were: contextualising and interpreting quotes, balancing quotes and text and use of the most illustrative quotes rendered in written style (p.266-267). Strict attention was paid to the integration of the quantitative and the qualitative findings rather than using them for comparative purposes.

4.6 Summary

This chapter outlined the research design and methodology used to test the research propositions. It described the rationale for choosing mixed methods for data collection and triangulation. It communicated the theoretical and practical considerations involved in choosing the selected constructs. The source of the interview data and the data analysis process was discussed. The drafting and testing of the questionnaire and the administration process involved in the survey are outlined. The characteristics of key respondents are described. A pragmatic, mixed methods approach was deemed appropriate as in-depth senior executive

perceptions of the innovation system were sought alongside sector-wide views which justified the use of a survey.

A number of external or environmental factors inevitably affect the results of this type of study. As articulated in in the previous chapter, firms were asked primarily about their innovation activity during the period 2008-2010 which coincided with recession in Ireland. This is controlled for as all samples are from the same population.

Chapters five and six present the empirical analysis for the software and engineering sectors respectively.

Chapter Five

Software SSI Fit

SSI-dimension fit at the intersect with age and strategic contingencies

5.0 How conducive is the software SSI based on firm contingencies?

This chapter analyses the primary data collected on the software sector. It is presented in two distinct sections. Age and strategy contingencies are addressed in sequence using both the quantitative and qualitative data sets to assess perceived SSI-fit.

The central motivation of the thesis is to ascertain whether SSI dimensions are more or less conducive to innovative capacity as firms mature. A secondary consideration is the degree to which the SSI is more or less advantageous to firms of contrasting strategic dispositions. The CEO of an adolescent telematics firm emphasised the importance of strategic intent alongside the ability to access the necessary resources for innovation-led growth.

> *If you were to single out one dimension that makes a difference in a big way, it's strategic intent. And for that you need leadership and you need vision, and then you need the resources to back it. [S2x_CEL]*

Strategic aspiration emerged from the interviews as a potentially important determinant of firm-system fit. Based on a growth construct proposed by Autio et al. (2000), strategic orientation was added to the survey to generate a deeper understanding of the ways in which firms' internal context might influence perceived fit. A chi-square test was performed to test the null hypothesis of association between the software system dimensions, firm age and strategic intent as reported by the senior executives surveyed. This chapter highlights significant relationships, supported by micro data from the interview process.

Insights from the field research are linked to theory, and where apposite, associations between the manufacturing engineering (focus of Chapter 6) and software contexts are recorded. As anticipated, the two sectors differ in many respects; however a number of similarities emerged. Discussion of the findings is divided into two sub-sections, firstly those SSI dimensions significantly correlated with age and secondly, those correlated with strategic intent. Conclusions are developed and a discussion of managerial, policy and theoretical implications are outlined in the summary.

As identified in the methodology chapter, the system measures selected represent the output of literature review, exploratory interviews, peer review discussions and chief executive feedback from interviews and pilot surveys. The key dimensions identified in the qualitative phase of the research comprise; skills, funding, innovation types, sources, partnering and intellectual property protection.

5.1 Overview of Software Contingencies

Table 5-0 and Figure 5-0 present an overview of significant system dimension-age/strategy associations. The associations indicate potential to impact innovative capacity. The survey sought information on thirty dimensions of system fit. Using the Pearson chi-square test of independence, associations are analysed and illustrated using an alpha level of .05, significance at the .10 level is also noted. Contingencies are coded according to age and strategy as outlined below. Interview participants are labelled by cohort age.

- Age: young (y), adolescent (a) mature (m)

- Strategic aspiration to maximise: sales growth (g), profitability (p), technical superiority (t), the value of the firm for eventual sale (e) firm longevity/stability(l)

Table 5.0 summarises significant age contingencies across all system dimensions.

System Dimension	Age Cohort		Strategy Cohort	
Skills - Importance to performance				
Leadership/General Management	0.03 **	Adolescent+		
Foreign multinational presence				
Expands skills base	0.008**	Adolescent +		
FDI increases competition for talent	0.005**	Mature-	0.046**	Technology-
FDI expands lobbying potential	0.02**	Adolescent +		
Dilution of government support			0.077*	Profit-
Funding				
Sought external funding			0.064*	Technology+
Access to angel investment	0.048**	Young-		
Business expansion scheme			0.083*	Exit+
Bank capital	0.083*	Mature -	0.010*	Exit+
Venture capital	0.036**	Mature ne		
Enterprise Ireland grants	0.053*	Adolescent -		
Innovation vouchers	0.079*	Adolescent ne		
EI stabilisation funding	0.049**	Mature+		
Retained earnings	0.068*	Young-		
European Framework (FP7) funding			0.091*	Technology+
Innovation types, sources, IP				
Importance of customers	0.005**	Young ne		
Organisation/Marketing impact				
New/significantly changed sales/ distribution			0.035**	Revenue+
Improved production or service			0.027**	Longevity+
Import of innovation sources				
HEIs (product/process)			0.004**	Growth ne

Significant at 95%** and 90%*probability: Positive+, negative (-) and neutral/no effect (ne).

Table 5-0: Software SSI - Summary of Significant Contingencies

5.2.1 Age-Skills Dimensions

This dimension comprises the skills, education, experience and ingenuity associated with human capital. The availability and impact of technical, commercial and general management personnel, as well as the effectiveness of mechanisms for talent development in-company and through external provision are analysed. Table 5-1 summarises the results of chi-square tests examining the relationship between the skills dimension and firm age.

System Dimension	Contingency	Cohort
Importance of skills to company's performance		
Technical/Engineering Skills	0.48	
Business/Commercial Skills	0.16	
Leadership/General Management Skills	0.03**	Adolescent +
Ease of filling vacancies		
Qualified technical and engineering talent	0.90	
Qualified business/commercial talent	0.21	
Leadership/General management	0.25	
Effectiveness of training and development programmes		
Technical/Engineering	0.51	
Business/Commercial	0.27	
Leadership/General Management	0.93	
Impact of presence of foreign owned multinationals		
Expands skills base through education and training provision	0.008**	Adolescent +
Increases competition for talent in the sector	0.005**	Mature (-)
Increases pool of managerial talent available to the sector	0.495	
Expands the domestic customer base	0.712	
Expands the sector's lobbying potential	0.02**	Adolescent +
Dilutes government support for indigenous companies	0.31	

Significant at 95%** and 90%*probability: Positive+, negative (-) and neutral/no effect (ne).

Table 5-1: Software SSI Age-Skill Contingencies

Age-Skill Contingencies

Significant Contingencies are:

- The degree to which leadership/general management competence is perceived as advantageous to adolescent firm performance
- The extent to which FDI benefits adolescent firms through education provision
- The perception among mature firms that FDI increases competition for talent
- The extent to which adolescent firms perceive that FDI boosts lobbying capacity.

Leadership and General Management impact on adolescent firms

The adolescent cohort reports superior performance associated with leadership team competence. A chi-square test indicates a significant positive association with 72% of adolescent firms reporting positive effects [X^2 (8, n=119), =16.780, p=<.032], compared to levels of 48% and 47% for the young and mature cohorts respectively. This may be due to prior learning on the part of adolescent firm management teams enabling them to

effectively design and iterate strategies and business models. This aligns with the findings of Kim et al. (2012), albeit for foreign subsidiaries, who determined that for adolescent subunits, the liability of newness is offset by the strength of senescence whereas the liability of senescence is offset by the strength of newness. This signals a potential tipping point in firms' life courses at which adolescence confers the benefit of management team learning without the liability of age. It may also highlight the need for agency engagement to address opportunities for scaling.

The CEO of an adolescent firm referenced the benefit of ten years' experience informing the management team's ability to set the innovation agenda. However, despite the findings for the cohort, and the contention that managers of firms in high velocity industries are likely to be more proactive innovators (Nadkarni & Barr, 2008), the CEO implies risk aversion as measured by revenue stagnation over the three prior years (€2.5m 2006-08).

> *I think strategically what we want to do is revitalise ourselves with a new vision based on innovation. We've so much experience of the market from what we've done over ten years, there's no reason why we shouldn't move into being an innovative company.....we're at a little bit of a crossroads. I suppose ten years in existence, in some ways that's probably a natural milestone. Also, given the market conditions, there's a little bit of an external stimulus to look at where you're at and what the next ten years is going to be about. [S2.2_Or]*

FDI-driven educational provision perceived positively by adolescent software firms

Continuing the theme of positive system effects for adolescent firms, respondents indicate that foreign owned firms drive the expansion of the skills pool through demand for education and training. While there was strong agreement across the age groups on the skills base, a chi-square test indicated significant association (at .10) with 33% of adolescent firms reporting beneficial impact on the education and training infrastructure [X^2 (8, n=117),

=20.831, p=<.008] compared to levels of 12% and 14% for the young and mature cohorts. This lower ranking echoes interview narratives on the competing demand for skills among indigenous and foreign-owned firms.

Participant narratives on gaps in the talent pool are reflected in a survey of Irish businesses (IBEC, 2011) which cites software development among the main skills shortages, with Java developers and project management skills also lacking. In addition to overseas recruitment, a number of interviewees referenced outsourcing abroad. Similar constraints in Silicon Valley necessitated widespread offshoring of R&D in the 1990s (Saxenian, 2006). One adolescent company rated the availability of technically skilled talent in the previous three years (2006-08) as highly inadequate. They recruited largely from Eastern Europe and Asia.

> *We have had to go abroad. I think there's a major issue in Ireland over contention for the supply of, not just software engineers, but scientists in general [S2.2_Or].*

Mature firm perception that FDI presence aggravates the skills shortage

With respect to indigenous firms competing for talent against the perceived might of the FDI cohort, there was a significant difference in the perception of mature respondents, with 91 per cent indicating that competition for talent had a potent negative impact on innovation capacity [X^2 (8, n=116), =22.065, p=<.005], in contrast to 74 per cent of adolescent and 67 per cent of young firms reporting detrimental effects. Interview data supports the perception of systemic disadvantage among mature firms, albeit feedback across cohorts was broadly similar.

Beyond the technical domain, one mature firm CEO described his company's marketing function as underdeveloped, rather than attributing the problem to skill constraints. Competition from foreign multinationals is however seen to pose a retention challenge.

> *On the marketing side it's relatively easy to fill positions. Our company may be underdeveloped in that area but I don't think that's anything to do with being able to hire people. The main problem that we find is with retention of staff in competition with the MNCs. [S3.2_Oc]*

The CEO also highlighted the perceived difficulty confronting indigenous companies accessing talent, suggesting that opportunities for on-the-job training and development in indigenous firms are outweighed by the employment security, superior earnings and career paths offered by multinational subsidiaries.

> *From the point of view of the root of the [skills] problem, I think the biggest problem is that the good ones go to the MNCs for higher wages – I think the training might be better in indigenous companies but notionally you might think you would benefit more from the regimes that exist in the larger companies. [S3.2_Oc]*

An adolescent firm survey respondent reflected similarly: … *very difficult to hire technical staff in Dublin due to competition from Google* [S.2_Saa]

Adolescent firm perception FDI presence expands the sector's lobbying potential

With regard to policy advocacy, there was a significant disparity between age cohorts on the perceived impact of FDI. Sixty four per cent of adolescent firm respondents suggested that their FDI counterparts make a positive contribution, compared to 36% of young and mature firms [X^2 (8, n=117) =17.714, p=<.023]. This may relate to the number of adolescent firms that are motivated to become involved in sector initiatives when they have reached a certain scale or maturity.

The following section addresses significant age associations in the funding domain.

5.2.2 Age-Funding Dimensions

Sources of external finance for software sector innovation include debt funding (bank borrowings through loans, overdrafts and mezzanine funding); equity (public and private venture capital and informal/angel investment); and grant aid. Venture debt did not feature in the Irish system until the entry of the Silicon Valley Bank in 2012. Internal funding sources include retained earnings and personal funds. Access to equity markets through public offerings and trade credit were excluded from the survey, as neither had an impact within the reference period.

Some participants identified distinct requirements for funding risk and working capital, but others did not specifically attribute expenditure on innovation, potentially signalling the near-market focus of development. For young companies, sources of capital are used interchangeably as principals seek to build technology and commercial capacity in tandem. One founder CEO articulated the position of his young firm.

> *We don't really cost expenditure on innovation … it's evolving: there is no differentiation in terms of costs to innovate versus costs of doing business. [S1.1_Az]*

Banks are not typically equipped to finance start-ups, or even more established companies, without tangible forms of collateral. In the context that most Irish start-ups are knowledge based and absent tangible security for traditional debt financiers, or predictable cash-flows to service loans, venture capital can be the default solution. Informants indicated that knowledge, skills and a customer base with contracts for supply and service have hitherto not been considered acceptable forms of collateral. Growing government pressure on indigenous banks to fund high technology companies with potential to scale may lead to a new approach to the valuation of intangible assets.

In the context of global competition, a number of respondents suggest that constraints in respect of the supply and drip-feeding of risk capital sit in stark contrast to comparative funding in the US. One adolescent telecoms firm reported having raised three million dollars in venture finance, but cited how a Silicon Valley based competitor had later raised ten times that level at a much earlier lifecycle stage.

> *There is no shortage of innovation and market vision in Ireland...the simple and fundamental issue is a lack of substantial risk funding for indigenous businesses. As an example, a US competitor received over $30M in series A-venture finance, as opposed to $3M for my company, a whopping factor of 10. This allowed the competitor to enter the market a few years after we received our initial finance and yet catch us up and garner market share in a short period of time.*
>
> *Unfortunately, there's serious risk aversion in Ireland compared to the US. When we get over that, Ireland can build a substantial indigenous base. Otherwise, we just stick to being innovative small suppliers that may turn into early Merger and Acquisition targets. [Sy_Shen]*

Such disparities have consequences for firms' potential to scale and might be construed as a barrier to entry, or as an inducement to exit. Where venture capital is limited, trade sales represent the sole alternative when financial constraints inhibit scale (Dahlstrand and Cetindamar, 2000).

Another young firm respondent echoed the effects of drip-feeding and the consequences for competitiveness, restating the contrast with early stage funding for US competitors.

> *The main difficulty we ran into was not being able to raise funding while our US counterparts, who entered the market after us with weaker technology, were adequately funded, grew and exited. The main lesson is that if we want to pursue consumer/digital product business models, we need to move to the US to raise funding. [S_SyLoc]*

Underscoring the capital market limitations which preclude small firms from raising funds to support R&D, insufficient levels of risk capital and delayed access to funding featured in interviews. This feeds the argument that private sector investment focuses on short term returns and thus public investment is needed to compensate in order to secure longer term growth (Dahlstrand and Cetindamar, 2000). Investing in over 70 High Potential Start-Up (HPSU) companies each year, EI manages a portfolio of investments in over 1300 client companies (Enterprise Ireland, 2013) on behalf of the Irish government. An exploratory interview with a Dublin-based VC yielded a broader view of funding:

> *Money is a facilitator because it allows you to bring in more people and invest ahead of the curve, so you don't have to fund it by cash flow etc., but it is not the sole driver of success. This is one criticism I have of many entrepreneurs, 'if only I had five more people, I could go into the US'. In my view, they don't get it. They need to prove it [their business model] on a smaller scale and say 'Now all my sales people are at their full capacity. They're all making their bonuses. They have 5 customers they can service, but there are another 20 they can't get to. [VC_DEL Exploratory]*

Table 5-2 summarises results of tests of the relationship between funding and age.

System Dimension	**Contingency**	**Cohort**
Sought external funding	.570	
Funding requests rejected	.232	
Business Expansion Scheme	.791	
Business Expansion Scheme Impact	.369	
Angel Investment Access	.048**	Young (-)
Angel Investment Impact	.636	
Bank capital access	.436	
Bank capital Impact	.083*	Mature (0)
Venture capital Access	.535	
Venture capital Impact	.036**	Mature (-)
Hire Purchase/Leasing	.410	
Hire Purchase/Leasing Impact	.410	
Enterprise Ireland equity	.223	
Enterprise Ireland equity Impact	.217	
EI Grants (R&D, RTI, Vouchers, FP7, Stabilisation)	.053*	Mature +
Innovation Voucher impact	.079*	Adolescent (-)
R&D Funding/RTI Grant impact	.852	
Stabilisation funding impact	.049**	Mature +

R&D Tax Credits impact	.912	
European Framework impact (e.g. FP7)	.307	
Retained Earnings impact	.068*	Young ne
R&D Tax credits access	.288	

Significant at 95%** and 90%*probability: Positive+, negative (-) and neutral/no effect (ne).

Table 5-2: Software SSI Age-Funding Contingencies

There was no significant difference in the number of firms seeking external funding contingent on age. Overall 72% of 114 respondents had sought external finance within the reference period (this contrasts with 55% in the manufacturing engineering sector). With respect to age, 78% of young; 71% of adolescent and 67% of mature firm respondents sought funding within the reference period. The data indicates a tenuous association between maturity and the ability to fund innovation internally and suggests a preference on the part of older firms to reinvest profits to that end. One mature company CEO reflected the views of a number of participants on external funding with emphasis on time lags.

> *... the problem is every time we raised money, we were using it to cover mistakes rather than to go forward because it takes so long to raise it. If we started today and I say I need a million – I would have it spent by the time I got it. [S3.1_Sn]*

5.3.2.1 Age-Funding Contingencies

Among significant contingencies were;

- The scant impact of bank and venture capital funding on mature firms
- The relative ease of access to EI grants by adolescent firms
- The perceived positive impact of EI stabilisation funding on mature firms
- The difficulty accessing BES funds for investment capital for young firms
- The negligible impact of retained earnings on young firms' capacity to innovate
- The non-impact of the EI innovation voucher scheme on adolescent firms
- The non-impact of venture capital on mature firms.

Venture Capital

The survey indicated that 95% of mature companies rated VC as having zero impact on their capacity to fund innovation in the reference period – although significant differences emerged across age groups [X^2 (6, n=74), =13.5, p=<.036] with 14% of young firms rating VC as highly impactful against only 4% of mature firms. While the survey data reflects the views of informants that VC is not an important enabler, the contrasting impact reported by younger firms is noteworthy and may be indicative of the greater availability of public VC administered by EI for young firms demonstrating potential to scale. One test for potential is that recipient firms must raise matching funding.

A young telecoms infrastructure provider described how the founders' exit from their first venture provided the matching funding that rendered the company eligible for EI investment. The agency provides matching funds subject to strict eligibility criteria. In many cases the associated paperwork and processes are cited as onerous.

> *EI gave us initial matching funding – we put in €300k personal funds based on our exit from the previous business and they matched that. All of the various programmes help but the application process is demanding. [S1.1_Az]*

Interviews revealed accounts of companies who succeeded in securing early stage VC funding and those who subsequently came to regard rejection as a lucky break, as their technologies failed to launch successfully. Firms questioned their investor-readiness and the viability of their business plans as evidenced by the comments of a mature firm CEO.

> *We never had a problem raising money we had a good story we genuinely believed it at the time, the business plan was great - but it was the biggest load of fiction. I had a number of mentors at the time [and] they were all saying go for it.... If I were going back seven years I would put 'me' against the wall and say 'look this is never going to happen'. It was so blatant, that it was never going to happen. [S3.1_Sn]*

The experience of the founder-CEO of a telecoms infrastructure firm in relation to accessing venture capital pointed to caution on the part of VCs.

> *The feedback was that we were too early and needed to establish a customer base. In reality I'm very happy that we didn't get funding three years ago because we would be toast by now. We would not have achieved the targets that we had set out we would be in a very different place now. [S1.1_Az]*

The primary research yielded mixed views on VC - some firms had succeeded in securing investment, but others regretted the absence of *smart investors* with technology, market and product expertise backed by networks of experts in the relevant area (Dahlstrand (Dahlstrand & Cetindamar, 2000; Norton & Tenenbaum, 1993). Some participants suggested that, despite their success in securing funds, they had not been *investor-ready*, due to inadequate business models or fledgling technologies. Consistent with Stinchcombe's (1965) liability of newness, the challenge associated with the successful launch and growth of a new (if not radical) technology is exacerbated by firms' lack of credibility and demonstrable track records (Hoffman, Parejo, Bessant, & Perren, 1998).

> *In terms of the start-up VC funding that we got……we made a plan around our product which was based on a new standard. We built an engineering team of about ten people and we also built up other areas with key capability. We had about four or five people in marketing and product management, roles like that. As it turned out we were too early to the market - nobody was interested, it was two years before we did our first material deal on the original product roadmap. [S1.2_Ro]*

This last point was echoed by a number of informants in respect of the development and diffusion of frontier technologies where commercialisation occurred considerably later than envisaged. Consistent with the technology adoption lifecycle, early stage companies frequently described the challenge of 'the valley of death' or 'crossing the chasm' (Moore, 1999), whereby the ultimate validity of the technology equated to companies' domain expertise, as larger firms were more adept at commercialisation, perhaps revealing coincident liabilities of newness and smallness (Child and Kiezer, 1984; Stinchcombe, 1965).

Angel Investment

Angel investment has varied impacts on age cohorts, with 87% of young respondents rating access as difficult, compared to 57% of adolescent and 67% of mature firms [X^2 (8, n=25), =13.965, p=<.048]. Given that young firms may be in a weaker position than their older counterparts in terms of liabilities affecting potential returns on investment, investors may prefer candidates with stronger management and financial track records. Hoffman et al. (1998) refer to calls for governments to expand their role in providing subsidised medium to long term R&D finance on an equity basis. In the case of the BES, for example, the government provides tax relief on investments up to a maximum of €150,000 in each tax year - relief is given at the individual investor's highest rate of income tax.

One CEO discussed the availability of angel funds following the flotation of an Irish company in his sector (e-learning), demonstrating the potential value of a system endowed with capital generated by IPOs and trade sales where high net worth individuals join the angel investor community. This signals the potential of serial entrepreneurs among sources of start-up funding allied to capacity to offer domain expertise and access to networks.

> *… CBT Systems had made a fortune for a number of people and Riverdeep had floated. We were riding the wave, we were in the right place at the right time, if we had waited another few months we wouldn't have raised a penny. [S3.3_Wb]*

Assessing financial drivers of technical entrepreneurship, Eisenhardt and Forbes (1984, p.32) cite 'the availability of venture capital, the savings rate, the existence of a wealthy elite and access to a stock market'. In respect of the wealthy elite, the capital generated in Ireland by previous exits can be described as emergent in respect of proving adequate funding for next generation firms. Despite a number of indigenous firm exits in the last decade, the scale of funds generated is insufficient to plug the gap in the software system's capital needs, this may be intensified by niche crowding (Aldrich, 1999) among knowledge-based firms, with numbers seeking funding far-exceeding the system's capacity to provide it.

Grant Aid

In the context of EI's R&D, training and capability building budget of €77.7m in 2010 (Enterprise Ireland, 2011), informants suggest that agency funding had a mid-range impact on their ability to innovate encompassing EI, County Enterprise Boards and Inter Trade Ireland as public sources. While marginally above the conventionally accepted 95% threshold of significance, there is an association between EI grant aid for innovation and firm maturity [X^2 (4, n=77), =9.328, p=<.053]. Fifty four per cent of mature companies rated EI grants as easily accessible, against 41% of young and 29% of adolescent firms. An

assessment of specific funding types produced another indication of significance - an association between stabilisation funding and the number of mature firms who saw it as having a significant and positive impact [X^2 (4, n=70), =9.513, p=<.049] on their capacity to innovate in the reference period. A significant number of respondents engaged in that fund for which detailed business plans constitute a key element of the qualification process.

Innovation Vouchers

In respect of innovation vouchers, there was an association above the significance threshold [X^2 (4, n=75), =8.381, p=<.079], with 85% of adolescent respondents ranking them as having no impact compared to 65% of mature and 55% of young firms perceiving them as being of limited value. Two respondents cited significant difficulty with the scheme:

> *We got an innovation voucher in 2009 for €5k. Had to give it back, as we found it difficult/time consuming to get any of the colleges to do the work. We outsourced the job to India for €400 [S_SySta6]*

An adolescent firm CEO commented on the research Technology and Innovation (RTI) fund available through EI. Companies afforded High Potential Start-Up (HPSU) status based on a new or innovative and exportable business idea in the manufacturing or internationally traded services sphere are eligible for RTI funds if they can demonstrate adequate matching resources based on two year cash flow projections.

> *In the past, there have been huge sources of R&D funding. We've principally had it through Enterprise Ireland RTI. The ratios are a bit odd. It's 35% spend in some cases and 50/50 in others, so it's not as lucrative as you might think. But there doesn't seem to be a lot of funding available at the moment, your only option is whatever's there plus commercial venture funds, which we wouldn't be on for [S2.2_Or].*

Retained earnings

Findings for the mature category contrast somewhat with prior research, as the survey found that internal funds are Irish software firms' primary source of finance (Hogan and Hutson, 2005; Mac an Bhaird and Lucey, 2010), albeit that no distinction is made between working and risk capital.

A mature company CEO recounted multiple rounds of funding including friends and family, public and private equity investment. Based on this experience, he suggested that a more iterative, bootstrapping approach to funding and early commercialisation would offer a superior route to growth throughout the life course of the business.

> *We've had a bit of self-funding and equity funding (Eircom Enterprise fund, EI funding and a bunch of investors). I've had very supportive backers – I fell into that as opposed to telling you that's what we should have done. The way we should have done it was to go out and get orders in the marketplace and then get the minimum family, friends and seed capital and nothing else. You have to create something that 'others want to get in on' as opposed to the other way around. [S3.1_Sn]*

Lean Start-Up

The above position is consistent with emerging Lean Start-Up thinking (Blank, 2005; Maurya, 2012, Ries, 2011), whereby software companies are encouraged to build a Minimum Viable Product (MVP) and engage in bootstrapping prior to seeking external funds. Echoing this, the CEO of one adolescent software company suggested that the Irish funding environment was adequate, offering a somewhat uncharacteristic assessment of the landscape: he articulates the lean approach.

> *Any business I've developed it has always been self-financed, except whenever self-financing was matched by government agencies, so 50:50. …. If I was working on a*

project that was going to take millions to develop I would never do it. I wouldn't take any investors, I couldn't be bothered, if it takes nine months to develop .., it's going to take six years to get it to market. I'll leave that to the academics. [S2.3_ Gt]

Bank funding

In relation to bank funding, 81% of mature firms rated access as difficult compared to 57% of young firms. Although significant at the 90% level, this suggests the differential availability of innovation funding across cohorts [X^2 (8, n=75), =13.96, p=<.083]. While interviews presented limited evidence of bank finance, the higher impact of short term bank debt on young firms may reflect the retained earnings constraint typical of newer firms compounded by the absence of alternatives, since raising external equity depends on the capital return an investor can expect (Cressy and Olofsson, 1997). The CEOs of young and mature firms share similar views about bank funding.

We never really had any discussions with the banks. For some reason I have in my psyche, that's not a way to go. [S1.1_Az]

Bank funding (laughter).Do banks fund? Not just now, did they ever? We looked at a couple but it was pointless. It's not that they don't understand the business, they are not in the business of taking risk but they don't admit it…. [S3.1_Se14]

Interviews revealed that mature companies enjoyed greater success in securing bank funding from overseas institutions, and that by way of exception in Ireland, banks were seen as a source of working rather than risk capital. Mature company perceptions differed somewhat, they referred to the positive attitude of UK and US-based banks.

We have been quite successful in raising mezzanine type bank funding in the UK. We have very little from the Irish banks - an overdraft facility of €100k, we got that up from €50K last year. We have about £2.8m debt in the UK. We have a guy there who will securitise software support contracts. Irish banks don't have the expertise and

the wherewithal to do that. When you have a software support contract you have fixed payments going into the future – one client is a million a year for the next 5 years so we can borrow against that, principally to make acquisitions [S3.2_Oc].

We talked to the banks here – they wouldn't support us to lease computers as we hadn't made any money. We went to Silicon Valley Bank, …, we met guys in chinos who gave us coffee and asked whether we were 'pre-revenue or pre-profit'. I asked whether it would make a difference and they said no, they were just curious. The environment is so different for companies like ours over there [S3.3_Wb].

The CEOs of adolescent and mature firms reflected the need for a systemic approach to working capital in the Irish banking mind-set. Such funding would primarily cover working capital requirements alongside intermittent needs to finance renewal or expansion efforts.

The Irish banks ask whether we have any unencumbered property and when we say no – the door closes, even cash-flow and projects don't have any impact on our discussions with them. Another thing that stunts the growth of this sector is that there's no working capital finance, there's no regular finance available which is why you must end up with the VCs. Equity is suitable for financing things like R&D but for working capital requirements, it's not. I cannot understand why we don't have it. I think that if the industry had access to the equivalent of two months' revenue, it would grow a lot faster. [S3.2_Oc]

The lines between funding for innovation and working capital are somewhat blurred. The banks' apparent inability to deal with the moral hazard implicit in software businesses, as distinct from more tangible (e.g. property) investment was a consistent theme in interviews. While there was limited evidence that software companies were discouraged from making loan applications for fear of rejection (Kon and Storey, 2003), the wider perception was that the banking system was a poor fit, supported by empirical research in the Irish software

sector suggesting that in many cases, software executives prefer outside equity to debt (Hogan and Hutson, 2005). An alternative interpretation coincides with the view of Han et al. (2009) that discouraged borrowers generally demonstrate a higher risk profile than other capital seekers, creating a stalemate between the banks and investment candidates.

5.2.3 Age-Innovation Dimensions

This section illustrates significant age contingencies in relation to innovation types, sources, protection of intellectual property and partnership dimensions.

In the context of market- or customer-led innovation, the implication that customer need equates to market validation is frequently not borne out, many informants indicated that products initially designed to fit niche requirements prove unscalable in the long term. One adolescent company CEO reflects negatively on *technology push* referring to the lesser success of research-led initiatives in comparison to customer-driven development.

> *Our solution has very much been driven by customers, it came out of the customer base rather than us dreaming it up in the lab and putting it out there. So that's probably a good thing because, it's quite focused on addressing a real need, a paying need. We really need a kind of proof positive to ourselves. We can't afford to do much beyond that [S2.2_Or].*

The same CEO alludes to the company's financial constraints, the need to get past its current *crossroads* status, and the desire to innovate beyond existing, contract-based customer requirements. This emphasises the risky nature of basic technical research which can result in underfunding by private firms.

> *The big challenge is the investment. We've done it in an agile way in that we've innovated on the back of our customer base, which is a way of lowering the bar in terms of the amount of funding. But if you're targeting a serious R&D initiative, the*

big challenge would be the investment associated - the cost and the resources. [S2.2_Or].

In keeping with lean-thinking, another adolescent company CEO articulated a value-based view of innovation with a primary focus on profit. As the only non-engineer among the software CEOs interviewed, he prioritised market over technical orientation. With the benefit of hindsight, other adolescent firm informants concurred with this view.

We could talk about our early stage, even pioneering, implementation of Software as a Service (Saas) but because I'm not a technology person, I can sell both the technology and the outcome .....the software is only a tool to fix a problem. Unfortunately what people see is a [technical] solution. The less innovation the better in my view. It doesn't have to be revolutionary ..... you only need to be that much better than your competitor, you have to be that bit more innovative, you don't have to invent something that will take you two years to bring to market, speed to market is more important. I don't want to be an innovative entrepreneur; I want to be a rich entrepreneur. [S2.3_Gtm]

Table 5-3 indicates significant contingencies. The 56 variables spanning innovation types, sources, IP and partnership dimensions uncovered just one significant variable.

System Dimension	Contingency	Cohort
New-to-market products or services before competitors	.653	
New-to-firm products or services available from competitors	.883	
New-to-market processes before competitors	.872	
New-to-firm processes already employed by competitors	.570	
Developed mainly within your company	.674	
Developed by company with other companies/ institutions	.169	
Developed mainly by other companies or institutions	.411	
Innovated through acquisition of machinery, equipment, software	.696	
New or significantly changed company strategy	.601	
New/improved systems for information, knowledge & skills	.153	
Major changes to the organisation of work within the firm	.430	
New/significant changes in relations with other firms/institutions	.928	
Advanced management techniques (e.g. Lean)	.312	
Significant changes in how product is offered to the market	.969	
New/significantly changed sales or distribution methods	.906	
New/significantly changed marketing methods	.721	
Apply for a patent	.249	
Register a trademark	.582	

Claim copyright	.643	
Patenting to prevent duplication/facilitate licensing	.295	
Patenting to deliver royalties	.370	
Copyrighting/trademarking	.275	
R&D (in-house or external)	.544	
Employees recruited from competing organisations	.797	
Employees or contractors qualified to PhD level	.398	
Technology licensed from others	.332	
Publications or technical meetings	.646	
Reverse engineering & patent disclosures	.823	
R&D (in-house or external)	.238	
Employees recruited from competing organisations	.165	
Employees or contractors qualified to PhD level	.484	
Technology licensed from others	.197	
Publications or technical meetings	.423	
Reverse engineering & patent disclosures	.178	
Increased range of products/services	.200	
Entered new markets or increased market share	.315	
Improved quality of products/services	.706	
Improved flexibility of production or service provision	.838	
Improved capacity of production or service provision	.629	
Reduced labour costs per unit output	.920	
Reduced materials/energy per unit output	.376	
Consolidated range of products/services	.369	
Co-operation on innovation activities (Yes/No)	.526	
Internal to your company	.239	
Suppliers of equipment, materials, components or software	.168	
Clients or customers	.005**	Young (0)
Competitors or other companies in your sector	.884	
Consultants, commercial labs or private R&D organisations	.691	
Industry networks	.457	
Government or public research institutes	.471	
Higher Education Institutions (recruitment/talent development)	.141	
Higher Education Institutions (product/process-projects)	.220	
Enterprise Ireland	.102	
County Enterprise Boards	.778	

Significant at 95%** and 90%*probability: Positive+, negative (-) and neutral/no effect (ne).

Table 5-3: Software SSI Age-Innovation Contingencies

Customers as sources of innovation

While much research has focussed on collaboration mechanisms that facilitate innovative output, young firm respondents reported customer input as having lower impact on innovation than adolescent and mature firms. A chi-square test indicates significant

association with 35% of young firms reporting that clients had a neutral effect on innovation over the reference period [X^2 (8, n=77), =22.136, p=<.005].

The Customer-Technology Nexus

As exemplified below, firms emphasise the collective importance of product, process and service technologies to performance. The sales director of one young business process software company highlighted technology as its core value, which predetermined potential viability in terms of being able to attract funding, employee talent and customers.

> *The technology is our key enabler. The reason being, the technology enabled us to attract the investment, the salespeople and also the market. The product offering (the technology), has allowed us gather those constituent parts along the way. The marketplace is obviously important but fundamentally, it boils down to the technology. The other bits were contributors, catalysts but not the core. The technology is what will deliver year on year [S1.0_VS].*

A mature firm founder echoed this qualification, speaking of how his technology focus had yielded to an emphasis on market share. In line with previous accounts, he suggests that technological prowess is pivotal but, at a certain stage, domain expertise takes precedence. One might interpret innovation as being more informed by market factors at later stages of the development lifecycle, when the technology reaches maturity and the *solution* (e.g. design, implementation and support services) is developed in line with current and emerging customer needs. While core technology is perceived as pivotal to firm value, implementation, customisation and services deliver on-going value and differentiation.

> *In terms of the balance of our growth – growth to date has definitely been down to our technology base and our products and the skill of our engineers. We are an engineering-led company and that has proven to be a long term recipe for non-failure, rather than success. That's why we've survived when the marketing bubble*

companies failed. Over the last 3 years, part of our growth has been through acquisition but again, we are selecting engineering led companies, we are buying them for their engineering IP and their specialist expertise in our area – we are buying them for their customer base as well. The tipping point happened at the end of 2006 where the commercial plank outweighed the technology expansion so we are now engaged in buying market share. .... our proposition is changing from pure technology to being a company that can deliver. [S3.2_Oc]

The CEO of an adolescent firm involved in engineering support systems for manufacturing referred to customer led innovation and how that was funded externally through EI's RTI programme matched by working capital. He earlier described how the company was at a strategic crossroads: having initially adopted a risk adverse approach, management was challenged as to the next phase of the company's life course.

We're innovating within the customer base which has strengths and weaknesses. We were spending between 5% and 10% of working capital, it has been proactive. It was RTI sponsored. We did one serious project and it didn't really work out, but we've done a low risk one which is much more commercially successful with EMI [Enterprise Manufacturing Intelligence], but you know... that is part of the issue for this company. How do you leverage it? I don't think we've any choice in the matter because, …… we're at a decision point between continuing in classic systems engineering mode with a lot of big systems out there to be engineered … or taking time to strategically pursue innovation through R&D and get to a different place. [S2.2_Orb].

The founder-CEO of an adolescent telecoms software company commented on the limited potential to protect or differentiate the firm based on emerging technology. Efforts to define intellectual property rights in software continue to stretch the limits of existing legal structures. In a theme that resonates with other informants commenting on wider

technological innovation, the CEO referred to significant reliance on relationship management and customer service.

> *I think the value of the business has been in the relationship with [our customers] O2 and Vodafone. That was key to this whole business because the technology wasn't there. There was no protection of it, there was no IP behind it, it was just an idea, and it couldn't be protected. The only protection was to deliver a top quality service to Vodafone and O2 to their customers. [S2.3_Gtm]*

The CEO of a mature company described the approach to building their most recent platform, advancing the notion of bringing customers on board with basic product functionality and nurturing them carefully through the product lifecycle. The lean approach to building a minimum viable product (MVP) with a readiness to reorient the offering according to customer needs (Blank, 2005; Ries, 2011) delivers the twin benefits of a revenue stream to fund development, combined with live validation, testing and fast iteration of the product. The adoption of such leaner organisational forms could support young firm entry as they attack more established organisations that have become inefficient in their use of resources (Aldrich and Auster, 1986; Sorensen and Stuart, 2000).

> *Crossing the Chasm emphasises – instead of rushing the building of the product, get it out there to your first five customers and then ramp it up -use whatever resources you need to get it to 1st, 2nd 3rd base – over a two year timeframe we built out the software. It's the quality of the product that drives the growth – not the quality of the sales team. The initial growth comes from the sales team but if you want to get serious global growth it has to come from the adoption of the product. [S3_Sen]*

This echoes earlier points about the parallel functions of technology and product bundles, each of which iterates with the product lifecycle and company life course, building on the

marketing concept that a single solution offers less value than one that can be combined with others to deliver greater functionality.

The foregoing analysis discussed the contingent effects of age on software SSI dimension fit. The following section enumerates strategic contingency effects.

5.4 Strategy Contingent Effects

The effect of growth intent on firm performance has been the subject of much interest in the literature (e.g. Baum and Locke, 2004; Berger and Udell, 1998; Ucbasaran et al., 2008). Following analysis of semi-structured interview output, a measure of firms' growth aspirations was included in the survey to assess the degree to which it might affect SSI fit.

5.4.1 Strategy- Skills Dimension

The following analysis of workforce skills dimensions integrates the output of interview and survey analysis to illustrate perceptions linked to firms' strategic aspiration. As with the tests for age, the availability and impact of technical, commercial and general management personnel were addressed in addition to talent development.

Table 5-4 summarises perceived skill and development contingencies.

System Dimension	Contingency	Cohort
Importance to company's performance		
Technical/Engineering Skills	.333	
Business/Commercial Skills	.268	
Leadership/General Management Skills	.733	
Ease of filling vacancies in the last three years		
Qualified technical and engineering talent	.560	
Qualified business/commercial talent	.104	
Leadership/General management	.785	
Effectiveness of training and development programmes	.051**	Technology (-)
Technical/Engineering	.661	
Business/Commercial	.680	
Leadership/General Management	.135	
Impact of presence of Foreign owned multinationals		
Expands skill base through education & training provision	.952	
Increases competition for talent in the sector	.046**	Profit (-)
Increases managerial talent available to the sector	.198	
Expands the domestic customer base	.777	
Expands the sector's lobbying potential	.279	
Dilutes government support for indigenous companies	.077*	Technology (-)

Significant at 95%** and 90%*probability: Positive+, negative (-) and neutral/no effect (ne).

Table 5-4: Software SSI Strategy-Skills Contingencies

5.4.1.1 Strategy-Skill Contingencies

Significant contingencies relate to the experience of those firms seeking to maximise profit and those seeking to maximise the technological superiority of their offerings;

- Firms seeking to maximise technical superiority perceive current commercial training and development offerings to be of limited benefit to their innovative capacity
- The technology-led cohort perceive that government support for foreign-owned software multinationals is significantly and negatively related to the resources available to indigenous firms
- Firms seeking to maximise profits perceive that the presence of the foreign-owned sector increases competition for the limited supply of qualified talent.

Business and Commercial Skills

There was a significant difference among cohorts as to the perceived effectiveness of upgrading business and commercial skills. 42% of companies seeking to maximise technical superiority recorded available programmes as minimally effective, against an average of 17% across all strategy types [X^2 (16, n=95), =26.230, p=<.051]. Learning and adaptation are widely identified as critical to firm growth, similar to extant research findings, age and experience are among the factors driving absorptive capacity (Geroski, 1995). With respect to competing for talent with FDI firms, there was a significant difference in perception among respondents seeking to maximise profitability, with 68% indicating competition with FDI as having a significant negative impact against an average of 36% across all strategy types [X^2 (16, n=116), =26.626, p=<.046].

The CEO of a mature firm suggests that indigenous companies need to engage actively in the battle for scarce talent, especially with higher education institutions.

> *My sister was working with Maynooth [University] when we originally got involved there, that contact allowed us to get the pick of the students but that's not the norm. One of the disadvantages that indigenous companies face is that we don't get the pick of the students; they are siphoned off by the multinationals. [S3.2_Ocu]*

Informants referenced the higher wages in the FDI sector, and the apparent short-sightedness of candidates to potentially greater role autonomy in indigenous firms. As outlined by the CEO of a young firm, competition from larger players demands a niche approach to recruitment as larger competitors are better positioned in respect of remuneration while exerting stronger influence over institutions as referenced earlier.

> *We promote other things that employees find attractive rather than have the big players relieving us of our guys for a higher salary to work for the likes of JP Morgan. At a certain age €10k seems like a huge amount of money. [S1.2_Roc]*

Competition for Technical Talent

While above the 95% significance threshold, 46% of firms aspiring to technical superiority suggest that FDI restricts the human capital supply to indigenous firms, the measure across all strategic cohorts for this dimension was 24% [X^2 (16, n=118), =24.588, p=<.077]. Large firms' strategic decisions are known to have a bearing on the levels of technical activity and economic competitiveness within sectors (Pavitt, 1990), an argument that appears to align with the survey and interview data.

5.4.2 Strategy-Funding Dimensions

Table 5-5 summarises perceived funding contingencies.

System Dimension	Contingency	Cohort
Sought external funding	.064*	Growth+
Funding requests rejected	.741	
Business Expansion Scheme	.203	
Business Expansion Scheme Impact	.083*	Exit+
Angel Investment Access	.626	
Angel Investment Impact	.497	
Bank capital access	.544	
Bank capital Impact	.010**	Exit+
Venture capital Access	.627	
Venture capital Impact	.809	
Hire Purchase/Leasing	.806	
Hire Purchase/Leasing Impact	.806	
Enterprise Ireland equity	.143	
Enterprise Ireland equity Impact	.139	
EI Grants (R&D, RTI, Vouchers, FP7, Stabilisation)	.824	

Innovation Voucher impact	.576	
R&D Funding/RTI Grant impact	.440	
Stabilisation funding impact	.213	
R&D Tax Credits impact	.569	
European Framework impact (e.g. FP7)	.091*	Technology+
InterTrade Ireland impact	.649	
Retained Earnings impact	.185	
County Enterprise Board access	.212	
R&D Tax credits access	.315	

Significant at 95%** and 90%*probability: Positive+, negative (-) and neutral/no effect (ne).

Table 5-5: Software SSI Strategy-Funding Contingencies

5.4.2. Strategy-Funding Contingencies

Significant associations in regard to funding and strategic contingency include:

- A positive association between those seeking to maximise technology and external funding requests
- A positive association between those seeking to maximise technology and EU Framework impact
- A positive association between firms seeking to maximise exit value and the importance of bank and BES funding.

Technology Innovation and External Funding

Firms expressing intent to maximise technological superiority lead the preference for external funding at 92%[4]. This may suggest greater emphasis on R&D investment. The lowest proportion of external funding (at 47%) was sought by those firms intent on maximising exit value, in contrast with the average level of 72% across all strategy types, which may indicate reluctance among owners to dilute equity while mitigating the risk of reduced autonomy.

Exit intent and Bank Funding

With respect to bank funding, a chi-square test indicates a significant and positive association between the importance of bank funding for innovation and the intention to maximise exit value [X^2 (16, n=75), =32.065, p=<.010]. Forty three per cent of companies

[4] Parallels engineering

indicating exit intent ranked bank funding as significantly important to innovation in the research period, compared to an average of 8% across strategy groups. The distinct impact of non-equity funding may reflect the desire to maximise value and owner equity in advance of a prospective exit event. One adolescent firm CEO described the need for state funding of working capital, adding that his firm had secured a debenture [medium-long term loan without collateral] in 2008. Prior to the interview, the firm had been in talks with an Israeli company regarding a trade sale but had failed to reach agreement.

> *The state doesn't have a venture fund for companies like us….they're doing it in the UK, and if you were serious in this country about indigenous industry you would have that. I feel the bias in Ireland is to FDI. We have a loan at the moment. It's been good, but it was put in place pre-September '08 and backed by the history of quite good banking from our end. [S2.2_Orb]*

Business Expansion Scheme

Although above the 95% threshold, there is an association between Business Expansion Scheme (BES) impact and strategic intent [X^2 (8, n=72), =13.96, p=<.083]. Fifty seven per cent of firms seeking to maximise exit value perceived BES funding as having a positive impact on innovation capacity in the reference period, compared to an average of only 18% across all groups. BES funding is attractive in that it delivers a capital injection of up to €2M with limited equity dilution or oversight by investors, providing greater managerial latitude than would be the case with angel or VC funding. The CEO of a mature firm illustrates the effectiveness of BES as an interim source of capital and refers to lower entry costs for software start-ups which may lead to more promising outcomes for this type of funding.

> *…in the middle part of our story 1997 – 2001 we raised 750K in BES and then did a further £250K when it came around again. I think we are one of the BES success stories. It's been great for us… They have extended BES to €2M, I think that's an*

adequate amount and I think we will see the fruits of that in 2 or 3 years' time - if and when software companies take it up. €2m is enough to get traction. The entry cost of setting up a software business has dropped now with all the cloud stuff. It will allow many more companies to avoid the clutches of the VCs. [S3.2_Ocu]

5.4.3 Strategy-Innovation Dimensions

This section assesses significant strategic contingencies associated with innovation types, sources, intellectual property and partnership dimensions. Table 5-6 summarises significant strategic contingencies across all system dimensions.

System Dimension	Contingency	Cohort
New-to-market products or services before competitors	.612	
New-to-firm products or services available from competitors	.347	
New-to-market processes before competitors	.312	
New-to-firm processes already employed by competitors	.466	
Developed mainly within your company	.375	
Developed by company with other companies/ institutions	.709	
Developed mainly by other companies or institutions	.847	
Innovated through acquisition of advanced machinery, equipment, software	.472	
New or significantly changed company strategy	.619	
New/improved systems for information, knowledge & skills	.296	
Major changes to the organisation of work within the firm	.532	
New/significant changes in relations with other firms/public institutions	.467	
Advanced management techniques (e.g. Lean)	.694	
Significant changes in how product is offered to the market	.138	
New/significantly changed sales or distribution methods5	.035**	Growth +
New/significantly changed marketing method	.227	
Apply for a patent	.838	
Register a trademark	.316	
Claim copyright	.526	
Patenting to prevent duplication/facilitate licensing	.166	
Patenting to deliver royalties	.181	
Copyrighting/trademarking	.567	
R&D (in-house or external)	.594	
Employees recruited from competing organisations	.396	
Employees or contractors qualified to PhD level	.768	
Technology licensed from others	.859	
Publications or technical meetings	.615	
Reverse engineering & patent disclosures	.839	
R&D (in-house or external)	.566	
Employees recruited from competing organisations	.277	
Employees or contractors qualified to PhD level	.952	
Technology licensed from others	.943	
Publications or technical meetings	.591	
Reverse engineering & patent disclosures	.428	
Increased range of products/services	.742	
Entered new markets or increased market share	.277	
Improved quality of products/services	.225	
Improved flexibility of production or service provision	.848	
Improved capacity of production or service provision	.027**	Longevity +
Reduced labour costs per unit output	.198	

[5] As for engineering

Reduced materials/energy per unit output	.107	
Consolidated range of products/services	.367	
Co-operation on any innovation activities	.100	
Internal to your company	.590	
Suppliers of equipment, materials, components or software	.681	
Clients or customers	.823	
Competitors or other companies in your sector	.515	
Consultants, commercial labs or private R&D organisations	.846	
Industry networks	.474	
Government or public research institutes	.489	
Higher Education Institutions (recruitment/talent development)	.567	
Higher Education Institutions (product/process-related projects)	.004**	Growth ne
Enterprise Ireland	.534	
InterTrade Ireland	.558	
County Enterprise Boards	.803	

Significant at 95%** and 90%*probability: Positive+, negative (-) and neutral/no effect (ne).

Table 5-6: Software SSI Strategy-Innovation Contingencies

5.4.3.1 Strategy-Innovation Contingencies

Significant association with respect to strategic contingencies are;

- Firms intent on maximising sales growth demonstrated significant adoption of new or significantly changed approaches to sales and distribution methods
- Firms seeking to maximise stability and longevity rated improved production capacity and service provision methods as having high impact
- Firms aspiring to maximise growth indicated that universities and Institutes of technology were not important sources of product/process related innovation.

Firms aspiring to maximise sales growth indicated significant differences in innovation in their sales and distribution methods, with sixty per cent rating the impact of these innovations highly [X^2 (16, n=89), =22.597, p=<.035] compared to 10% across alternative strategy types. Given the link between effective sales and company growth, this relationship might be anticipated. The CEO of an adolescent company with a clear focus on commercial outcomes referred to designing products and prioritising profitable routes to market.

> *Market accessibility is highly significant; access to market was our key to success. People make it difficult for themselves. If I was designing a business tomorrow I*

would look at the network of people who are going to use it, I would then find out how difficult it is to get access and then I'd design the product. [S2.3_Gtm]

A mature firm CEO described his sales and marketing challenge and his plan to innovate using a viral/client referral programme necessitated by the lack of resource for alternative channels, an approach bolstered by the networked nature of the company's online solution.

We don't have the money to go out and spend on marketing and communications, so it has to be viral. I'm looking at referral to allow our product to take off because we don't have the money to do anything else. [S3_Sen]

In respect of improved production and service provision, those firms seeking to maximise longevity rated them as significant. A chi-square test indicates significant and positive associations, with 56% of firms with sustaining strategies reporting that innovation in production or service capacity delivered significant impact [X^2 (16, n=108), =28.511, p=<.027]. In respect of process innovation, a mature company CEO commented on a change of approach as his business pivoted, placing significant emphasis on productivity and process design following lessons learned in prior iterations:

In terms of non-technology processes, we micromanage that better than most. We looked at every process and we said – 'why are we doing these things this way', in other words we looked at the whole cost model ... People sympathised with us – going through 2 years with practically no money. We were limited in what we could do in that period – but we got more out of it. Adversity is a great servant. [S3.1_Sen]

Reflecting on high tech service-related output, an adolescent firm CEO refers to the consequences of transitioning from technology to human input and cost competitiveness.

Information engineering is bringing this kind of technology and industry knowledge together. Systems engineering is the painful process of projects, and it's as much human as technology (based). In fact, it's more human than technology, so one

assumes our friends in the East are going to eat our lunch. And we wouldn't be the only Irish company saying that right now. [S2.2_Orb]

A young firm participant talked about process improvement in general, and how offering a hosted service (Software as a Service – SaaS) enabled fast and efficient commercialisation.

In the last 12 months there were 158 innovations of note. Not daily but weekly, there would be changes and innovations. Because it's a hosted service, the whole client community has access to our updates right away. There is a very small amount of personalisation to the end-user client, so everybody has access to the tool, it's an enterprise tool. We do productise it but we don't customise it, we would sell it to someone in collections as a 'collection tool (and) to logistics as a 'logistics tool'. The whole product is the same for everyone, they just configure it differently. [S1.0_VS]

Firms seeking to maximise growth indicated that universities and institutes of technology were not important sources of product/process related innovation. Forty per cent of these firms ranked third level institutions as having no impact at all on innovative output [X^2 (16, n=76), =34.89, p=<.004] compared to 15% across the other strategy classes.

Albeit referring to human resources rather than product or process developments, one young firm CEO summarises industry-third level relationships as 'pretty tragic'. Another CEO who described his firm's technology as having 'plateaued' in terms of growth, talked about how academics or students would not be motivated to work on it.

We have tried consistently to keep engaged with all of the universities. What that means is finding one or two people to form a relationship with it order to keep an eye on what's going on. So in UCD we have a couple of people that will allow us to give a talk. I get to meet some of the students at the wireless mobile classes. It's the same in Trinity and Waterford Institute of Technology. I'm a true believer in having

some sort of virtuous cycle of engagement that we ourselves drive through the colleges. It works much better in the US. Here it's pretty tragic. [S1.2_Roc]

I think you just get yourself on certain computing programmes and bring in projects but the win-win is you get good graduates. In this climate and two or three years down the road, there'll be so many masters' graduates; I suspect there's an opportunity. We've never been able to harness them. I remember we tried a couple of students here and our technology for those students would be relatively old. You know, it just wouldn't be... it's not a playground [S2.2_Orb].

This chapter analysed significant associations between firm contingencies and SSI dimensions in the software sector. Following the summary of findings below, Chapter Six provides parallel analysis for the engineering sector.

5.5 Summary of Findings - Software SSI

The significant relationships affecting system-contingency fit for the three age and five strategic intent cohorts in the reference period are summarised below. With respect to age, young software firms perceived the SSI as offering the least best fit, compared to their adolescent and mature counterparts. With regard to strategic aspiration, those firms aspiring to maximise technical superiority perceive least fit with the system.

Young firms

The survey identifies largely negative associations for young firms in respect of funding. The cohort recorded significant association in respect of access to Angel funds, a deficiency aggravated by firms' inability to compensate with retained earnings. The survey findings, with some exceptions, correlated with informant interviews. An unanticipated finding for this cohort was the negligible importance attached to clients as sources of innovation.

Adolescent firms

The adolescent cohort indicates positive and significant fit in respect of the perceived impact of leadership and general management on firm performance. The cohort also recorded positive correlation in relation to benefits derived from the presence of foreign-owned subsidiaries driving the skills base through the education and training systems. The cohort also positively identified the impact of multinationals in respect of lobbying capacity.

The relative non-impact of the EI innovation voucher scheme on adolescent firms' innovation capacity contrasted with the positive and significant correlation with access to EI grants. In the former case, engagement with third level institutions appears to have been a source of frustration and delay in the delivery of the voucher scheme, a response which

echoes the views in the engineering sector, where there was a perceived a lack of urgency and business acumen within third level institutions.

Mature firms

There was a significant positive correlation in respect of the impact of EI stabilisation funding on mature firms: otherwise, the balance of associations was negative, with the perception that foreign multinationals increased competition for talent putting pressure on an already inadequate talent pool. In terms of funding innovation, the qualitative data appears to suggest that bank and venture capital funding have no impact on mature firms' capacity to innovate, and reflects a lack of access to external funding rather than management reluctance to deploy it (Vos et al., 2007).

Firms seeking to maximise profitability

Firms in the profit-oriented cohort indicate negative associations with respect to FDI creating competition for the limited supply of talent. Given that competition in the recruitment of high quality technical staff has been identified as a serious constraint to growth (Hoffman et al., 1998), policy makers and state agencies should be cognisant of the liability of scarcity (Carroll and Hannan, 1989; 2000) and the potential for adverse impact on the innovative potential of indigenous firms.

Firms seeking to maximise sales growth

Firms aspiring to maximise sales growth demonstrated significant adoption of new or significantly changed sales and distribution approaches during the reference period. As reflected across a number of age and strategy groups, this cohort indicated significant negative associations with HEIs as potential sources of product and process innovation.

Firms seeking to maximise technical superiority

The survey indicates a positive relationship between firms aspiring to technological superiority and successful bids for external funding, and a related correlation was found with EU Framework programmes having positive impact. In terms of recruitment and talent development, those seeking technical superiority perceived current commercial training and development offerings as having limited impact on innovation. The survey also found that government support for foreign-owned software companies was significantly and negatively related to the resources available to indigenous firms. This competition for resources reflects views expressed by interview informants in respect of public funding and talent.

Firms seeking to maximise value for eventual exit/acquisition

Firms expressing strategic intent to exit through a trade sale or acquisition indicated positive and significant associations with bank and BES funding sources for innovation: both sources are likely to preserve management autonomy while building value for sale or acquisition.

Firms seeking to maximise the longevity of the firm

Firms aspiring to longevity and stability rated improved production capacity and service provision methods as having positive and significant impact on innovation. The interview data supports this finding suggesting that there may be a link between the desire for longevity and patterns of innovation across the product lifecycle whereby process innovation overtakes product innovation over time (Abernathy and Utterback, 1978). McGahan and Silverman (2001) find no evidence of a shift from product to process innovation with firm maturity, though it cannot be assumed that the desire for firm longevity is solely an aspiration among older firms.

The next chapter assesses system fit for the manufacturing engineering sector.

Chapter Six

Engineering SSI Fit

SSI dimension-fit at the intersect with age and strategic contingencies

6.0 How conducive is the engineering SSI based on contingency?

Following the pattern of analysis of the software SSI in chapter 5, this chapter presents the analysis undertaken on the engineering system to ascertain whether, employing an age lens, system dimensions are more or less conducive to younger or older firms. This is followed by consideration of the degree of SSI fit related to differing strategic aspirations.

6.1 Overview of Engineering Contingencies

The survey sought information on thirty dimensions of firm-system fit. To follow is an overview of significant associations combined with associated data on micro level activities. Contingencies are coded and mapped by age and strategic aspiration:

- Age: young (y), adolescent (a) mature (m)
- Strategic aspiration to maximise: sales growth (g), profitability (p), technical superiority (t), the value of the firm for eventual sale (e) firm longevity/stability(l)

Significant relationships employ an alpha level of .05, while significance at the .10 level is also noted. Employing Cochran's goodness-of-fit, the approximation is adequate if no expected cell frequencies are less than one and no more than 20% are less than five.

Table 6-0 (overleaf) summarises system dimension fit in terms of significant age and strategy relationships.

System Dimension	Age Cohort		Strategy Cohort	
Skills				
Ease recruiting leadership/general management	.052*	Young+		
Leadership/general management training effect	.072*	Young+		
FDI competition for talent in the sector			.076*	Technology-
Funding				
Funding requests rejected	.016**	Young-	.058*	Technology-
Access to bank capital	.080*	Young-		
Access to EI Grants	.083*	Young-	.057*	Revenue+
Impact of retained earnings	.045**	Mature+		
Innovation Types/Sources				
New-to-firm prods/services available from competitors	.018**	Adolescent+		
Development mainly within the company	.014**	Adolescent+	.044**	Longevity+
New/significant changes in sales/distribution			.046**	Longevity+
Innovated via adv. machinery, equipment or software	.093*	Young-		
Access to industrial design registration advice	.079*	Young-		
Access to copyrighting trademarking advice	.074*	Adolescent+	.043**	Profit+
Access to R&D resources	.050**	Adolescent+		
Impact of innovation in materials/energy	.080*	Mature+		
Import of consultants, commercial labs, private R&D	.016**	Young-		
Import of networks as an innovation source			.088*	Profit -
Govt./public research as an innovation source			.004**	Profit -
Degree of impact of InterTrade Ireland support			.020**	Longevity+

Significant at 95%** and 90%*probability: Positive+, negative (-) and neutral/no effect (ne).

Table 6-0: Engineering SSI - Summary of Significant Contingencies

6.2 Age Contingent Effects

6.2.1 Age-Skills Dimensions

This section analyses skill and workforce dimensions relative to significant age associations. The field research presents a picture of a sector in transition. During the boom many companies struggled to meet demand, hiring indiscriminately in order to 'get product out the door' (E1.2), but post-boom, firms shifted focus to maximising operational efficiency through lean initiatives and, to a lesser extent, new products and services.

Informants employing diversification or growth strategies hire graduates with the intent of moulding their skills. Production skills were largely developed on the job or provided by trade-certified migrant workers as these skills are in short supply domestically. One participant described an agency subsidised recruitment campaign in Poland which led to a workforce of approximately one third Polish origin. Another firm employs Polish, Latvian, Russian and Chinese nationals and credits its migrant workforce with sustaining the business. Despite the broad reach of recruitment efforts, mechanical engineering design skills remain lacking in Ireland (IBEC, 2011).

The field data further indicate limited supply of hybrid technical-commercial skills, a gap mirrored in the software sector. Hybrid skillsets appear widely sought-after in sales and business development roles where technical competence is an important component of market awareness, solution design and customer relationship management. The following quotation represents the view of an adolescent firm survey respondent on recruitment.

> *[It is] very difficult to find technical people that have qualifications and experience in product development. [E_Sy_Mic]*

The dearth of skills may be assuaged by the number of family firms where hybrid capabilities are developed by management over time, or absorbed by long-serving employees.

Firms aspiring to growth describe in-market recruitment of sales personnel to capture appropriate language, cultural skills and market intelligence. With the exception of sales roles, participants describe moulding employee skills to firm-specific needs allied to a preference for staff living within the locality. Some firms experienced difficulty transitioning personnel who had previously held operational roles in large scale multinationals cementing the desire to *home-grow* staff. This can result in sector-based knowledge becoming highly idiosyncratic at the firm level (Malerba, 2002) reducing the potential for knowledge to diffuse among firms over time. Consistent with that, structural training deficits are addressed through in-house initiatives which in turn limits the potential for achieving scale. Changes to the trade apprenticeship system drove a need for greater engagement at firm-level. For many participant companies this constituted the sole mode of entry for new employees. Promotion opportunities are generally available to those *graduating* through the company system. The state sponsored apprenticeship programme is generally perceived as inadequate. Firms suggest standards are grounded in subjective measures of quality creating a competitive drag for host companies. Many candidates present with limited skills in basic measurement and part making. The problem appears not to be unique to Ireland - informants report similar challenges among UK peers.

A number of participants described the need for senior management training and development while recognising that this tends to lag functional and operational priorities. Learning is widely identified as critical to growth. As already noted, the post boom period saw companies make the transition from order-takers to crafting survival strategies

including new products and entry to new markets with new customers, placing heavy demands on management.

Learning by doing

The connection between skills and technology intensive production is a consistent theme in comments about firm-level employee development. Informants describe a machinery oriented approach, which embeds on-the-job training, as one informant noted:

> *Training is part and parcel of the acquisition of new machinery. Suppliers come in for two weeks, return after two months and deliver another week and so on. That's the majority of our technology training [E3.2_Pre].*

The research addressed the availability and impact of technical, commercial and general management personnel, and the effectiveness of mechanisms for talent development in-house and through the formal education and training system. The survey also sought to establish the impact of FDI. A number of informants referenced negative effects including diversion of human capital and dilution of government support. The revenue potential from local subsidiaries presents very limited scope for compensation.

A number of relationships emerged with more prevalent differences in the perceived conditionality of age than strategic aspiration. In the skills category, none qualify at the 95% confidence level. Notably, the limited availability of leadership and general management skills was perceived to impact negatively on innovation among adolescent software firms, whereas young engineering firms found it easy to recruit during the reference period (2008-2010). Young respondents also perceived that the training and development provision at senior management level is effective. Contrary to the positive impact of FDI in promoting the needs of the software sector, there is no related fillip to engineering sector skills and

lobbying capacity. Significant contention for staff with FDI subsidiaries was perceived solely by those firms seeking to maximise technology leadership. Table 6-1 summarises the output of the contingency analysis between skills and firm age.

System Dimension	Age	Cohort
Importance to company's performance		
Technical/Engineering Skills	.577	
Business/Commercial Skills	.190	
Leadership/General Management Skills	.148	
Ease of filling vacancies		
Qualified technical and engineering talent	.405	
Qualified business/commercial talent	.285	
Leadership/General management	.052*	Young+
Effectiveness of internal/external training and development		
Technical/Engineering	.261	
Business/Commercial	.429	
Leadership/General Management	.072*	Young+
Rating impact of foreign owned multinationals in the sector		
Expands skills base through education and training provision	.392	
Increases competition for talent in the sector	.214	
Increases pool of managerial talent available to the sector	.311	
Expands the domestic customer base	.669	
Expands the sector's lobbying potential	.168	
Dilutes government support for indigenous companies	.825	

Significant at 95%** and 90%*probability: Positive+, negative (-) and neutral/no effect (ne).

Table 6-1: Engineering SSI Age-Skill Contingencies

6.2.1.1 Age-Skill Contingencies

Significant age-skill contingencies are;

- Positive impact on young firm recruitment at general management level
- Positive impact expressed by young firms on the effectiveness of structured programmes to upgrade leadership and general management capability.

Leadership and General Management Recruitment

With regard to recruitment for management positions, there is a positive association (marginally above the 95% threshold) with 50 per cent of young firms reporting ease of recruitment [X^2 (8, n=55), =1.40, p=<0.052] compared to only 15 per cent of adolescent and

mature firms. This contrasts with the general contention that young firms' capacity to recruit experienced management represents a liability

The survey and the interviews related difficulty in hiring appropriately skilled sales and technical candidates; however neither was significantly correlated with firm age. In terms of commercial and business skills, the MD of one young engineering company described how recruitment had 'shifted up a level' from responding to market demand in the boom (revenue grew from €2M in '04, to €4M in '05 and €8M in '06) to hiring sales representatives and professional engineers to generate new business in the downturn.

> *Because we had plenty of work, we didn't focus on selling. Effort was put into getting the job done and getting it out the door so you took in whoever you could to do that whereas now we have a sales manager, we're looking at product development, all that sort of stuff. We have a couple of graduates here from Queen's University and different places over the last three years so that's sort of shifted up a level. [E1.2_Ini]*

Leadership and General Management Training

In parallel with the findings for general management recruitment, young firm respondents reported positive impact in respect of structured leadership and general management training. An association above the 95% threshold was found, with 50 per cent of young firms reporting high impact [X^2 (8, n=59), =14.4, p=<.072] compared to levels of 7 per cent for adolescent and 22 per cent for mature firms.

Enterprise Ireland's client management development portfolio is available to all firms demonstrating potential to scale. Programmes originally designed in conjunction with high tech industry groups (e.g. Leadership for Growth at Stanford University, Accelerated Growth Programme for CEOs at Cambridge University) have subsequently been made available to

selected firms across all sectors. One young firm MD referred to lack of attention to management development and a tendency to become too involved in operational activities.

> *… management development training would be the big gap. I have a production manager and getting him to move away from the day-to-day stuff to do actual management is the big challenge. You can clock up your hours and justify your salary at the end of the week by getting orders out whereas you're leaving the management stuff behind. [E1.2]*

This may suggest a need for greater monitoring and support from non-executive directors, agency development advisors and mentors. It also speaks to the importance of firm-level contingency within the SSI – in this case, managerial engagement.

6.2.2 Age-Funding Dimensions

The sources of external finance for innovation explored in the interviews spanned debt funding (bank borrowings, hire purchase and leasing) equity (government backed and angel investment) and grant aid. Internal sources included retained profits and founders' equity/personal savings. Contrary to expectation, trade credit did not feature significantly. Venture capital was excluded as it was not a feature of the landscape in the reference period.

Innovation funding is dominated by retained earnings. Informants emphasise reinvestment of profit in plant, machinery and training as key platforms for innovation and productivity growth. Informal risk or angel investment was not perceived as a component of the funding system, with the exception of one firm engaged in the BES. Hire purchase agreements appear to constitute the most common form of funding for capital equipment. In some cases machinery acquisition and related training are partially subsidised by state agencies.

Agency funding for the engineering sector was provided by County Enterprise Boards (CEB) and more commonly by EI and InterTrade Ireland, the latter largely in the form of support for business-academic partnerships. In line with findings on the UK Small Firms Training Loans Scheme, the majority of companies surveyed indicated that training would not have happened so quickly, or at the same level, had support not been available (Storey, 2004). Similarly, empirical data indicate that agency funds are *accelerators of* rather than *gatekeepers to* innovation, conferring additionality in terms of the timing of outputs. Where agency funding is not forthcoming, development projects are generally self-funded, which parallels findings from the software sector, where informants report that projects are no longer mounted to capture state funding (terms such as 'grant syndrome' and 'grant harvesting' are used), but rather to escalate execution.

Mature firms demonstrated comparatively greater aversion to external funding. Having survived previous economic shocks, financial autonomy is tied to limiting dependence on external sources. The relatively stable financial status of mature and adolescent firms renders the banks supportive in respect of routine services and working capital rather than risk capital. In many cases, overdraft facilities had been secured although the banking crisis created pressure to convert these to loans.

Of the dimensions researched, owner equity and self-funding emerge as the most important enabler of innovation, the latter comprising the exclusive source of finance in the majority of cases; the external capital market is perceived on a continuum from inadequacy to irrelevance. The data suggests that state agency funding has a low impact compared to perceptions in the software SSI. The survey distinguished between those respondents who had sought external funding for R&D or wider innovation activity and those who had not.

Table 6-2 summarises significant age contingencies across all system dimensions.

Funding	Contingency	Cohort
Sought external funding	.268	
Funding requests rejected	.016**	Young-
Business Expansion Scheme	.169	
Business Expansion Scheme Impact	.281	
Angel Investment Access	.361	
Angel Investment Impact	Constant**	
Bank capital access	.080*	Young-
Bank capital Impact	.274	
Hire Purchase/Leasing	.995	
Hire Purchase/Leasing Impact	.361	
EI equity	.174	
EI equity Impact	.437	
EI Grants (R&D, RTI, Vouchers, FP7, Stabilisation)	.083*	Young-
Innovation Voucher impact	650	
R&D Funding/RTI Grant impact	.114	
Stabilisation funding impact	.272	
R&D Tax Credits impact	.983	
European Framework impact (e.g. FP7)	.527	
InterTrade Ireland impact	.245	
Retained Earnings impact	.045**	Mature+
R&D Tax credits access	.121	

Significant at 95%** and 90%*probability: Positive+, negative (-) and neutral/no effect (ne).

Table 6-2: Engineering SSI Age-Funding contingencies

6.2.2.1 Age-Funding Contingencies

With respect to age, the significant contingencies were;

- the proportion of young firms seeking external funding
- the level of rejection experienced by young firms
- the degree to which angel/informal risk investment is not a functioning component of the system
- the prevalence of self-funding among mature firms.

Although there was no significant difference among age groups, an aggregate 55% of engineering respondents indicated they had sought external funding in the reference period compared to 72% of software companies): the majority (68%) were young firms compared to 46% of adolescent and 57% of mature firms. This might be considered counterintuitive, given the minimal physical asset requirements associated with software production,

however financing is often required to conduct R&D at the pre-product or pre-service stage (Westhead & Storey, 1997).

External Funding Rejection Rates

Young firm respondents reported higher rejection rates in applications for funding R&D and wider innovation activities, perhaps due to funding agencies seeking levels of accountability associated with more established organisations. A chi-square test indicates a significant association [X^2 (4, n=78), =12.23, p=<.016], with 32 per cent of young applicants being refused, in contrast to levels of 6% of adolescent and 4% of mature firms. This may be a consequence of the liability of newness and smallness (Aldrich and Auster, 1986; Stinchcombe, 1965), signifying the greater degree of moral hazard and unpredictability confronting younger firms who lack the track record and security of more mature counterparts.

Field data demonstrate limited potential for equity funding in the context of the market for engineering risk funding. Given generally low returns to scale, equity investment is practically non-existent. An exploratory interview with a partner in a VC indicated that *time-to-money* and potential to scale in the sector fall short of venture capitalist's expectations. Similar to the perceptions about bank funding in the software sector, this dimension appears absent from the system. No cross tabulation measures were computed for the impact of angel investment. One MD described his young firm's stance in relation to the organic funding, raising questions as to whether the company might generate superior innovation led growth were risk capital more accessible.

> *In relation to Bank funding and Business Expansion Schemes, we haven't needed that over the eleven years. After the first year, we have been sufficiently profitable to fund our growth. And we have been continually in profit since. [E1.1_Com]*

There was one reference to BES (Business Expansion Scheme) investment in the semi-structured interviews. The scheme's long term impact was perceived to have been detrimental to the company's financial position in the context of a subsequent 50 per cent drop in turnover. The BES funds were raised and managed by the company's accounting firm: the owners understanding of the commitments involved for the firm was unclear.

> *The BES would have been for a particular project. There was some capital equipment bought with it but a higher portion of it went into working capital and then we've had bank funding for both capital equipment and working capital as well. I think looking back as to when the BES funding first started about four years ago, there wasn't really a plan as to how to ….., as to how to re-finance. ... Our accountant put the scheme in place with their clients so the funding came through them. They were managing it, so there really wasn't a good understanding of some of the implications on our side. [E3.1_Mca]*

The suggestion that a high proportion of BES funding was employed to fund working capital reveals liquidity constraints with funds diverted from growth initiatives to operating costs. In a further reference to angel funding, a mature firm informant suggested that external funding was not required, again in the context of retained earnings.

> *It's all self-funded. There is no angel investment. There's enough margin in the business to sustain development. [E3.2_Pre]*

Agency Funding

Young and adolescent firm participants reported positive feedback in relation to agency funding; however this was found not significant for any cohort in the survey. There was a negative association in respect of age and access to EI grant funding, albeit above the 95% threshold [X^2 (8, n=39), =13.966, p=<.083]. 46 per cent of young firm respondents indicated significant difficulty in securing grants, compared to much lower levels for adolescent and

mature firms. This relates to the impact rating for R&D and Research Technology and Innovation (RTI) funding, with 54% of young firms indicating that the grants had no impact at all, against only 15% of adolescent and mature firms sharing that perception: again, the level of significance was above the 95% threshold [X^2 (4, n=38), =8.265, p=<.082]. Some informants referred to the costs of establishing and managing agency relationships, suggesting that young firms find it difficult to justify diverting resources to the effort. One young firm MD reflected on his experience of seeking agency funding through his County Enterprise Board.

> *They seem to grant aid farcical projects, they don't look for scalability. They asked for a business plan. I spent a bit of time putting it together and they came back and offered us three grand. It cost me more to do the business plan [E1.3_Dl].*

Another young firm MD explained his rationale in relation to innovation funding. The onerous application process aside, the firm was successful in securing a grant.

> *… whereas before we would have thought we'll do it to get the grant, over the last two years you do it because you think it's worth doing. Then you apply for the grant and if you get it well and good, if you don't you carry on anyway [E1.2_In].*

The experience of one adolescent company in respect of EI requirements for matching funding was mixed. The stabilisation fund, launched in 2009, was designed to support viable but vulnerable businesses during in the economic downturn. Linked to a business plan, it involved granting preference shares to EI.

> *We had a problem with EI stabilisation fund. Their hurdle rate is too high. They wanted us to put money aside for five years but we don't want to tie it up for that long. As one of our strategic goals, we want to identify new products that leverage our core technology and that will require flexibility.*

> *There was some help from EI in the very early days that wasn't really used properly; it was the old grant syndrome. We manage that very tightly now. [E2.2_Dr]*

A mature firm director alludes to reliance on agency support in securing funding to bolster the company's finances in light of a significant drop in earnings due to the recession.

> *We will be talking to EI about their stabilisation fund. There is a variety of financing options available and our accountants are working on that but probably not as hard as I'd like them to be. We'd love this to be all self-funding but it isn't. [E3.1_Mc]*

Self-Funding and Retained Earnings

Self-funding was reported as the principal source of innovation and working capital among engineering informants and this was generalised in the survey. There is a significant and positive relationship between self-funded innovation and mature firms [X^2 (4, n=36), =9.730, p=<.045], with all respondents indicating the high impact of self-funding, against 62 and 58 per cent ratings for young and adolescent firms respectively.

Interview extracts underline the prevalence of self-funding, with some informants suggesting it as preferred - if not exclusive. Contract research revenue (e.g. prototype design and build) represents an increasing source of capital and input into product and process innovation. Two of the three mature firms interviewed claimed to have had no recourse to external capital: both expressed steadfast commitment to self-funding having learned from experience that financial independence was core to survival.

> *We've had no agency funding. We fund innovation from cash-flow. It's been that way since the start. It's a strong business that way. There is a bit of cash there in the background. The premises were bought and paid for. We lived through the 80s, so we've seen this before. We've been with the same bank since 1966 [E3.3_Lmh].*

Bank Funding

There was no significant difference with respect to age and bank funding. With few exceptions, participants reported low impact on innovation, associating banks with overdraft facilities and the provision of general services rather than risk finance. As reflected by the managing director of one adolescent firm, the majority of SME relationships with their banks are based on routine services (Binks & Ennew, 1997).

> *…we've quite good relationships with our bank. I suppose if you hadn't their support you'd be in trouble. …. We're a positive cash flow company so we wouldn't be using an overdraft, we'd only be using it as a lot of people would use their bank. [E2.1_Bel]*

The MD of an adolescent firm describes his position on self-funding, and how its relatively stable financial situation underpins a broadly supportive banking relationship:

> *In relation to the banks, we are in a relatively good position. We didn't go out and buy a company. There's no millstone around my neck. We have small stock, no major debt. The bank has helped us with funding which is adequate at the moment but if we were in a different situation, they would be very difficult. Historically we have been self-funded all along. The growth has been organic and external funding has not been particularly critical to that. [E2.2_Dr]*

While the research depicts innovation as principally fuelled by retained earnings, the working and risk capital constraints reported by young firms suggest significant system weaknesses in bank funding, compounded by state agency restraint. Adolescent and mature firms perceive no real alternative to self-funding while external funds dilute autonomy. This raises questions as to whether growth prospects are subject to the retained earnings trap (Walsh, Niosi, & Mustar, 1995).

6.2.3 Age-Innovation Dimensions

This section provides an assessment of innovation types and sources, partnership and intellectual property dimensions. Innovation modes vary significantly across the sector. Many mature firms are engaged in modifying their portfolios to address product and customer lifecycle maturity, leveraging core competencies and technologies to develop new applications and services. Productisation of services featured across age groups in the drive to maximise revenue and competitiveness through customer preference. Services previously provided gratis are being monetised. In some cases, prototype and design services provide opportunities for downstream product development and manufacturing sub-supply.

Innovation mode

The survey indicated a significant relationship between adolescent firms and the introduction of products and services already available from competitors. In other cases, novel applications were designed based on existing or, less frequently, new platforms. Instances of proactive innovation were driven by problems with existing portfolios or efforts to address unbalanced revenue profiles. For companies operating in mature markets, informants referred to addressing over-dependence on key clients through product and process innovation, largely through productivity improvements, lean innovation programmes and maximising automation through investment in machinery and training.

Collaboration

With some exceptions, engineering firms did not perceive their suppliers as active innovation partners, although there was evidence of collaboration on process innovation. One young firm had extended its relationship with a UK-based supplier to a partnership

offering consulting expertise in return for lead referrals. A mature firm established a similar relationship with a UK-based sheet metal supplier including the provision of design services.

In the area of intellectual property (IP) management, while young firms refer to expense and complexity, there is recognition that IP offers additional advantage through branding and tax relief. One mature firm planned to engage in offshore production under licence, but the design had been released into the public domain and the initiative was withdrawn undermining plans to scale overseas production. The survey revealed several significant associations between age and innovation. Contingent effects were more prevalent for strategy than age cohorts. Table 6-3 summarises the age- innovation contingency analysis.

Innovation Dimensions	**Contingency**	**Cohort**
New-to-market products or services before competitors	.775	
New-to-firm products or services available from competitors	.018**	Adolescent+
New-to-market processes before competitors	.802	
New-to-firm processes already employed by competitors	.756	
Developed mainly within the company	.014**	Adolescent+
Developed by company with other companies/ institutions	.461	
Developed mainly by other companies or institutions	.148	
Innovated through advanced machinery, equipment or software	.093*	Young-
New or significantly changed company strategy	.805	
New/improved systems for information, knowledge & skills	.295	
Major changes to the organisation of work within the firm	.972	
New/significant changes in relations with other firms/institutions	.466	
Advanced management techniques (e.g. Lean)	.854	
Significant changes in how product is offered to the market	.681	
New/significantly changed sales or distribution methods	.460	
New/significantly changed marketing methods	.444	
Apply for a patent	.525	
Register and industrial design	.484	
Register a trademark	.853	
Claim copyright	.746	
Patenting to prevent duplication/facilitate licensing	.111	
Patenting to deliver royalties	.403	
Registering an industrial design	.079*	Young-
Copyrighting/trademarking	.074*	Adolescent+
R&D (in-house or external)	.127	
Employees recruited from competing organisations	.542	
Employees or contractors qualified to PhD level	.372	
Technology licensed from others	.205	
Publications or technical meetings	.900	
Reverse engineering & patent disclosures	.572	
R&D (in-house or external)	.050**	Adolescent+

Employees recruited from competing organisations	.558	
Employees or contractors qualified to PhD level	.463	
Technology licensed from others	.727	
Publications or technical meetings	.453	
Reverse engineering & patent disclosures	.131	
Increased range of products/services	.488	
Entered new markets or increased market share	.110	
Improved quality of products/services	.492	
Improved flexibility of production or service provision	.390	
Improved capacity of production or service provision	.737	
Reduced labour costs per unit output	.190	
Reduced materials/energy per unit output	.080*	Mature+
Consolidated range of products/services	.306	
Co-operation on any innovation activities in the last 3 years	.503	
Internal to the company	.637	
Suppliers of equipment, materials, components or software	.335	
Clients or customers	.681	
Competitors or other companies in your sector	.410	
Consultants, commercial labs or private R&D organisations	.016**	Young-
Industry networks	.900	
Government or public research institutes	.288	
Higher Education Institutions (recruitment/talent development)	.851	
Higher Education Institutions (product/process projects)	.693	
EI	.267	
InterTrade Ireland	.193	
County Enterprise Boards	.608	

Significant at 95%** and 90%*probability: Positive+, negative (-) and neutral/no effect (ne).

Table 6-3: Engineering SSI Age-Innovation Contingencies

Figure 6-2 maps SSI fit in terms of significant (95%) positive and negative age contingent relationships reported in the survey. Indications of correlation (negative, positive and neutral) are identified by dimension and cohort group.

The data indicates that much innovation focussed on increased productivity and differentiation, although profiles varied among firms engaged in producing finished goods and those engaged in sub-supply. Firms describe entry into adjacent technology and market fields, leveraging the potential to apply existing knowledge and skills and driving operational excellence through new production processes and labour-enhancing technologies. A significant number of firms described the imperative of redressing overreliance on large

customers. Diversification through product development and licensing-in technology were among potential alternative sources of revenue cited.

Servitisation

As referenced earlier, the impact of the recession on capital expenditure led to design services emerging as a new revenue source. Servitisation creates value by adding services to product offerings (Vandermerwe & Rada, 1989). In the manufacturing sector, servitisation appears to be driven by the parallel emergence of more complex customer demands and the need to raise defences against competition (Santamaría , Jesús Nieto, and Miles, 2012), particularly from lower cost countries. Manufacturing servitisation has been shown to deliver transformative impact on what might otherwise be relatively low value or commoditised products.

Design services and servitisation

The tendency for software ventures to fund product development through consulting revenue emerges as an important and less cited feature of innovation in engineering firms, particularly within the mature cohort. Consistent with absorptive capacity developing as a by-product of a firm's manufacturing operations (Cohen and Levinthal, 1990), initiatives include the exploitation of design and prototype opportunities to boost revenues and expand income streams, alongside the assurance of standards for OEM partners. The sector’s services output appears broadly in line with manufacturing companies across Europe, with servitisation levels of approximately 6 per cent (Eurostat, 2009). This contrasts with findings that over 25% of cash flow in Irish software firms is generated by services (Hogan and Hutson, 2005), largely driven by the need for integration with source data and legacy systems.

6.2.3.1 Age-Innovation Contingencies

Among the important associations with respect to innovation type and age were:

- young firms' limited tendency to innovate through machinery, equipment or software acquisition
- young firms' difficulty seeking advice on registering industrial designs
- adolescent firm propensity to introduce new-to-firm products or services already available from competitors
- adolescent firm tendency to introduce new offerings developed mainly in-company
- adolescent firms access to advice on copyrighting and trademarks
- adolescent firm access to in-house and external sources of R&D
- young firms found consultants, commercial labs and R&D providers of limited import
- energy and material efficiency innovation were most marked among mature firms

A significant difference emerged in relation to adolescent firms' introduction of new-to-firm products and services which were already available from competitors [X^2 (2, n=75), =7.897, p=<.018]. Market-based innovations often employ simpler new technologies (Zhou, Kin and Tse, 2005) and the preliminary stages of product innovation in Irish SMEs tends to be dominated by design and marketing personnel with engineering and production playing a secondary role (Roper, 1997). Replication was discussed in interviews to a limited extent, while a number of participants described a more disruptive approach aimed at bringing simplified versions of more complex products to the market as described by two CEOs:

> *We took (waste recycling) bailers and did a Ryan Air on them, we took a 'no frills' approach….. How cleverly can we build our products? The fewer components we have, the quicker and the better we can make it. It's got to do with the process but it's fundamental to the design. If we don't design simplicity in, we can't process equipment in the right way. The Germans are masters at over processing. The first thing we ask is; can we make the product with 3 or 4 pieces rather than 8 or 10? We*

can be as good as the benchmark if we cut the waste, by cutting out components and PLCs [programmable logic controllers]. Given the level of people operating the machinery, it needs to be a button or a lever, it needs to be simple [E2.3_Ma]

If you take Germany, you would automatically think that they want the latest and the most up to date technology. We have been very successful in Germany, because a lot of companies are dissatisfied with the units breaking down. That doesn't mean the German companies buying our product wouldn't be selling a highly sophisticated product of their own, but they want a basic solution to do the basic job. [E1.1_Co]

The MD of an adolescent engineering firm referred to charging for services delivered to OEM (Original Equipment Manufacturer) partners. The firm monetised its existing design offering which had previously been provided gratis as a source of differentiation to gain 'preferred supplier' status.

With the OEMs, we provide a design service and it's something, taking a look at our competition, we are getting better at charging for. Before, it would have been a source of differentiation but we think more about it now and we charge for all that [E2.2_Dr].

Allied to replicating competitor offerings, there was a significant positive association in respect of adolescent firms relying mainly on in-company capabilities when developing new offerings [X^2 (2, n=69), =8.492, p=<.014]. While supply chain channel partnerships are more common, upstream innovation partnerships are rare. Beyond the tendency to craft new offerings with customers, proactive collaborations with suppliers, competitors and institutions appear infrequent. One adolescent cohort MD described a prospective acquisition or partnership strategy for development of complementary offerings, a practice not reflected by other informant firms. The company outsourced design and compliance

work to compensate for human capital constraints within the system, on a commercial rather than a partnership basis.

> *Outsourcing (our) design is structured, planned and budgeted. Colm [Project Engineering firm offering mechanical design, project management and CE marking] has very solid qualifications and competencies. ... At the time we brought Colm in, we couldn't get anybody else with the required skills. He can put bodies into the business on an as-needed basis. It's very flexible – we do pay more for it but at the end of the contract we are not obliged to carry forward. The level has reduced recently. You can only do so much development. [E2.3_Ma]*

In relation to engineering firms innovating through the acquisition of new machinery, equipment or software, there was a difference at the 90% level of confidence in the number of young firms reporting not having done so during the reference period [X^2 (12, n=64), =4.75, p=<.093]. This may be due to firms continuing to leverage investments made prior to the recession, or lack of investment capital. The MD of one young engineering firm described how the bulk of the company's profits were reinvested in machinery.

> *Basically anything the company made over the last five years was ploughed back in. We've probably spent about five million on machinery over the last ten years and that's mostly CNC (Computer Numerically Controlled) machinery. [E1.2_In]*

Protection of intellectual property was generally perceived as important, and interview data indicated that the ease with which firms could obtain protection depended on experience levels. Young firms indicated significant difficulty in respect of advice and support on industrial design registration [X^2 (6, n=29), =11.327, p=<.079]. In contrast, adolescent firms found it easy to access information on copyrighting and trademarking [X^2 (6, n=28), =11.507, p=<.074]. One young firm MD described the company's array of protection mechanisms

including design copyright, and referred to the disadvantages of patent registration exposing it to the threat of reverse engineering.

> *A lot of the patents that we have filed are for specific areas of the product, not the complete unit. We also have design copyrights on the overall look of the product. In 1998 we filed one patent …… But one of our competitors figured a way around it and since then I don't file patents for the sake of filing. It educates your competitor; it makes it too easy for them, you are handing it to them on a plate. [E1.1_Co]*

Alluding to the difficulty experienced by firms exploring intellectual property protection, a young firm MD suggested the need for a 'one-stop-shop', including comprehensive understanding of the costs and time involved.

> *How do you go about it? Who is out there to offer that? You'll get EI to come in and say, we'll do a bit for you….. If you could get a one-stop shop and get an expert to say it will cost you €60k to patent that product. It's the amount of time you have to put into it yourself is the killer. [E1.2_In]*

This may signal the need for improved communication on the supports available from organisations such as incubators and EI. The data also indicate the value of learning-by-doing in regard to leveraging IP. A significant proportion of engineering sector production constitutes sub-supply rather than entire value chains of activity, so IP largely rests with contracting clients. This has implications for companies choosing to diversify, as subcontractors are less likely to carry out R&D, and may lack the market and technical competencies to develop original solutions.

> *Nearly everything we do is sub-supply. We are manufacturing things that other people have designed so patents don't apply. [E3.2_Pre]*

Internal and external R&D sources

Adolescent firms reported finding in-house and external R&D resources easy to access during the reference period [X^2 (8, n=62), =15.533, p=<.050], although there was more evidence of development than of research, with many participants indicating that much R&D was customer driven or near-market based.

> *We are investing about 9% of our turnover through R&D tax credits. We have a dedicated R&D team on the premises. When we had 200 people (now 160) we had about 40 involved day-to-day in R&D. That could mean new products or improving existing products. That doesn't mean they are all engineers - some are factory floor guys, putting it together. People-wise 20% of our employees are dedicated to R&D, compared to 10 % of our turnover. R&D is a lot more labour intensive. [E1.1_Co]*
>
> *Our R&D budget about 2-3% of turnover. Lean is a separate issue. We have a weekly R&D meeting, a structured team and a process that goes with that. [E2.3_Ma]*
>
> *R&D is the one thing we'd all love to be doing but it's kind of up there in plans. There are things happening where the guys are, maybe not constantly but occasionally trying to reduce cycle times but that's part of the process. We've had an RTI grant, we've had the productivity improvement fund and we've just got the growth fund. The RTI grant we got when we got into the automotive game to help us fund the engineering time put into manufacturing components because it was new for us, there were new methods of machining that we had to learn and experiment with, …..it worked out that it was a lot more of our time than we thought so we were grateful for the grant. There was a huge amount of work when it started, we had test beds and we had fifty different trials. .. we learned a lot from the whole experience that enabled us to quote other business, so that was a success. [E2.1_Be]*

In a related area, young firms reported the relatively limited importance of consultants, commercial labs and private R&D providers in supporting innovation activities [X^2 (6, n=48), =15.676, p=<.016]. This may be related to their greater focus on near-market development

with direct response to customer needs, reducing risk, minimising unknowns and potentially allowing them to build retained earnings for future innovation initiatives.

The foregoing concludes the analysis of age-related contingencies and impacts on innovation capacity. The next section analyses the impact of strategic contingencies.

6.3 Strategy Contingent Effects

Having analysed SSI-age contingent effects on firm capacity to innovate, this section analyses system dimension fit in line with firms' strategic aspirations encompassing profit maximisation, sales growth, technological superiority, maximising exit value and enterprise longevity (Autio et al.,2000). Structural factors are analysed against each cohorts' stated intent. One study of SMEs in the manufacturing industry found that the outcomes of business strategies were directly related to the strength of the resource base (Hewitt-Dundas and Roper, 2000). The research also pointed to industry maturity as an important aspect of market structure, which seemed to determine the scope for technology based product innovation, a finding which is particularly pertinent to this research, juxtaposing the dynamism of the software industry with the relative stability of the manufacturing engineering sector. In the wider debate about whether companies are driven by industry or firm-specific factors - strategic intent being central to the latter - Mason (1939) points to the significant influence of firms' reactions to the prevailing market. Linked to firm age, Child and Kieser (1984) highlight the role of management change when incumbent leadership identifies with a development strategy whose relevance may reduce over time.

6.3.1 Strategy-Skills Dimension

Table 6-4 summarises the output of the contingency analysis. It indicates only one significant contingency at the 90% level.

Skills	Strategy	Cohort
Importance to company's performance		
Technical/Engineering Skills	.404	
Business/Commercial Skills	.161	
Leadership/General Management Skills	.662	
Ease of filling vacancies in the last three years		
Qualified technical and engineering talent	.509	
Qualified business/commercial talent	.282	
Leadership/General management	.181	
Effectiveness of internal/external training/development		
Technical/Engineering	.969	
Business/Commercial	.412	
Leadership/General Management	.135	
Rating impact of Foreign owned multinationals in sector		
Expands skills base through education & training provision	.464	
Increases competition for talent in the sector	.076*	Technology-
Increases pool of managerial talent available to the sector	.484	
Expands the domestic customer base	.750	
Expands the sector's lobbying potential	.453	
Dilutes government support for indigenous companies	.441	

Significant at 95%** and 90%*probability: Positive+, negative (-) and neutral/no effect (ne).

Table 6-4: Engineering SSI Strategy-Skills Contingencies

6.3.1.1 Strategy-Skills Contingency

One significant skill contingency emerged:

- the perceived negative effect of competition for talent with foreign-owned firms among those expressing intent to maximise technical superiority

62 per cent of technology led firms at the 10 per cent level of confidence [X^2 (16, n=78), =24.7, p=<.076] perceive significant competition for talent with the FDI sector compared to an average of 41 per cent across all strategy groups. Unlike the software sector where skills are more transferable, the engineering sector appears to be battling public perception in relation to careers in manufacturing. Rather than competing directly for talent, the limited presence of multinationals manufacturing in the sector may act as an impediment to educational provision based on the reduced demand for graduates. The correlation of FDI talent rivalry with firms seeking to maximise technical superiority may be due to graduates who could otherwise contribute to leading-edge innovation in indigenous firms being drawn to work, not only for foreign-owned companies, but also in the sectors they dominate

As previously cited, the need to *home-grow* skills, appears due to the lack of appropriate human capital infrastructure and the difficulty firms experience in attempts to integrate experienced recruits from multinationals. The dearth of trade skills was perceived to be rooted in a growing cultural aversion to manufacturing roles allied to inadequacies in the education and training systems. The 'Making it in Ireland: Manufacturing 2020' report (Forfás, 2013b), outlining the Irish government's vision for the sector, cites the need to address negative perceptions of manufacturing and to promote its inherent career potential.

Public perception aside, demand for trade skills emanates almost uniquely from indigenous firms narrowing the prospects available to job seekers. In output terms, foreign-owned firms represent a much lower share of the manufacturing category (Forfás, 2013b) with consequent dilution of the lobbying power more typical of the software and pharmaceutical sectors. One mature engineering firm informant suggested FDI bias on the part of state agencies.

> *…..what really is annoying is that they put huge effort into the multi-nationals. They get premises for them, they give them training and research grants, they help them locate markets, and they find subcontractors including people like us who can help them, all orientated towards them. Nothing orientated towards companies that are actually trying to build locally. [E3_SSM]*

6.3.2 Strategy-Funding Dimensions

Table 6-5 summarises funding contingencies relative to respondents' strategic intent.

System Dimension	Contingency	Cohort
Sought external funding	.036**	Technology+
Funding requests rejected	.058*	Technology-
Business Expansion Scheme	.136	
Business Expansion Scheme Impact	.874	
Angel Investment Access	.392	

Angel Investment Impact	Constant**	
Bank capital access	.329	
Bank capital Impact	.742	
Hire Purchase/Leasing	.301	
Hire Purchase/Leasing Impact	.996	
EI equity	.697	
EI equity Impact	.912	
EI Grants (R&D, RTI, Vouchers, FP7, Stabilisation)	.057*	Growth+
Innovation Voucher impact	.935	
R&D Funding/RTI Grant impact	.693	
Stabilisation funding impact	.978	
R&D Tax Credits impact	.819	
European Framework impact (e.g. FP7)	.583	
InterTrade Ireland impact	.536	
Retained Earnings impact	.829	
County Enterprise Board access	.423	
R&D Tax credits access	.671	

Significant at 95%** and 90%*probability: Positive+, negative (-) and neutral/no effect (ne).

Table 6-5: Engineering SSI Strategy-Funding Contingencies

6.3.2.1 Strategy-Funding Contingencies

Among the important funding associations with respect to strategy were:

- external funding reliance of firms intent on maximising technical superiority
- the level of rejection for funding on the part of firms targeting technical superiority
- the ease with which growth-oriented firms can access EI funding

A significant difference emerged in the levels of external funding sought among engineering strategy cohorts, all those seeking to maximise technical superiority had sought external funding [X^2 (4, n=73), =10.26, p=<.0361]as against approximately 50 per cent across all other categories. This may reflect the capital intensity inherent in product and process innovation for technologically advanced outputs. This association was underlined by the relationship (albeit outside the conventional 95 per cent threshold) between technology-led firms and those who had had a request for R&D or broader innovation funding rejected [X^2 (8, n=78), =15, p=<.058]: Thirty per cent of technology-driven respondents had external funding requests rejected, against an average rate of 12% across other cohorts.

Agency funding is provided by the CEBs, EI and Inter Trade Ireland. The survey indicated mixed experience across strategy types: at the 96% significance threshold, 80 per cent of growth oriented firms recorded EI grants as accessible [X^2 (8, n=39), =15.123, p=<.057] against an average of 44% across the strategy types.

One firm obtained assistance from EI in a licensing initiative undertaken to redress the effects of the downturn (their largest sub-supply customer equated to 70% of turnover). The MD described the onerous procedures associated with grant aid.

> *Agency funding I would say, the usual cry you probably hear everywhere is accessibility and the amount of paperwork that you need to get it. [E1.2_In]*

Interview participants generally perceived agency funding availability as favourable. In line with feedback from the software sector, grants accelerate implementation rather than having a gatekeeping effect. Interview extracts are indicative of the general view - that innovation projects must meet internal return on investment criteria: if agency funding is secured thereafter, that is advantageous but it is not an end in itself. Some accounts suggest this was not the case historically.

> *In relation to RTI, we probably wouldn't do as much without the support. The way I look at a grant is; if you can't justify doing it without the grant, don't do it. I am working on one at the minute and they are getting more difficult. [E1.1_Co]*

> *Finance for us is a matter of self-financing. We invest and write it off every year. We get state finance for capital plant. EI funded the lean project – we would not be able to run it at the rate we have if state support was not available. [E2.3._Ma]*

> *We don't do grant harvesting with EI. We did a round of RTI a couple of years ago but it's our preference to go it alone. If a project only stands up because of grant aid, there's no point. If the business case is strong, we can fund ourselves. [E3.2_Pre]*

6.3.3 Strategy-Innovation Dimensions

Strategic aspirations had a more substantial impact than age a number of significant relationships emerged. Table 6-6 summarises output from the contingency analysis.

System Dimensions	Contingency	Cohort
Introduction during the last three years		
New-to-market products or services before competitors	.208	
New-to-firm products or services available from competitors	.530	
New-to-market processes before competitors	.291	
New-to-firm processes already employed by competitors	.695	
(If yes) Who developed these innovations?		
Developed mainly within the company	.044**	Longevity+
Developed by company with other companies/ institutions	.242	
Developed mainly by other companies or institutions	.199	
Innovated through adv. machinery, equipment or software	.796	
Organisational or marketing innovation impact		
New or significantly changed company strategy	.471	
New/improved systems for information, knowledge & skills	.754	
Major changes to the organisation of work within the firm	.547	
New/significant changes in relations with other firms/institutions	.360	
Advanced management techniques (e.g. Lean)	.330	
Significant changes in how product is offered to the market	.483	
New/significantly changed sales or distribution methods	.046**	Longevity+
New/significantly changed marketing methods	.337	
IP protection sought in the reference period		
Apply for a patent	.389	
Register and industrial design	.237	
Register a trademark	.134	
Claim copyright	.321	
Ease of obtaining advice on IP protection		
Patenting to prevent duplication/facilitate licensing	.455	
Patenting to deliver royalties	.405	
Registering an industrial design	.115	
Copyrighting/trademarking	.043**	Profit+
Importance of sources of innovation in the reference period		
R&D (in-house or external)	.179	
Employees recruited from competing organisations	.478	
Employees or contractors qualified to PhD level	.627	
Technology licensed from others	.580	
Publications or technical meetings	.358	
Reverse engineering & patent disclosures	.131	
Ease of access to sources of innovation		
R&D (in-house or external)	.730	
Employees recruited from competing organisations	.245	
Employees or contractors qualified to PhD level	.339	
Technology licensed from others	.183	
Publications or technical meetings	.432	
Reverse engineering & patent disclosures	.987	
Impact of the innovation activity in the reference period		
Increased range of products/services	.263	
Entered new markets or increased market share	.622	

Improved quality of products/services	.506	
Improved flexibility of production or service provision	.811	
Improved capacity of production or service provision	.896	
Reduced labour costs per unit output	.727	
Reduced materials/energy per unit output	.741	
Consolidated range of products/services	.603	
Co-operation on any innovation activities	.763	
Importance of the sources to innovation activity		
Internal to your company	.793	
Suppliers of equipment, materials, components or software	.776	
Clients or customers	.945	
Competitors or other companies in your sector	.281	
Consultants, commercial labs or private R&D organisations	.360	
Industry networks	.088*	Profit(-)
Government or public research institutes	.004**	Profit(-)
Higher Education Institutions (recruitment/talent development)	.894	
Higher Education Institutions (product/process projects)	.831	
Enterprise Ireland	.315	
InterTrade Ireland	.020**	Longevity+
County Enterprise Boards	.141	

Significant at 95%** and 90%*probability: Positive+, negative (-) and neutral/no effect (ne).

Table 6-6: Engineering SSI Strategy-Innovation Contingencies

6.3.4.1 Strategy-Innovation contingencies

Among the important associations with respect to strategic intent were:

- the degree to which companies aspiring to longevity developed new products and services in-company
- the positive impact achieved by firms seeking longevity through new or significantly changed sales or distribution methods
- the degree to which firms seeking longevity found InterTrade-Ireland to be significant to their innovation activity
- the ease with which profit seeking firms secured support in relation to copyright protection and trademarking
- the limited impact of industry networks on the innovation activities of profit seekers
- the low impact of government/public research for profit seekers

In-house innovation

Among firms who innovated within the reference period, those seeking longevity were most likely to do so independent of other organisations or institutions [X^2 (4, n=69), =9.793, p=<.044], this echoes the EU commission finding that Irish SMEs are mostly inclined to

innovate in-house (EC, 2012, p.9). Cooperation in respect of sales processes and routes to market dominated interview discussions. Sales partnerships were prominent whether through customers, channels or networking with competitors: but there was scant evidence of co-operative product and service innovation. The General Manager of one firm described the approach to openness in general.

> *We have an independent streak. …. We had a guy who came in and chaired our meetings, he was known and trusted. We talked about where we were going and how we were going to get there. Perhaps it's because an accountant owns the company, we hold our cards close to our chest. [E3.3_Lmh]*

Further illustrating the company's independence, despite being listed as an EI client, the firm claims to have no relationship with the agency. Another firm's Business Development Director described the company's position on co-operation while describing his desire to work more closely with partners.

> *We are not involved in any lobby groups or industry associations, we don't have the time. I would like to see a closer relationship between the likes of ourselves and the spinouts from 3rd level. I see a lot of research going on in 3rd level for foreign multinationals…. Which is easier – to sell an idea to Intel and they send you a nice tax-free royalty cheque every month or to try to set up a business, possibly make more and possibly make nothing but employ people and create wealth? [E3.2_Pre]*

The implication is that university researchers prefer to partner with larger firms, in this case FDI. In regard to R&D collaboration with the third level sector, the linkages between enterprise and academia are few – but the higher incidence of collaboration among foreign companies with third level education - both inside and beyond Ireland - is noteworthy (Forfás, 2004b, Ramirez et al., 2013). As noted above, individuals may seek to reduce risk by partnering with large firms with the prospect of earning royalties as opposed to establishing

a start-up. This lends support to the notion that, globalisation strengthens the need for national and sectoral innovation policies, rather than reducing it (Edquist, 2011).

Channel-Process Innovation

There was a significant and positive association between firms seeking to maximise sustainability and the degree of impact achieved by using new or significantly changed sales and distribution methods [X^2 (16, n=58), =26.623, p=<.046]. 75 per cent of firms seeking longevity rated such innovation as high impact. A number of firms placed significant emphasis on securing effective routes to market. One informant described indirect sales channels and how partners offer much greater scale via an agency approach. With limited exceptions, suppliers don't engage in referral due the competitive nature of the market.

> *We use feed supplier channels …. There's not a standard, it's different for each mill. Overseas that will be the main approach. On the scale of it – we're looking at CB in the UK, they've got four mills and forty four reps covering that whole area. The mills Ireland will have a maximum of six reps, it's a different scale and we'd be lucky if we get a bin out of one rep at a time. ……. They have loose relationships with our competitors over there but we have got a competitively priced product and it's unique so we're quite optimistic. [E3.1_Mca]*

> *Finding good distributors that we can get insurance cover and a credit limit on is key. All our sales are through distribution. Even if something comes in directly, we fulfil indirectly, you couldn't run it any other way. [E2.3_Mac]*

Copyright Protection and Trademarking

There was a significant difference between the perceptions of different strategy groups on the ease with which firms could secure copyright protection and trademarking during the reference period [X^2 (9, n=28), =17.360, p=<.043]. 71 per cent of profit seekers reported advice as highly accessible. Interviews indicated that firms who engaged routinely in IP

protection had established relationships with experts, and were highly selective about the types of patents they sought in order to avoid exposing blueprints to their competitors.

Industry Networks

There was significant association, at the 10 per cent level, between firms seeking longevity and network engagement, with 60 per cent reporting the positive impact of networks on innovation [X^2 (16, n=48), =24.051, p=<.088]. The significance of distribution/supply chain networks was widely referenced with regard to growing sales internationally with less reference to product-based network collaboration as noted earlier. One MD suggested a strong preference for building and managing his own network - largely oriented to generating leads. This was mirrored by a software informant who engaged primarily in networks focussed on customers rather than communities of practice.

> *We don't bother with the Chamber of Commerce and stuff like that, we make our own contacts. We have a good network of technical sales guys in Ireland and around the world. [E1.3_Dal]*

MD reflected on participation in a regional network addressing sector-specific issues and also to partnership with educational institutions.

> *Every 8 weeks there are about 6 companies that meet in Mullingar, we've been meeting for about the last 10 years. ……It's hard to know when to engage, you should not just engage when you are going to get something out of it. …. you never know what's going to come of those relationships, you always learn something. The company works with Engineers Ireland and with IEEF to a limited degree. Also DIT Bolton St. features a lot. I forged very strong relationships with them. We also have strong relationships with TCD, Harper Adams and Loughborough. [E2.2_Dr]*

The MD of an adolescent firm commented on her firm's unofficial network membership:

The Irish Medical Device Association (IMDA) - we're not officially members but I think we're included because we're an EI client. They are very strong. Boston Scientific is part of the IMDA and they really push on that front. That is an organisation worth keeping in with, I went to the last thing they had …….. and made a few contacts and kind of just figuring out who's who in Galway and what's happening and the smaller companies. It's good for that type of thing but it's an unofficial network as far as we're concerned. [E2.1_Bel]

Government and Public Research Institutes

There was a significant association relative to the impact of government and public research institutes on innovation, with 80 per cent of profit seeking firms perceiving low impact [X^2 (16, n=48), =34.897, p=<.004], and firms seeking longevity recording the highest levels of dissatisfaction. Given the largely science-led nature of public research in Ireland, such engagement would primarily be centred on third level institutions. The interview data allude to the long lead times associated with third level research, and the perceived lack of fit between the work of Science Foundation Ireland and the engineering sector. The interview extracts support the survey output.

People who need prototypes go to universities or colleges and it takes forever to get anything done because they work six months in the year …. They're starting to turn away from universities to commercial people like us. The thing about colleges is if you're not fashionable, they don't want to know. It's not leading edge stuff but as far as we are concerned, design work puts food on the table [E1.2_Ini].

Coming back to agencies like SFI, we had a presentation within our (Government appointed) Enterprise Group and I asked the question; 'if you take our business, could you give me the name of someone within SFI that I could at least communicate with to understand whether they are doing anything that might help us?' But the reply was 'why would you need to talk to anyone within SFI?' And I said; 'is it not there to help us?' When we probed further, we discovered there are very few people within EI who know what goes on there. [E1.1_Com]

This coincides with prior research emphasising the lack of pre-competitive research in the engineering disciplines (IEEF, 2011) and the notion that frontier research in Ireland is more likely to serve the needs of the FDI population (Ramirez et al., 2013).

InterTrade Ireland

Firms seeking longevity found InterTrade-Ireland to be a highly impactful contributor to innovation [X^2 (12, n=48), =24.033, p=<.020]. Interviewees ranked its capability development programmes highly in the technical/production area. Management development in general was seen as offering potential to counter reactivity among informant companies. In both contexts, InterTrade Ireland's Fusion programme was perceived as being of significant importance. One firm aiming for both fast growth and longevity refers to Fusion in the company's context.

> *We are availing of the Fusion Programme through InterTrade Ireland. We took on a graduate just over two years ago for Lean Manufacturing and that has worked out very well. The programme is over and that graduate is with us fulltime. We have done a second programme focussed on Design for Manufacturing and Assembly (DFMA) and that graduate will start soon. I have found the Fusion programme very good; it is run in conjunction with the University of Ulster. I wouldn't have employed a graduate this year otherwise. We would have continued on with our product development and incremental development on that slant. ….. I don't just want to invest in the programme for eighteen months; I want that person to stay on afterwards. In reality it is [still] home growing people. [E1.1_Com]*

This outcome reflects outcomes of similar innovation programmes in the Netherlands. The link to knowledge centres, and the percentage of turnover invested in R&D were found to be the most important factors for innovation in Dutch manufacturing SMEs (Keizer et al., 2002).

6.4 Summary of Findings - Engineering SSI

The significant relationships mediating system fit according to the age and strategy cohorts are summarised below. With respect to age, young engineering firms perceive the SSI as offering the least best fit, compared to their adolescent and mature counterparts. With regard to strategic aspiration, those firms aspiring to maximise technical superiority perceive poorest fit with the SSI.

Young firms

The survey identifies positive associations in respect of leadership recruitment and training however the balance of the system fit for young firms is negative, including rejection of funding requests, restricted access to EI grants and bank capital. This cohort delivers lower levels of innovation through advanced manufacturing technology, and perceives the degree of access to advice on registering industrial designs as inadequate. Engagement with consultants, commercial labs and sources of R&D is also sub-optimal.

Adolescent firms

Adolescent firms indicate positive and significant system fit in respect of new-to-firm products and services, access to advice on copyrighting and trademarking and R&D resources. These variables underline the association between new products, the development effort required to select, create and launch offerings and the parallel need to secure property rights. As represented by informants, this cohort appears to have engaged to a greater extent in business change including succession planning.

Mature firms

There were significant associations in respect of funding innovation through retained earnings and process innovation outcomes. The association between maturity and

innovation retained earnings funding is consistent with interview data: in the context of challenges to secure external funding through earlier stages of the company lifecycle, self-funding may be a product of necessity and philosophy in parallel.

The significant positive association with process innovation aligns with the theory suggesting this type of innovation increases with firm and product lifecycle maturity (Abernathy and Utterback, 1978). However, it contrasts with findings of generally low levels of process innovation in the LMT sector (Heidenreich, 2009) and also in the Irish high tech sector (Jordan and O'Leary, 2011), which indicates that older businesses are less likely than younger ones to introduce new processes.

Firms seeking to maximise profitability

Profit oriented firms indicate significant negative correlation with network participation and government/public research institutes as innovation sources. The qualitative data revealed some scepticism about the value of networks not directly related to sustaining or securing sales revenue. Engineering firm experience with regard to government and public research institutes, consistent with the findings of Ramirez et al. (2013), suggests that third level institutions lack urgency and that Science Foundation Ireland and related institutes are not designed to serve the needs of the sector. A positive relationship exists in respect of access to copyrighting and trademarking advice, which may indicate superior leverage of property rights to secure market preference and to assert competitive differentiation.

Firms seeking to maximise sales growth

The cohort aspiring to maximise sales indicate positive correlation with regard to accessing EI grants. Given the assumptions surrounding revenue and jobs growth, it might be

speculated that the business and market plans prepared to support EI funding requests are viewed positively in line with the agency's qualification criteria.

Firms seeking to maximise technical superiority

The survey indicates a negative relationship between firms aspiring to technological leadership, competition with FDI for talent and rejection of external funding applications. The former may be linked to the need for advanced engineering skills. The FDI sector's high tech orientation, along with superior remuneration and career paths, may divert high performers away from the indigenous manufacturing sector.

Firms seeking to maximise value for eventual exit/acquisition

Exits are not a feature of the mechanical engineering sector: no significant associations were found. This is consistent with industry norms and qualitative research output.

Firms seeking to maximise the longevity of the firm

Firms aspiring to longevity identified positive relationships in respect of support from InterTrade Ireland, and also the impact of process innovation on sales and distribution methods. These firms also indicated positive correlation with innovations produced mainly within the company – as noted earlier, the in-company orientation correlates with informant input and extant research.

This concludes the empirical analysis for the engineering sector. The concluding chapter presents aggregate analysis of findings in relation to both sectors in line sectoral dimensions, contingency variables and the frameworks employed as a basis for the research.

Chapter Seven

Concluding Discussion and Remarks

7.0 Conclusion

Since its inception, the National Systems of Innovation (NSI) concept has evolved to recognise the territorial, technological and sectoral heterogeneity of institutional interactions. While the concept has adapted to reflect meso variants, including the sectoral systems of innovation (SSI) framework applied here, it remains agnostic about firm-level contingencies exposing an important gap in our understanding of factors that potentially impede innovation. The findings of this research offer a number of important insights into how firm contingencies affect system fit, given that the ability to acquire and systematise resources are known to be significant predictors of growth.

This chapter outlines the key theoretical, management and policy implications of the thesis. It describes the major contributions of the research and notes that in some instances the absence of statistical support for a theoretical relationship in one sector represents a significant observation on system fit in another (see Table 7.0), supporting the adoption of a dual-sector approach. The chapter concludes by noting the primary limitations of the study, potential opportunities for future research and central contributions to theory and policy.

Arguments for more functional analysis of SSIs encompassing the parallel emergence and transformation of firms and institutions have had limited impact on the theoretical debate thus far. Responding to demands for studies adopting a problem-solving approach to the design of sectoral policy (Edquist, 2005; 2011), this research advocates micro-level analysis. It also seeks to combine institutional theory with strategic choice theory insofar as internal factors are known to be more important determinants of success than external variables (Acs et al., 2014; Hoffman et al., 1998).

Integrating the SI, firm age and strategy literature, a framework was developed to capture the regulating influence of firm-level variables on system fit. Analysis of the results indicates empirical support for adaptation of the current framework. Insights developed into the impact of age and strategic aspiration, an area not subject to prior examination; represent a valuable contribution to our knowledge of SSI fit. The framework proposed (Figure 7-0) suggests that improvements can be achieved in capacity and performance by examining the effect of contingencies on key system dimensions, with important implications for theory and policy. The research also signposts the need for more research to establish firm-level variables that may regulate system fit e.g. firm size, R&D expenditure and export intensity.

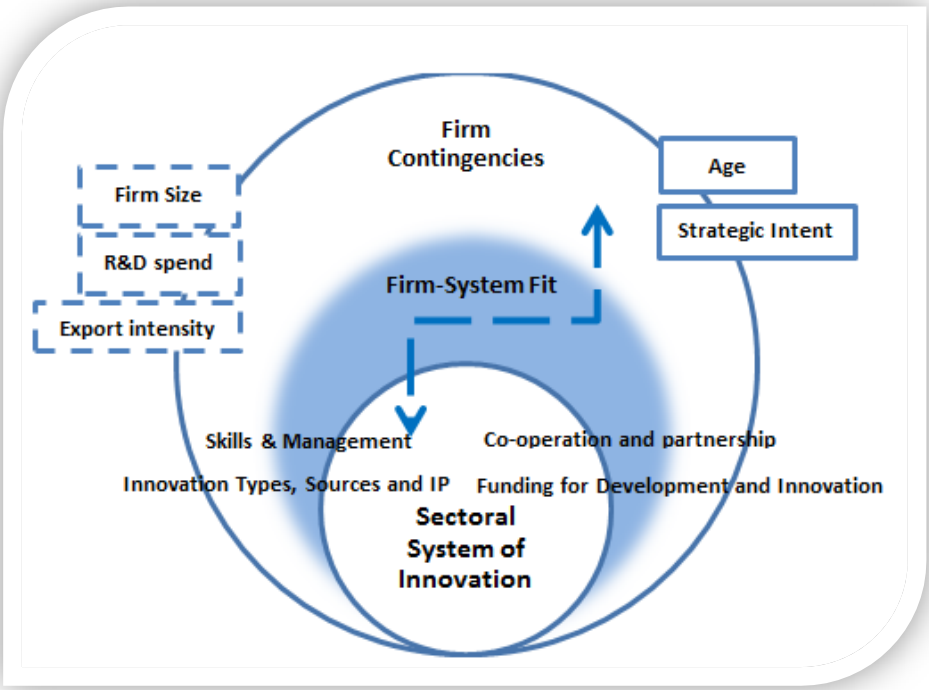

Figure 7-0: Proposed Micro-Level SSI Contingency Framework

7.1 Firm Contingencies – System Dimensions and Fit

Despite longstanding theoretical and practical focus on SME innovation by academics and policy makers, the degree and effects of interaction between firm-level and system-level variables remain unclear. As such, increasing awareness of the micro conditions that promote positive interaction with the SSI represents a valuable contribution. The framework assessed how previously unexamined associations regulate fit. The results indicate that the relationship between firm age, strategic aspiration and SSI dimensions is significant in respect of a number of measures.

Virtually all theories about organisations presuppose some process of adjustment over time. Just as the institutional infrastructure supporting start-ups is likely to prove unproductive for adolescent and mature organisations, the resources that support a venture's survival are completely different from those required for technology leadership. In parallel with growing emphasis on the temporal aspects of evolutionary processes within organisations, there is growing recognition of significant difference in the strategic direction of high-growth and non-growth firms suggesting that policy makers should adopt a more adaptive mind-set with regard to age and strategic orientation.

While the dynamics influencing growing firms have not been fully understood, this research shows skills and training, funding, innovation sources and processes to be among the most important resources in designing environments for innovation. Within the wide range of variables analysed, these dimensions emerged as the most significant in correlation with firm age and strategy. Table 7-0 below provides an overview of significant positive and negative associations and demonstrates important patterns for selected cohorts.

	Contingency	Age			Strategic Intent				
	System Dimension	Young	Adolescent	Mature	Profit	Revenue	Technology	Exit	Longevity
Skills/Training	Leadership/General Management availability		.03 **						
	Leadership/ Management Training access	.052*							
	Leadership/Management training effect	.072*							
FDI Presence	FDI Expands skills base		.008**						
	Increases competition for talent			.005**			.046**		
	FDI expands lobbying potential		.02**						
	FDI Dilutes govt. support				.077*		.076*		
Funding	Sought external funding						0.064*		
	Access to angel investment	0.048**							
	Business expansion scheme							.083*	
	Bank capital			0.083*				.010*	
	Venture capital			0.036**(ne)					
	Enterprise Ireland grants		0.053*						
	Innovation vouchers		0.079* (ne)						
	EI stabilisation funding			0.049**					
	Retained earnings	0.068*							
	EU Framework (FP7) funding						0.091*		
	Funding requests rejected	.016**					.058*		
	Access to bank capital	.080*							
	Access to EI Grants	.083*				.057*			
	Impact of retained earnings			.045**					
Innovation Types/Sources/Supports	Importance of customers	0.005**							
	HEIs (product/process)					0.004**			
	New-to-firm prods/services available from competitors		.018**						
	Dev. mainly in-company		.014**						.044**
	Innovated via advanced machinery, equip or software	.093*							
	Access to industrial design registration advice	.079*							
	Copyrighting trademarking advice		.074*		.043**				
	Access to R&D resources		.050**						
	Materials/energy innovation			.080*					
	Import of consultants, commercial labs, private R&D	.016**							
	Import of networks source				.088*				
	Govt./public research source				.004**				
	InterTrade Ireland support								.020**
Process	New/significantly changed sales/ distribution				0.035**				046**
	Improved production capacity or service provision								0.027**

Key: Significant at 95%** and 90%*probability: Positive+, negative (-) and no effect (ne). Software Engineering – diagonal up border

Table 7-0: Overview of contingencies

Age cohort – Patterns of System Fit

While young engineering firms recorded positive perceptions in respect of access to and effects of training and development, the survey exhibits predominantly weak fit for funding, innovation sources and supports for the dual-sector cohort. The adolescent cohort indicated mainly positive system fit with regard to access to copyrighting, trademarking and R&D resources in the case of the engineering and skills availability and FDI presence in the software sector. This may reflect a degree of age-related viability. The mature software cohort indicated poor fit in terms of FDI contention for talent, bank capital and venture capital availability, however as might be expected, EI stabilisation funds were positively correlated – having been largely designed to support mature companies. The mature engineering cohort indicated positive fit vis-à-vis the use of retained earnings and materials/energy innovation output.

Strategic intent cohort – Patterns of System Fit

Engineering firms intent on building longevity demonstrated positive fit in respect of in-house innovation, support from InterTrade Ireland and new or significantly changed sales and distribution methods. The latter was positively correlated for software firms seeking to maximise profits whereas engineering firms in this cohort perceived predominantly poor fit.

Significant regulating effects relating to funding, human capital and innovation types and sources are discussed in more detail below.

7.1.1 Funding

Deficient access to external funding is frequently cited as the most significant barrier to innovation. Investment is heavily influenced by financial sector developments, in particular, the limited availability of bank and risk finance. Research indicates that SME access to non-

bank sources of finance is too low and that this is particularly detrimental to the development of Irish SMEs (OECD, 2013). Working capital and cash flow also present challenges, as small firms are often compelled to accept extended payment terms.

The positive relationship between the reinvestment of profits and firm age indicates increased reliance on internal equity as firms mature. Retained earnings and financial slack are shown to play a significant role in funding firm growth. In a study of capital structure over the firm lifecycle, La Rocca, La Rocca and Cariola (2011) found that debt is key to funding early-stage businesses in a 'bank-oriented country' (p.107), while mature firms rebalance their capital structure by substituting debt for internal capital. This profile is replicated across both sectors in the current research. However, access to debt finance is constrained among young firms, reinforcing the *liability of newness* (Stinchcombe, 1965) argument; it is also consistent with Boswell's (1973) reference to financial institutions' 'in-built allergy' (p.193) to infant firms, given their standard requirement for balance sheets and trading accounts for a three to five-year timeframe. An adolescent software firm director recounted a bank's reluctance to provide overdraft facilities until the firm reached profitability – *'… there's no bank funding. They'll give us an overdraft now when we are profitable, but they wouldn't give it to us when we needed it'*. [S2.1_Vs]

Software funding

Firms in the computer software and services sector are known to be doubly encumbered in raising finance, due to the intangibility of their assets in conjunction with their age profile. Information asymmetry, moral hazard and adverse selection characterise research on high-tech funding. Three observations are particularly noteworthy in relation to age. For mature firms, the EI Stabilisation Fund (designed to support viable, vulnerable businesses during the

downturn) had a significant positive effect (p=<.005), whereas venture capital was perceived to have no effect (p=<.036) on the cohort, perhaps indicating reduced appetite among equity investors to fund established companies.

Relative to the needs of young software firms, restricted access to angel funds was significantly correlated (p=<.048). As might be anticipated, early-stage firms expressed similar constraint in respect of retained earnings (p=<.068). These findings reinforce the general understanding that resources assume greater importance in young firms. However, it is also apparent that *liability of newness* (Stinchcombe, 1965) limits those same firms in predicting resource requirements, amplifying moral hazard. As the director of a young software firm observed, *'We had €7m by drip feed. It has been scary at times. At the outset, we were too optimistic in our forecasting'* [S1.0_VS]. In the same vein, another young firm MD commented in relation to fundraising: *'The feedback was that we were too early and needed to establish a customer base. In reality I'm very happy that we didn't get funding three years ago….. We would not have achieved the targets that we had set out we would be in a very different place now'* [S1.1_Az]. These associations, in combination with testimony from interviews, suggest potential for management development and improved financial acumen.

With regard to the impact of strategic intent on software funding fit, access to bank capital (<.010), and to a lesser extent Business Expansion Scheme funding (<.083), were significant and positive for those companies seeking to exit. This implies a preference for financial autonomy on the part of such firms, while amplifying the need for debt funding options.

In keeping with the experience of firms in the engineering sector, software firms aspiring to technology leadership were significantly correlated with applications for external funding

(<.064). Moreover, a modest positive correlation (<.091) with access to European Framework (FP7) funding among the technology-led software cohort was not reflected in the engineering sector. Pre-competitive research in engineering disciplines is not well established and researchers are known to be less motivated by the challenges of low-technology firms. This aligns with the high-tech orientation of FP7 and the parallel focus of the research community. Access to retained earnings among those aspiring to technology leadership pointed to constraint (<.068), suggesting that in the absence of broader private sector funding, options for firms seeking scale remain narrow.

Engineering funding

The predominance of self-funding in the engineering sector contrasts with the capital structure of the software sector, which is often associated with external shareholders seeking early returns. Contrary to the position in the software sector, there was no evidence of public equity investment. European policy makers recognise the importance of promoting risk capital and liquid equity markets to help high-tech companies develop (Carpenter and Petersen, 2002), but this is absent for manufacturing which is more capital intensive. The field data suggest that while liquidity constraints inhibit innovation, the position is mitigated by retained earnings. In common with their European peers, Irish-owned SMEs cite myriad difficulties raising finance for capital investment both before and since the 2008 financial crisis. A recent government report setting out the potential for Irish manufacturing (Forfás, 2013a) outlines the funding position and reflects significant dependence on external finance due to capital intensity:

> *For manufacturing, … capital investment is not a luxury; it is inextricably linked with business development and growth. Manufacturing CEOs cite unavailability of*

finance as a genuine constraint to the future development of the sector in Ireland (p.x).

In most cases, engineering firms grow organically and do not seek external capital, beyond significant plant and equipment acquisition. This may have negative long-term consequences, as economic growth can be constrained by overreliance on internal funds.

Analysis of the engineering funding dimension resulted in a number of significant age associations. The findings indicated particular constraint for young engineering firms. In common with many countries, lack of early-stage finance consistently emerges as a challenge with firms forced to rely on internal funds for innovation. Young engineering enterprises also demonstrated poorest fit, based on rejection of funding applications (p=<.016), somewhat limited access to EI grant aid (p=<.083) and absence of angel investment (p=<.000). The latter is consistent with slower rates of return in LMT sectors. As one financial sector informant commented, 'time to money is too drawn out in traditional manufacturing' (DP_1.0). In contrast, mature firms indicated significant correlation in terms of the positive impact of retained earnings on innovation capacity (p=<.045). This suggests an accumulation of earnings by owners whose firms are successful enough to survive to middle-age. It is also consistent with prior findings that equity and debt funding provided by principal owners increase as firms move into middle and old age (Berger and Udell, 1998).

The MD of one mature firm commented in relation to external funding: *'We've had no agency funding. We fund innovation from cash flow. It's been that way since the start. It's a strong business was a result'* [E3.3_Lmh]. While financial autonomy may appear positive, as referenced above, it signals a potential revenue trap, given that retained earnings are generally insufficient to finance significant technology development. Bootstrapping R&D

tends to confine initiatives to those that generate short-term returns – firms, by necessity, prioritise development over research and, as a potential consequence, follow the market rather than lead it.

With respect to strategy, engineering firms in the technology leadership cohort who sought external funding were significantly correlated (p=<.036), as was rejection of those applications (p=<.058). This is likely to be symptomatic of high rates of capital intensity compounded by protracted returns, as referenced above. Contrary to the earlier finding of restricted access to EI funding for young firms, those engineering firms claiming aspiration to growth indicated significant correlation (p=<.057) in respect of ease of access to grant aid. This advocates qualification criteria which align agency goals with growth metrics.

Theoretical contribution

While a number of the research findings align with extant theory, others suggest the need for theory development. The potential inherent in theorising the impact of firm contingencies on funding, and the likely utility of a diagnostic approach which takes much greater account of firm age and strategy, could inform practice and policy. The research shows that young firms report consistent difficulty in accessing formal sources of finance – a situation replicated across a range of countries (e.g. Lawless et al., 2013; Westhead and Storey, 1997). Evidence underscores capital market imperfections which preclude small firms from raising sufficient funds to support R&D. From a system perspective, these components are considered at a macro-meso level, but little focus is afforded to the role of firm-level dynamics.

Significantly, the challenge to economic growth posed by mature firms' overreliance on retained earnings, coupled with the funding constraint experienced by young firms and

those aspiring to technology leadership, would benefit from more detailed analysis such that inhibiting factors could be calculated and addressed. Specifically, tests and remedies for the finance-related liability of smallness (Freeman, Carroll and Hannan, 1983), newness (Stinchcombe, 1965) and obsolescence or senescence (Sorenson and Stuart, 2000) could advance theory within the SSI domain.

In light of negative findings in relation to external funding, grant aid and retained earnings signalled by firms aspiring to technology leadership, greater understanding of how technology-led strategy is crafted, funded and executed by SMEs is warranted.

Managerial implications

While the availability of external investment is seen to assuage liabilities of newness in start-ups, the funding lacuna for young firms exerts persistent pressure on growth prospects and, when allied to the absence of seed funding, acts as a barrier to later rounds of investment. This links to the challenge for SMEs in that the problems encountered and the skills necessary to deal with them change as firms grow, and thus the ability to anticipate and manage issues is one of central importance to on-going development. With respect to SME practitioners, it could be argued, in line with the findings of Cressy and Olofsson (1997), that improved capacity for management and strategy formulation will be central to the future availability and subsequent management of funding. Survival prospects significantly depend on managements' ability to adapt strategy to changes in the environment (Geroski, 1995). Where such skills are lacking, management development should be afforded priority.

Offering a somewhat uncharacteristic assessment of the funding landscape, the CEO of one adolescent software company suggested that the funding system is adequate; the only non-engineer among all of the software executives interviewed portrayed a lean approach to

business start-up with significant emphasis on business model fit. *'I've never got an investor and I never would ask an investor for money without having a business model working. The business model is the key'* [S2.3_ Gt]. Extending beyond the realm of funding, however central to return on investment, this offers some reinforcement of the merits of management development allied to a theme that emerged in this research relative to hybrid engineering commercial skills. The development of technologies that do not have a viable business model presents a significant risk to sustainable innovation outcomes.

Policy implications

In addition to the near universal recommendation of increased funding, the research points to three parallel routes to releasing bottlenecks: first, a coordinated approach to management development; second and relatedly, attraction of investors based on desirable investment opportunities and third, leveraging grant and investment aid through a transparent system of funding that ties grant approval to stages of commercialisation.

One source of growing debate is that successful entrepreneurial activity attracts funding, and not vice versa (Kao, 2009; Kreft & Sobel, 2005). Extending the previous theme of prioritising management development, this implies that policy should focus on creating an environment which is attractive to high-potential entrepreneurs, rather than attracting venture funding per se. While government and VC funds are typically associated with financing innovation in the high-tech sector, ambitious software programmes introduced by the EU Commission and national governments have been shown to have a limited effect on the European software industry (Mowery, 1999). Results for the Irish software sector in respect of top-line revenue growth are similarly disappointing. With regard to the development of the funding system, the role of policy makers in diagnosing firm-level

perspectives spanning age, managerial autonomy and strategic aspiration appears merited. The alternative would be to suggest that agencies and policy makers should assume the resources and expertise of venture capitalists and investors; however, requisite funding and acumen may be in short supply.

In the absence of significant policy initiatives, evidence from interviews indicates that firms in both sectors employ bootstrapping allied with the sale of professional services to counteract the lack of financial slack. Where retained earnings are insufficient to fund the development of leading technologies, public sector funding represents one short-term option to plug the gap. However, firms seeking such funding would benefit from a more transparent, if not directive, application and evaluation regime. The EU Horizon 2020 programme contains many of the elements of the acclaimed SBR programme for US technology SMEs. The programme is structured in three phases: financing exploration of the technical feasibility of an idea or technology, proof of concept, pre-prototyping and the evaluation of the potential for commercialisation to support the move from the laboratory into the marketplace (Autio et al., 2014). Given that state agencies are charged with the administration of Horizon 2020, the lessons learned from the deficiencies of FP7 and the positive outcomes of the SBR programme might filter through to other channels. This behoves management acumen and development, parallel to that suggested at the firm level, on the part of state agencies.

Financial and human capital are recognised as being pivotal to innovation. Following analysis of the funding contingencies, the next section addresses significant associations in respect of firm contingencies and skills.

7.1.2 Human Capital

Knowledge is recognised as the most fundamental resource in the modern economy; moreover, it is clearly linked to skills and innovation. Penrose (1959) interpreted growth as an outcome of a firm's entrepreneurial and managerial knowledge capacity.

The systemic effect of education is already well established. This research suggests the need for more detailed diagnosis of the nature and variety of skills needed alongside more business-oriented third-level support for the technical and commercial research needs of SMEs. It is important to analyse the skills necessary for development, as well as the balance between pure and applied research. Much of the narrative in this domain has a scientific rather than a commercial emphasis, and it would be beneficial to develop a shared understanding among policy makers, state agencies and educational institutions as to how SME-based R&D, as distinct from micro firm and large-scale enterprise R&D, is constituted in relation to the types of skills needed to support its various facets.

FDI and general management-level observations are particularly noteworthy in respect of human capital. Relative to the positive and negative impacts of FDI, the adolescent software cohort recognised a complementary role in respect of expanding the skills base and lobbying capacity. By contrast, mature software firms and those aspiring to technology leadership, in both the engineering and software sectors, identified contention for talent as a significant constraint. With regard to leadership roles, these were seen to exert a positive impact on performance in adolescent software firms, whereas young engineering firms perceived ease of recruitment as well as ease of access to management training and development.

The effects of FDI, many of which were unanticipated prior to this research, are analysed separately below.

Software – human capital

Human capital is critically important to the competitiveness of the software sector globally – most notably in respect of development personnel. It is also recognised that software skills are a vital dimension of systemic competitiveness across other sectors, including manufacturing systems, medical devices, healthcare, green tech and financial services. Beyond development skills, informants observed the need for hybrid technical and commercial aptitude.

The historical shortage of skills has been identified as an impediment to the development of domestic software industries throughout Europe. More recently, the shortage of skills in Ireland, including the growing trend towards off-shore production, has been reported (Fitzgerald, Lenihan, Lopez-Gomez, & O'Sullivan, 2014). Scarcity of talent is likely to depress the potential for sustainable growth at affordable salary levels. Such is the dearth of supply, that 55 per cent of demand for technically qualified ICT employees in Ireland is currently met by foreign nationals (Forfás, 2012b).

Alluding to the aggravating effects of FDI within the system, one respondent commented: *'Programmers at all levels [are] scarce, due in part to large multinationals absorbing the best talent.'* A mature firm CEO expressed a view in relation to competition for talent and implications for muted growth of the indigenous sector: *'I think it's one of the reasons why the indigenous industry is somewhat stunted, why we are economically crowded out by the multinationals'* [S3.2_Oc].

The adolescent software cohort identified the positive and significant impact of FDI presence on lobbying (p=<.02) as well as educational provision (<.008) alongside promotion of employment prospects more generally. Lobbying is formally spearheaded by ICT Ireland

and the Irish Software Association (ISA), which represent the interests of indigenous and foreign-owned companies under the umbrella of IBEC. Beyond promoting the needs of the sector – primarily in the human capital, taxation and funding arenas – ISA subsidises upskilling and management development programmes for employees and the wider labour force.

The findings echo conclusions by O'Malley and O'Gorman (2001) and O'Riain (2004) to the effect that foreign-owned technology subsidiaries generate beneficial effects by raising skill levels in the workforce; albeit prior research is absent micro data on indigenous firms. At the population level, it is noteworthy that, with limited exceptions, weak ties have been identified as a persistent factor undermining the growth potential of both sectors. The adolescent software cohort also identified a significant and positive correlation between leadership, general management and innovation outcomes (p=<.046). Managerial autonomy and adaptability is widely acknowledged in the literature while senior management is known to play a key role in solving the problems that allow young firms to progress to subsequent stages of development.

Interviews reflect a dearth of qualified developers emerging from third-level institutions, a constraint exacerbated by the superior remuneration and development opportunities offered by the FDI sector. In keeping with the findings of Barry and Bradley (1997) and Lawless et al., (2012), skill levels are typically greater in subsidiaries, and wages are approximately 20 per cent higher than in the indigenous sector. In the words of the founder of a mature software company: *'The money and the benefits in the larger companies are much better. Also, the job security is better; every economic crisis wipes out a bunch of indigenous companies because we don't have access to funds'* [S3.2_Oc].

Foreign-owned companies appear to aggravate the *liability of scarcity* (Carroll and Hannan, 1989; 2000) in respect of technical skills for mature software firms (p=<.005) as well as those aspiring to technical superiority (p=<.046) and, to a lesser extent, those seeking to maximise profits (p=<.077) due to perceived dilution of government support. The resulting *tight niche packing* (Carroll and Hannan, 1989) is intensified by ongoing sponsorship of entry to the sector both indigenously and through subsidiaries, but without a concomitant effort to address the skills gap albeit, initiatives are ongoing in relation to education provision and improved access to employment visas for qualified individuals.

The weakest aspect of system fit relates to contention for software engineering and design skills – a situation that is not dissimilar to other economies, including Silicon Valley. However, the situation in Ireland is greatly aggravated by competition from overseas subsidiaries offering superior remuneration and career prospects.

Engineering – human capital

The engineering employee base is multifaceted, encompassing a broad range of unskilled, apprenticed and degree-qualified personnel. While sectors like manufacturing engineering are deemed LMT; this classification masks significant levels of new process and product adoption, and their impact on innovation. While the traditional engineering sector can be characterised as LMT, with R&D expenditure levels at one to three per cent of revenue (Smith, 2005), production processes are often highly knowledge intensive. As illustrated by the Director of a mature firm: *'People talk about the promise of the knowledge-based economy. I think what we need is a knowledge-based manufacturing economy'* [E3.2_Pr].

The availability of skills and competencies varies significantly across technical, commercial and managerial roles. Young engineering firms recorded ease of recruitment (p=<.052) at

leadership and general management level. However, a number of participants contrasted the availability of degree-qualified applicants seeking supervisory roles against gaps in production engineering and technical programming skills. Indeed, the latter are reported as largely absent from the domestic labour pool. A recent Irish government report (Forfás, 2013a) references the need for enhanced management capability and leadership skills to drive innovation and export growth in the new manufacturing era. The positive correlation in respect of leadership and management for young firms appears to downplay imbalanced system output with regard to the supply of production-oriented skills vis-à-vis graduate-level candidates for manufacturing roles.

A related theme that emerged repeatedly in interviews, but which was not found to be significant for a specific cohort, is the dearth of hybrid skills in the talent pool. While this analysis of age-skills dimensions presents a view of age contingent variables in the senior management and development fields, including a somewhat positive association with training provision (p=<.072) for managerial employees, the contingency perspective somewhat underplays the field data in respect of combined commercial-technical skills. This aspect of human capital acts as a constraint to establishing product-market fit and crafting business models as expressed in the viewpoint: *'It's hard to get a commercial person who has a technical-engineering background … They are much sought after and there aren't many around'* [ESY_BC].

Notably, among those firms aspiring to technology leadership, competition for talent presented the sole significant correlation for the FDI dimension of the engineering SSI (<.058). The latter may signify problems with the supply of elite technical skills or the

possibility that human capital is diverted to foreign-owned subsidiaries for reasons observed in the indigenous software sector – superior remuneration and greater career prospects.

Theoretical implications

While any suggestion that innovation is monopolised by high-tech firms has been long discredited, debates on national research and technology policies are perceived to suffer from 'high-tech myopia' (Heidenrich, 2008, p.1), implying the superior potential of research-intensive sectors. The findings, while reflecting the known differentials in policy focus, also suggest the need for more theory development in the area of human capital. Supply-side considerations include the perceived adequacy of leadership and general management talent among young firms, and contention for human capital with both indigenous and foreign-owned high-tech firms among those striving for technology leadership. While there has been much theory development in the area of FDI externalities, the advantages and disadvantages of FDI vis-à-vis specific sectors and firm-level contingencies within those sectors have not received attention to date.

Managerial implications

In light of the recognition among the adolescent software cohort of the complementary role played by FDI in expanding the skills base and buttressing lobbying capacity, practitioners in non-strategic sectors should seek to address deficits in this regard. The near absence of manufacturing engineering FDI representation amplifies the need for awareness building among indigenous firms. While the research uncovered a number of informal local and regional engineering sector associations, engagement with the national lobbying platform, IBEC's Irish Engineering Enterprises Federation umbrella body, was minimal.

Policy implications

The findings have several policy implications. The significance of technology skills for innovative output took precedence in interviews with adolescent and mature companies, where many report cultivating skills in-house, or being compelled to recruit abroad due to inadequate domestic provision. Unlike software engineering where skills are more standardised, expertise in engineering is less homogenous, which drives the tendency to *mould* employees in line with company practice. This cements a propensity for experience-based learning, including strong tacit knowledge. The inclination to mould skills in-house may be a symptom of idiosyncratic management, and aligns with the preference for independence, which is further reinforced by self-funding. Albeit more tangential than the suggested effects of FDI on the software sector, liability of scarcity (Carroll and Hannan, 1989; 2000) and tight niche packing (Carroll and Hannan, 1989) have an impact on the traditional engineering sector in respect of those seeking technology leadership positions.

This concludes analysis of the findings and implications of the research in relation to the human capital dimensions of the SSIs. The next section analyses system dimensions related to innovative output.

7.1.3 Innovation Types, Sources and Supports

In line with theory, the field data characterise SME innovation as largely reactive and incremental. Based on solutions and adaptations required by customers or available from competitors, the majority consist of relatively small improvements, thus supporting the contention that most of the knowledge for innovation originates in near-market sources rather than technical research (Fagerberg, 2009; Lundvall et al., 2002; Roper, 1997).

Beyond products, the data present ample evidence of business model innovation in the form of companies developing new routes to market, innovating export distribution channels, developing products under licence and process innovation adding value through productivity improvement, design, development and manufacturing services.

Software – innovation types, sources and supports

There was one significant age-related correlation in respect of the innovation input variables for the software sector. While much research focusses on collaboration mechanisms that facilitate innovative output, specifically in the context of resource-constrained SMEs (Eisenhardt and Forbes, 1984; Lundvall et al., 2002), young cohort respondents reported direct customer input as having no effect (p=<.005) on innovation. This runs contrary to the general understanding that interaction with customers has stronger effects on the probability of product innovation (Jordan and O'Leary, 2011) and the near market emphasis cited above. The result may indicate that collaboration has a restrained influence on more radical product innovation, cementing the view that customer interactions focus mostly on incremental change (Un, Cuervo-Cazurra and Asakawa, 2010). Otherwise, technology-oriented firms are seen to demonstrate less interest in market-based innovations if they do not involve state-of-the-art technologies (Zhou, Kin and Tse, 2005). While both scenarios represent innovation, it may be that young firms do not classify incremental improvement as innovation, or, alternatively, that early innovation initiatives among young firms are conceived internally and become subject to market interaction and customer validation later. Consistent with the finding on customer interaction, interview narratives suggest a life course effect in adolescent and mature companies' attitudes to technology: many reported how early *technology push* gave way to more client-centred solutions, with holistic offerings overtaking or embodying standalone technology. This is illustrated by a young firm CEO who

described technology as important but subservient to his firm's potential to create value, emphasising a growing appreciation for non-technology-based innovation and diffusion: *'You obviously have to have the technology in the first place, but technological innovation has a medium impact on our potential to grow…Execution is more important than technological superiority. If you asked me five years ago, I would have said [it was] top priority but … I don't think it's so much about the technology as about how you deliver the offering and the service that you support it with'* [S1.1_Az].

Among significant software strategy-related associations in respect of innovation types and sources were the link between profit-oriented firms and the impact of changes in sales and distribution methods, as well as the apparent ineffectiveness of higher education institutions as a source of innovation for that cohort. Improved production and service provision methods were significantly correlated among those firms seeking longevity.

Firms aspiring to maximise sales growth indicated significant correlation with respect to innovation in sales and distribution methods ($p=<.035$) compared to alternative strategy types. Given the link between effective sales and company growth, this relationship might be anticipated; but interview data suggest that such innovation is not commonplace. An exploratory interview with a partner in a VC firm illustrates how weak go-to-market strategies can result in commercial failure despite the presence of market opportunity and novel solutions. The partner reflected: *'… when I look across our successful and unsuccessful companies, there's no difference in their technical capabilities, but there is a difference in their ability to sell and go out to the market and meet customers, convince them they should have their product, and that they should pay for it and not be with anyone else'* [VC D].

Software firms seeking to maximise growth indicated that third level institutions were not important sources of product/process-related innovation, having no impact on innovative output (p=<.004). This resonates with extant findings that HEIs do not have a significant effect on business innovation (Jordan and O'Leary, 2008; McCann and Simonen, 2005; Roper, Du and Love, 2008). More pointedly, in the Irish high-tech sector, Jordan (2011) and Jordan and O'Leary (2011) found a negative relationship between the frequency of interaction with academic researchers and the probability of product and process innovation.

Firms seeking longevity, in keeping with lifecycle theory on process innovation, reported that innovations in production or service capacity delivered significant positive impact (p=<.027). While process-oriented output was high among more mature companies, and thus consistent with the need to formalise methods and standards, significant elements of the value delivered to customers concerned process outputs. One company founder actively set out to build a technology-intensive business that would scale up without related increases in headcount and capital outlay. He described leveraging previous experience in a people-intensive business to achieve his objective: '*I took my knowledge about running a service business and this, I suppose, is where the innovation came from. I was looking for a business that could be upgraded by adding a server instead of a person. Scalability was the most important thing for me, regardless of the idea. … It's not a people-intensive business it's a technology-intensive business'* [S2.3_Gtm]

The theoretical, managerial and policy implications are summarised below, following analysis of findings for the traditional engineering sector.

Engineering – innovation types, sources and supports

Adolescent engineering firms accounted for the majority of significant associations, including launch of new-to-firm products and launching services already available from competitors (p=<.018), a tendency to develop products primarily in-house (p=<.014) and ease of access to R&D resources (p=<.050). In relation to the in-house focus on new product introductions, a number of informants described a disruptive innovation stance, crafting solutions similar to '*more sophisticated German counterparts' (without reference to reverse engineering),* by taking a low-cost, low-complexity approach to achieving market fit and competitiveness.

Young engineering firms reported the relatively limited import of consultants, commercial labs and private R&D providers in supporting their innovation activities (p=<.016). This likely relates to their focus on near-market development, with direct response to customer needs reducing the necessity for research and potentially allowing them to bootstrap future innovation initiatives.

Significant associations with regard to strategic intent were dominated by firms aspiring to business longevity in the areas of in-house innovation (p=<.044), changes in sales and distribution methods (p=<.046) and benefits attained from working with InterTrade Ireland (p=<.043), primarily through education partnerships. Profit-seeking firms reflected negatively in relation to government and public research support (p=<.004), with many suggesting that preference is afforded to foreign investment initiatives, due to their superior employment impact.

Theoretical implications

Given the economic potential in technology start-ups, there is significant scope for empirical work in the context of business model innovation. The work of Osterwalder and Pigneur (2010) and Maurya (2012) on business model visualisation, as well as the work of Blank (2005) and Ries (2011) on customer and lean development, has been widely diffused among start-up communities. This research suggests that the pattern of learning which emerges through a firm's life course can be escalated through live case studies carried out in conjunction with HEIs. This is particularly important in light of resource constraints combined with mortality rates among start-ups.

By extension, while a number of authors counsel against regarding servitisation as a remedy for sustaining manufacturing business in tough markets, they note significant potential for helping companies to exploit higher-value activities (Baines et al., 2009; Reinartz and Ulaga, 2008). The parallel process of productisation in software firms, whereby many offerings are developed in response to customer-specific needs – essentially creating unrepeatable propositions which undermine potential to scale – would benefit from extended empirical analysis. Baines et al. (2009) cite the dearth of research available to help practitioners make the necessary transition.

Implications for practitioners

While SMEs aspiring to growth are assumed likely to establish partnerships (Hansen and Hamilton, 2011), the data presents mixed evidence of inter-firm collaboration for new product and service innovations. Overall, collaboration levels were consistent with Robson and Bennett's (2000) assertion that supply chain collaboration constitutes the most significant route to partnering for SME innovation. However, the preference for

independent development of new offerings is in line with research findings that 'Irish SMEs are inclined to innovate in-house' (European Commission, 2012, p.9). The limited importance of customer engagement for innovation in young software firms supports this analysis and is allied to the restricted outside involvement in development of new products and services in adolescent engineering firms and in those seeking longevity. Historically, LMT firms have displayed a decline in propensity to collaborate, with levels of R&D-type partnering decreasing from about 20 per cent in the 1960s to 10 per cent in the 1980s and 5 per cent in the 1990s (Hagedoorn, 2002).

Customer collaboration facilitates faster proof of concept and mitigates the risk associated with frontier-type projects. This thinking represents a precursor to the lean start-up concept (Ries, 2011; Maurya, 2012) which places emphasis on building products iteratively, based on product-market hypothesis testing throughout the preliminary stages of the product lifecycle. With regard to collaborative R&D relationships, Love and Roper (2001) observe that networking may lead to risk-sharing, allowing firms to undertake developments that would be too costly or risky to undertake independently. One process innovation identified in interviews is sales lead sharing among companies within a regional engineering association: when orders are too large for one company to fulfil, contracts assigned to one entity are delivered in collaboration with other association members, thus creating cooperative-competitive relationships. A broader purview in respect of cooperation with industry networks, competitors, customers and suppliers merits managerial consideration.

Implications for policy

Continuing the previous theme, but with a different focus for policy makers, firms are known to maximise R&D returns by directing product research towards customers (Grimpe

and Sofka, 2009). However, the data show that much of firms' R&D efforts were focussed on near-market opportunities (development), and that agency funding criteria were largely aligned with customer and market feedback. While this has overwhelmingly positive consequences for market validation, it may foreshadow ambitions for more radical innovation. In addition, while the production of game-changing technology is a challenge for SMEs in the context of the many constraints discussed in this thesis, there may be merit in facilitating companies to take bigger risks – with limited exceptions; this appears to be the preserve of institutional researchers in conjunction with multinationals. As illustrated by a business development director of a mature engineering firm: *'I see a lot of research going on in third level for MNCs. NUI Maynooth is like a research vessel for Intel and, similarly, UCG ties in with Boston Scientific – rightly so, they are massive employers with huge revenue streams for the country'* [E3.2_Pre].

To continue the theme of game-changing technologies, higher education institutions are considered a bulwark of Systems of Innovation, yet the findings suggest a lack of fitness for purpose for growth-oriented SMEs in the software sector. While not significant, for other cohorts, the problem appears to be pervasive. Just as research at the technology frontier is more likely to serve the needs of Ireland's FDI population, applied research on behalf of SMEs both in terms of product-market fit and route to market across the technical and commercial domains could be given priority at institutional level. This suggests striking a better balance between institutional emphasis on the absorption, adaption and diffusion of technologies alongside technology development. Ideally managed by enterprise agencies in conjunction with HEIs, this area is amenable to a pilot approach, the design of which would include management and evaluation criteria. In the context of institutional objectives, this

plank of the system could yield results which would embed relationships for the wider benefit of students, firms and educators.

While not significant for a specific cohort, third-level business incubators were seen as a potential source of competition for human capital, diverting talent into start-ups rather than supporting established firms to scale up. Lundvall et al., (2009) point to the challenge of high volumes of start-ups in contrast with a short supply of entrepreneurship initiative within existing firms. One mature firm CEO observed that '… incubation gives you a safe haven and … all the talent is getting diverted into micro companies that will never go anywhere' [S2.3_GT].

Given the unanticipated effects of FDI on innovation system fit, the following provides a brief analysis of the impacts that emerged from the research.

7.1.4 Foreign Direct Investment

Context

The role played by FDI vis-à-vis system-fit for indigenous firms emerged in exploratory interviews. While extant research acknowledges the positive and negative effects of FDI on the economy of host nations, the perceived level of impact was as potent as it was unanticipated. Specific FDI variables were created for the survey as existing measures (Community Innovation Survey) did not adequately capture direct effects on system fit. While there is some impact on manufacturing engineering firms, specifically in respect of human capital and more generally in terms of perceived dilution of government support, pros and cons are predictably greater for the software SSI, given the concentration of high-tech subsidiaries.

Despite synergies between the indigenous and foreign-owned sectors, such as joint lobbying of the education system, Irish-owned firms appear to suffer from a liability of smallness (Freeman, Carroll and Hannan, 1983) in respect of lower wage rates, reduced job security and fewer opportunities for progression. While share options are seen to offer a positive alternative for employees of indigenous software firms, exit potential is largely tied to trade sales given the limited number of IPOs, exacerbated by the number of de-listings since the early 2000s. Associated theories on the liability of newness (Stinchcombe, 1965) and niche packing (Carroll and Hannan, 1989) combined with the evidence from this research, provide strong indications that FDI exerts a preponderantly negative impact on system resources and, as a consequence, on the innovative capacity of indigenous firms.

Policy implications

The dual structure of the Irish economy, induced by a long-term commitment to FDI-led industrialisation, has resulted in two distinct economic sectors. Beyond the weak interactions between the foreign and indigenous sectors, and contrary to prior findings of the positive influence of FDI on the competitive advantage of indigenous firms (O'Malley and O'Gorman, 2001), the research for this thesis uncovered unexpected levels of contention between the two. While the role played by FDI in the Irish economy is overwhelmingly positive, the beneficial effects are inadvertently diluted by what appear to be poorly managed consequences. Larger, more established firms have access to a greater array of resources and they enjoy advantages over smaller counterparts, including being better positioned to compete for qualified labour with inevitable consequences for growth. This presents particular liabilities of smallness and newness in the Irish software SSI. The effect of inward investment is likely to diminish the human capital available to indigenous

firms, thus creating the potential for 'the rich getting richer while the poor get poorer' (Anderson and Tushman, 1986, p.445)

While SSI elements can reinforce each other in promoting processes of learning and innovation, as observed by Lundvall (1992, p.2) 'virtuous and vicious cycles' are also a by-product of the system. If, as DiMaggio and Powell (1983) suggest, the number of organisations in a population is a function of environmental carrying capacity, the data reveal contrary effects with regard to the supply of talent, and to a lesser extent, government focus within the system. As noted above, the talent constraints exert greatest impact on mature software firms, but also have impact on those striving to deliver technologically advanced propositions across both the software and engineering sectors.

This research suggests that employing separate policies and agencies to design and govern FDI and indigenous firms leads to parallel consideration (with minimal evidence of cross-over), rather than an integrated ecosystem approach. Independent of advocating consideration of firm-level contingencies, the design and execution of policy rooted in the SSI framework would engender tighter scrutiny of mutual effects – ultimately delivering a more robust and potentially self-reinforcing system with direct and indirect spill overs.

While indigenous software firms recognise the potential benefits of sub-supply and the increased lobbying power offered by their FDI counterparts, continued promotion of the software sector against the backdrop of an insufficient talent pool appears to result in firms adapting firstly, through overseas recruitment and secondly, through offshoring of design and engineering effort. An alternative consequence in the context of superior prospects and financial sureties offered by multinationals is that the adequacy of resources within the software SSI and those aspiring to technology leadership in the engineering sector, forces

indigenous firms to persist on the margins of the resource base (Carroll & Hannan, 2000). While policy makers and state agencies indicate awareness of tight niche packing (Carroll & Hannan, 1989), public debate on the problem is limited and to some extent dissuaded – constituting something of an elephant in the room.

Liability of scarcity

An important aspect of environmental adoption is the potential effect of density at the time of firm foundation, leading to higher mortality rates across the life course of the population. Additionally, founding conditions are said to have a disproportionate effect on young firms (Eisenhardt and Schoonhoven, 1990; Stinchcombe, 1965), as conditions at birth and early infancy shape development in significant ways (Kimberly, 1980). In light of the likelihood of diminishing returns as resources become depleted, Aldrich (1999) warns of the potential for 'niche-crowding' (p.269) as competition for resources intensifies in high-density environments. The density-delay hypothesis originating in mathematical population models suggests an *imprint effect* of firm density at founding. In their *starting point* argument, Carroll and Hannan (2000 pp.241-242) coin the term 'liability of scarcity' and outline the adverse effects of density at the time of firm foundation, including intense competition creating resource scarcity and *tight niche packing* resulting in new entrants competing for thinly spread resources, leading to higher than average mortality rates. This extends the debate about the practice of governments 'picking winners' where existing resource constraints appear to be compounded by attracting new entrants into targeted, yet resource-poor, sectors.

With respect to early-stage firms, some organisational ecologists believe that businesses, once born, have little if any flexibility to change and will succeed or fail according to

environment-based selection (Engel and Teece, 2012), where variations in early stage resources have significant long-run impact on mortality.

Niche-crowding may exemplify the situation in emerging high-technology domains, with significant competition for skills across indigenous and foreign-owned sectors further compounded by contention for seed funding and equity funding. On the contrary, low-tech manufacturing sectors may, as a consequence of low population density, suffer from insufficient numbers opting for non-high tech careers, exacerbated by cross-sectoral competition for managerial talent and, to a lesser extent, investment capital. System analysis in this context should take into account the size of a population relative to generic and industry-specific resources.

This concludes the analysis of significant associations and implications of the research. To follow is a review of research limitations and prospects for future research.

7.2 Limitations of this research

While a range of exciting and valuable contributions have been drawn from the data, in common with most research, this analysis has a number of limitations which need to be considered in interpreting the results. Some elements represent interesting topics for future research.

In relation to the extent to which findings are transferable to a broader sample, the research context was confined to two sectors in a single national territory which may limit its external validity. While it is anticipated that many of the variables could be adapted to other sectoral systems, the data originate uniquely from Irish SMEs, leaving open to question the generalisability of the findings to other economies. The latter is partially illustrated by

contrasting results from the software and engineering sectors. Employing the same framework, comparative analyses in different institutional contexts could add to the generalisability of the findings.

A second limitation arises from the nature of the study and the ability to draw inferences for longitudinal relationships from cross-sectional data. This includes survivor bias. Differing macro-economic conditions add to the difficulty of drawing long-term implications from cross-sectional research and one-off surveys of innovation-related activity. Building on systems thinking, innovation is recognised as a cumulative phenomenon which leverages existing knowledge and strategies, including prior inventions and innovations; therefore the results are best interpreted as suggesting *associations* among the selected variables at one point in time.

On a related issue, the adoption of a questionnaire as a research instrument, while supported by in-depth interviews, falls short of a sophisticated temporal study. As observed by Pettigrew, Woodman, and Cameron (2001) , the preferable way to 'reveal multiple levels of context in the interaction field is to have a time series sufficiently long to show how firm, sector and economic levels of context interact'(p.699). It is hoped that the shortcomings of the questionnaire are at least partially offset by the insights provided through the interview process.

7.3 Future Research

The research findings provide several new insights; however, they also indicate the potential for further research on the mobilisation of firm-level contingencies in the design, management and evaluation of system fit.

Beyond a cross-sectional study, there is scope to explore the regulating effect of age and strategic intent longitudinally and within other territories. Such studies would benefit from analysis of the software and manufacturing engineering sectors to provide added insights through comparative sector analysis.

The findings in this chapter contribute to the apparent gap in the literature for a more systematised understanding of the impact of firm dynamics on system fit. However, there is significant opportunity to extend the contribution by supplementing the model with alternative contingencies such as firm ownership structure, measures of value-add, export orientation and business models. This might necessitate the integration of theoretical frameworks from other disciplines, capturing further complexities of SSI fit.

Finally, while this research concentrated on correlating individual contingencies with system dimensions, contingencies are known to occur together, potentially with conflicting implications. Cross-correlation of firm-level contingencies would likely offer further insights into the complex and multi-dimensional nature of system-fit. This could produce additional fine-grained data, supplementing the findings of this study and adding to the theoretical understanding of system fit.

7.4 Key contributions

The empirical evidence provided in this research represents important contributions to the SSI literature in respect of theory and policy. The following section focuses on six central contributions, three in the realm of theory and three in the policy domain.

Theoretical Contributions

While current SI theory embraces the notion that the policies and institutions which enable growth are context specific, the theory offers limited recognition of specificity at the firm level. As Pettigrew et al. (2001) contend, it is crucial to use context analytically and not just as a stimulus environment. The micro perspective adopted in this research extends theory on a number of levels:

Firstly, the findings support a supplemental approach to the study of SSI suggesting that combined analysis of respective micro and institutional-level variables could yield richer theory than standard macro and meso-level perspectives. This research represents the first empirical analysis of contingency-based system fit, theorising the relationship between firm-level variables and innovation system dimensions. The findings suggest that research combining the analysis of respective micro and institutional variables can yield richer theory than the standard macro and meso-level perspectives adopted heretofore.

The second theoretical contribution is the novel integration of literature on SSI, age and strategic intent. The three literatures have developed independently of each other, yet each is focused on how firms adapt to internal and external dynamics. The theories on systems of innovation, age and strategic intent have not previously been linked in this way.

The third theoretical contribution is the principal age and strategic contingency perspective. The empirical research uncovered systematic relations between SSI-fit and observable firm-level variables. Judgements about SI have tended to be based on a macro or whole-system view whereas this research suggests that the same system may work very differently for companies with distinct age and strategy profiles within the same sector, suggesting that a more contingent view is needed. Notably, the integration of firm contingencies within the

framework has provided more insight than the comparative case study approach employed in the extant literature.

Policy Contributions

Despite the institutional perspective that macro and micro environments are inextricably interwoven (Zucker, 1977), policy design, as currently practiced, relies largely on territorial and sectoral frameworks with limited consideration of micro-level characteristics. Firm contingencies offer scope for policy adaptation through the use of rich company data to chart system fit. Insights derived into the reciprocity of firm age, strategic aspiration and fit create the potential to refine current policy by examining not only those dimensions which support or impede innovation, but to further distinguish the effects of different contingencies on distinct sectors. Notably, this study intersects with the emergent National Systems of Entrepreneurship concept, which aims to capture 'the moderating effect of institutional conditions on individual processes' (Acs et al., 2014, p.490). This has implications for pragmatism in the design of policy and for benchmarking innovation systems with respect to firm contingencies. Policy makers and their agencies have a substantial role to play in crafting institutional designs that take advantage of fit. This suggests a diagnostic, rather than a blueprinting approach to system design, incorporating theory and firm-level data to produce models. As observed by Fagerberg, Mowery, & Verspagen (2009) research findings are often too general to be instructive for policy makers. The results of this research do not justify a generalised diagnostic approach; however, they do suggest merit in assessing selected variables within key sectors. The micro perspective adopted in this thesis has the potential to inform policy on a number of levels:

Firstly, the model demonstrates the mutually impactful roles of firm-level contingency and system dimensions in innovation system design. The contingency view offers a possible alternative to the normative approach which typically proposes universal policy solutions to meet complex and sometimes contradictory sectoral and organisational challenges. Policy designers may thus be encouraged to assess dual-fit.

A second contribution relates to the comparative analyses of innovation and enterprise in distinct SSI. By establishing the extent to which firm contingency affects system fit across two contrasting sectors, this research examines emergent and traditional firms in parallel, making a contribution to 'cross-level' policy design. Consistent with prior research (e.g. Rumelt, 1991) industry-wide factors may matter less than firm dynamics, underscoring the importance of policy makers drawing on agency.

The final policy contribution focuses on the influence of contingency-based system fit on micro-level performance. Insight into fit based on firm contingencies represents a potentially valuable contribution to our knowledge of how innovative potential can be enhanced. This is in harmony with the thinking of Rodrik (2009) that development economists should adopt the role of 'diagnosticians' (p.5) helping decision makers to choose the right model and remedies for their specific realities, offering some reinforcement of the suggestion that policy-makers should adopt a more diagnostic approach to innovation system design and management.

7.5 Closing remarks

Through the lens of firm contingency, this research sought to examine whether the current conception of SSI policy adequately reflects firm dynamics. It analysed what is known about innovation, based on two contingencies i.e. firm age and strategic aspiration, in the context of framing conditions within two SSIs. More specifically, it aimed to uncover whether particular age and strategy cohorts are more or less conducive to fit with selected system dimensions. The research challenges the conceptualisation of SSI by demonstrating that system properties respond differently based on distinct contingencies within sectors.

The research elaborates on several issues that are core to innovative capacity and it brings to the fore several concerns in need of managerial, policy and scholarly analysis. Insight into system fit based on firm contingencies represents a valuable contribution to our knowledge of how innovative potential can be enhanced through an improved understanding of policy design and evaluation. The evidence in the thesis points to the significance of a micro-level perspective.

Drawing on a variety of disciplinary backgrounds, this research began by analysing the overarching systems of innovation, firm age and strategic aspiration literature. Within the framework developed, sectoral system dimensions were correlated with firm-level characteristics. Significant associations based on the output of dual sector surveys were supported by qualitative data from interviews to qualify and elaborate the framework, thus re-interpreting the SSI through the lens of significant contingencies.

A primary objective was to move beyond the macro/meso-level focus on SI by focusing on the heterogeneity of firms and the question of how SSI fit is affected by the resulting

diversity in micro-level processes. Through the medium of strategy and age-driven variables, organisational development engenders contingent conditions, creating inherent potential for synergies and conflicts with the system. While recognising that firm-specific factors are central to explaining the innovative capacity and output of companies across the software and manufacturing engineering sectors, we established that age and strategic contingencies have a significant and heterogeneous effect on system fit. This calls into question the degree to which systems should be designed with reference to firms' sectoral, technological or territorial profile – suggesting that micro-level contingencies are similarly influential to innovative capacity. The insights offer potential to explain and address gaps in system configuration by fostering a more contextualised understanding of the SI domain.

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Appendices

Appendix 1: Overview of research sites - Phase 1

Firm	Areas of activity	Informant
Engineering SME	Instant UpRight is a global provider of access solutions, manufacturing and supplying their instant alloy tower system and custom-engineered scaffolding access solutions for the Aviation, Power Generation and Industrial markets	Managing Director, John Nevin
	Trenchlink designs and manufactures a system of interlocking, ductile iron road plates which are to cover utility trenches maximising safety with minimum disruption for road users.	Managing Director, David Byrne
Software SME	FlexTime develops and supplies web oriented solutions for Flexible Working, Time & Attendance and Staff Scheduling	Managing Director, Ciaran Rowsome
	Soft-ex develops web-based Telecom Data Intelligence and enterprise communications management tools for mobile and fixed operators and corporate enterprises.	Managing Director, Ian Sparling
IBEC	The Irish Engineering Enterprises Federation (IEEF) promotes and supports the competitiveness and prosperity of the engineering sector in Ireland through the representation of the sector's interests to national government and EU institutions, the provision of business and market information to companies, and development of specific programmes on key business issues.	Director, Marion Byron
	The Irish Software Association (ISA) provides a voice for the technology sector to enable companies to build their ability to scale, increase funding levels in sector and push the sector's requirements in the political sphere in a coherent way.	Director of the ISA, Paul Sweetman
Enterprise Ireland	Responsible for strategy & policy in relation to the development of the indigenous internationally traded firms, Enterprise Ireland provides direct supports to Irish companies at all stages of development to foster job creation and export growth. Their programmes offer a range of assistance in the broad categories of: Company Growth, Capability Building, High Potential Start Ups, Seed and VC Programmes, and Research collaboration and commercialisation.	Manager, Engineering Markets Division, Neil O'Sullivan
		Manager, Internationally Traded Services & Software Division, Jim Cuddy
Venture Capital	Delta Partner is a VC firm investing primarily in Ireland and the United Kingdom. The firm was established in 1994 and had €250m under management at the time of interview.	General Partner, Maurice Roche
	Kernel Capital has a portfolio of investee companies across, technology, life science and general industry. The company was established in 2002 and had €173m under management at the time of interview.	Founder and Managing Partner, Niall Olden

Appendix 2: Overview of research sites - Phase 2

Firm	Areas of activity	Age	Employees /Revenue (2009)	Informant
S1.1	Technology supporting automated business processes Wireless internet services providers	6	10/700k	CEO
S1.2	Wireless technology to detect physical proximity between people, businesses and devices.	8	11/750k	CEO
S1.3	Middleware supplier to the travel industry	7	116/9M	Chief Technology Officer
S2.1	Automated customer contact solutions	11	22/3M	Sales Director
S2.2	Systems integration solutions for laboratory and manufacturing systems	11	22/2.5M	Managing Director and Co-Founder
S2.3	Mobile marketing media services	11	11/900k	Founder Director
S3.1	e-invoicing services for accounts payable, accounts receivable and billing	14	13/1.2M	CEO
S3.2	Software for retail and lab optical industry	14	86/10M	CEO
S3.3	E-learning solutions	22	65/5.6M	CEO
E1.1	Multidirectional forklifts	11	200/45M	Managing Director
E1.2	Sub-supply of steel fabrications and end products to the agricultural, industrial, sports and marine sectors	15	70/6.5M	Managing Director
E1.3	Engineering systems for gas generation	17	11/1.4M	Managing Director
E2.1	Precision engineering sub-supply to medical, electronic, aerospace and automotive customers	31	67/6.9M	Managing Director and Head of Operations
E2.2	Manufacture of excavator attachments and hitching technology	31	110/13.5	Managing Director
E2.3	Clean-tech machine fabrication	34	50/6.2M	Managing Director
E3.1	Metal fabrication including custom-built components and design and manufacture of galvanized silos	40	72/7.5M	Sales & Market Director
E3.2	Sub-supply of precision machined components and fully tested electro-mechanical assemblies	42	75/11M	VP Business Development
E3.3	Mechanical and structural engineering including conveyor and marine systems	40	38/5.1M	General Manager

Appendix 3: Phase 2 Interview Schedule

Introduction

The objective of the interview is to gain insight into chief executive level perceptions of the engineering and software Sectoral Innovation Systems respectively. Questions are general in nature and the interview should take no more than an hour to complete.

Questions

Demographics:	Date of incorporation:
Turnover 2006/2007/2008	Employees 2006/2007/2008

1. Please describe your company's founding history
2. How would you describe the core activity of the business – has this changed since its foundation?
3. What have been the key drivers of innovation over the past three years?
4. How would you describe your firm's strategy for growth – strategic intent?
5. How would you categorise your business in terms of low-medium-high technology?
6. How would you categorise the rate of growth in your sector low-medium-high?
7. To what extent to you cost innovation activity? If so, what metrics do you use?
8. How, if at all, does your company protect Intellectual Property?
9. Considering your firm's most recent innovation project, how long did it take to bring the project to market?
10. Thinking about the Quality and Skills of the workforce 2006-2008
    a. How adequate was the supply of Technology and Business graduates
    b. How important have Technology and Business graduates been to the growth and development of the business?
11. Thinking about advancing capability via training and development 2006-2008
    a. How adequate is the range of Technology and Business programmes on offer
    b. How important have such programmes been to the development of your business?

12. Thinking about the availability of funding for innovation 2006-2008
    a. How adequate was the supply of funding (Bank/Equity/Retained earnings/Agency)
    b. How important has such funding been to the development of your business?
13. Thinking about innovation partnerships 2006-2008
    a. To what extent has your company engaged with external partners
    b. How important have such partnerships been to the development of your business?
14. Thinking about technology-based Innovation (Goods/Services/Processes) 2006-2008
    a. To what extent have you engaged in innovation?
    b. To what extent were those innovations developed in-house or with external partners?
    c. How important have the innovations been to the development of your business?
15. Thinking about non-technology-based Innovation (e.g. Business model/Procedures/Routes to Market) 2006-2008
    a. To what extent have you engaged in that type of innovation?
    b. To what extent were those innovations developed in-house or with partners?
    c. How important have such innovations been to the development of your business?
16. In terms of resources, what do you believe are the most important determinants of innovation in the sector?

Many thanks for taking the time to participate in this study. We realise that your time and experience are valuable and your contributions are much appreciated.

Appendix 4: Questionnaire Review Panel

Commercial Review Panel

Mr. David Byrne, Managing Director, MD, Trenchlink

Mr. Raomal Perera, Entrepreneur and co-founder Network365/Valista and ISOCOR

Mr. Simon Rees, Sales and Marketing Director, Idiro Technologies

Mr. John Wall, Managing Director, GxP Systems

Mr. David Walsh, General Manager, KelTech Engineering

Academic Review Panel

Dr. Anthony Buckley, Lecturer, School of Marketing, Dublin Institute of Technology (DIT)

Dr. Joseph Coughlan, Head of School, Accounting and Finance, DIT

Dr. Daire Hooper, Lecturer, School of Management, DIT

Mr. Paul O'Reilly, Head of School, Management Studies, DIT

Professor Stephen Roper, Professor of Enterprise and Director of the Enterprise Research Centre, Warwick Business School

Professor Pamela Sharkey Scott, Maynooth University.

Extract from feedback on original Questionnaire

General comments: Generally, font size too small.

Some questions congested.

Refinement of cover letter

Refinement of follow-up letter.

Appendix 5: Survey Questionnaires

Software SSI Survey 2011

1. Background information

*1. Please provide general information about your company and your role

In what year was your firm founded?

What is your company's core business?

What is your job title?

How many years have you been in your current role?

*2. Estimate your company's average number of employees [fulltime equivalents] for the years:

2008

2009

2010

*3. Approximately what proportion of current employees hold a degree [e.g. BA/BSc or Masters/PhD]

% in science or engineering

% in other subject areas

% non-graduates

*4. On a scale of 1 to 5, how important are the following objectives to your company's growth? *[5 highest to 1 lowest in order of priority]*

	1 Lowest Rank	2	3	4	5 Highest Rank
Maximising profitability	○	○	○	○	○
Maximising sales growth	○	○	○	○	○
Maximising technical superiority	○	○	○	○	○
Maximising firm value for sale/acquisition	○	○	○	○	○
Maximising firm sustainability/longevity	○	○	○	○	○

*5. In achieving those growth objectives, please rate the importance of the following types of innovation:

	1 Not important	2	3	4	5 Very important
Developing new or significantly improved products	○	○	○	○	○
Developing new or significantly improved services	○	○	○	○	○
New or significantly improved production processes	○	○	○	○	○
New or significantly improved marketing/sales processes	○	○	○	○	○
New or significantly improved organisational processes (Business practices, workplace organisation or external relations)	○	○	○	○	○

***6. Rate your agreement with each of the following statements about your markets:**

	1 Strongly Disagree	2	3	4	5 Strongly Agree
Competition is cut-throat	○	○	○	○	○
Customer expectations are stable	○	○	○	○	○
Technology developments in our industry are rather minor	○	○	○	○	○
There is a high level of product/service innovation	○	○	○	○	○
Service differentiation for our product is high	○	○	○	○	○
Technology changes provide big opportunities in our industry	○	○	○	○	○
Production/process technology is changing rapidly	○	○	○	○	○
Market growth is high	○	○	○	○	○
It's very difficult to forecast where technology in our industry will be in the next 3 years	○	○	○	○	○

2. Skills

***7. How important were the following types of staff to your company's performance in the last 3 years?**

	1 Not important	2	3	4	5 Very important
Technical/Engineering (Design Engineering, Development, Solutions Architect)	○	○	○	○	○
Business/Commercial (Sales/Business Dev., Marketing, Product management)	○	○	○	○	○
Leadership/General Management (CTO, CFO, etc.)	○	○	○	○	○

***8. How easy was it to fill vacancies across these staff groups in last 3 years?**

	1 Difficult	2	3	4	5 Easy	N/A
Qualified Technical/Engineering talent	○	○	○	○	○	○
Qualified Business/Commercial talent	○	○	○	○	○	○
Qualified Leadership/General Management talent	○	○	○	○	○	○

Please detail any skill gaps in recruitment over the last 3 years

***9. Rate the effectiveness of internal and external training and development programmes undertaken to upgrade skills in the last 3 years?**

	1 Low	2	3	4	5 High	N/A
Technical/Engineering	○	○	○	○	○	○
Business/Commercial	○	○	○	○	○	○
Leadership/General management	○	○	○	○	○	○

***10. Rate your agreement with each of the following statements regarding the presence of foreign multinationals in your sector in Ireland.**

	1 Strongly Disagree	2	3	4	5 Strongly Agree
Expands skill base through education and training provision	○	○	○	○	○
Increases competition for talent in the sector	○	○	○	○	○
Increases the pool of managerial talent available to sector	○	○	○	○	○
Expands the domestic customer base	○	○	○	○	○
Expands sector's lobbying potential	○	○	○	○	○
Dilutes government support for indigenous companies	○	○	○	○	○

3. Innovation types, sources and protection of intellectual property

Innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation, external relations or partnerships.

***11. During the last 3 years, did your company introduce:**

	Yes	No
New-to-market products or services **before** your competitors?	○	○
New-to-firm products or services **already available** from competitors?	○	○
New-to-market processes **before** your competitors?	○	○
New-to-firm processes **already employed** by competitors?	○	○

12. *If you answered YES* to any of the above, who developed these innovations?

	Yes	No
Developed mainly within your company	○	○
Developed by your company together with other companies or institutions	○	○
Developed mainly by other companies or institutions	○	○
Innovated through acquisition of advanced machinery, equipment or software	○	○

13. *In the event* that you engaged in organisational or marketing innovation, rate the *impact* of that activity over the last 3 years?

	1 Low	2	3	4	5 High
New or significantly changed company strategy	○	○	○	○	○
New/improved systems to exchange information, knowledge & skills	○	○	○	○	○
Major changes to the organisation of work within your firm (e.g. changes in management structure or integrating different departments or activities)	○	○	○	○	○
New or significant changes in your relations with other firms or public institutions (e.g. through alliances, partnerships, outsourcing or sub-contracting)	○	○	○	○	○
Advanced management techniques (e.g. Lean, Agile)	○	○	○	○	○
Significant changes in how your product is offered to the market (e.g. Implementation methods, SaaS or financing options)	○	○	○	○	○
New/significantly changed sales or distribution methods (e.g. new distributor agreements or license sales)	○	○	○	○	○
New/significantly changed marketing methods (e.g. new lead generation methods or social media)	○	○	○	○	○

***14. Over the last 3 years, did your company:**

	Yes	No
Apply for a patent	○	○
Register a trademark	○	○
Claim copyright	○	○

15. *In the event* that you sought advice or support on Intellectual Property protection in the last 3 years, how easy was it to obtain?

	1 Difficult	2	3	4	5 Easy
Patenting to prevent duplication/facilitate licensing	○	○	○	○	○
Patenting to deliver royalties	○	○	○	○	○
Copyrighting/trademarking	○	○	○	○	○

16. In the last 3 years, how important were the following sources of innovation for your company?

	1 Not important	2	3	4	5 Very important
R&D (in-house or external)	○	○	○	○	○
Employees recruited from competing organisations	○	○	○	○	○
Employees or contractors qualified to PhD level	○	○	○	○	○
Technology licensed from others	○	○	○	○	○
Publications or technical meetings	○	○	○	○	○
Reverse engineering & patent disclosures	○	○	○	○	○

17. *Where relevant*, how easy was it to access these sources of innovation in the last 3 years?

	1 Difficult	2	3	4	5 Easy	N/A
R&D (in-house or external)	◯	◯	◯	◯	◯	◯
Employees recruited from competing organisations	◯	◯	◯	◯	◯	◯
Employees or contractors qualified to PhD level	◯	◯	◯	◯	◯	◯
Technology licensed from others	◯	◯	◯	◯	◯	◯
Publications or technical meetings	◯	◯	◯	◯	◯	◯
Reverse engineering & patent disclosures	◯	◯	◯	◯	◯	◯

18. Rate the impact of your company's innovation activity on the following criteria in the last 3 years:

	1 Low	2	3	4	5 High
Increased range of products/services	◯	◯	◯	◯	◯
Entered new markets or increased market share	◯	◯	◯	◯	◯
Improved quality of products/services	◯	◯	◯	◯	◯
Improved flexibility of production or service provision	◯	◯	◯	◯	◯
Improved capacity of production or service provision	◯	◯	◯	◯	◯
Reduced labour costs per unit output	◯	◯	◯	◯	◯
Reduced materials/energy per unit output	◯	◯	◯	◯	◯
Consolidated range of products/services	◯	◯	◯	◯	◯

4. Co-operation and innovation output

***19. In the last 3 years, did your company co-operate on any innovation activities (e.g. with customers, suppliers, state agencies or educational institutions)?**

◯ Yes

◯ No

5. Co-operation and partnership

20. In the last three years, how important were each of the following sources to your company's innovation activities?

	1 Not at all	2	3	4	5 To a large extent
Internal to your company	○	○	○	○	○
Suppliers of equipment, materials, components or software	○	○	○	○	○
Clients or customers	○	○	○	○	○
Competitors or other companies in your sector	○	○	○	○	○
Consultants, commercial labs or private R&D organisations	○	○	○	○	○
Industry networks	○	○	○	○	○
Government or public research institutes	○	○	○	○	○
Universities/Institutes of Technology (recruitment/talent development)	○	○	○	○	○
Universities/Institutes of Technology (product/process-related projects)	○	○	○	○	○
Enterprise Ireland	○	○	○	○	○
InterTradeIreland	○	○	○	○	○
County Enterprise Boards	○	○	○	○	○

***21. For those partners important to your company's innovation over the last three years, please indicate where your counterpart was based [tick one or both].**

	Based in Ireland	Based internationally
Suppliers of equipment, materials, components or software	☐	☐
Clients or customers	☐	☐
Competitors or other companies in your sector	☐	☐
Consultants, commercial labs or private R&D organisations	☐	☐
Industry networks	☐	☐
Government or public research institutes	☐	☐
Universities/Institutes of Technology (recruitment/talent development)	☐	☐
Universities/Institutes of Technology (product/process-related projects)	☐	☐
Enterprise Ireland	☐	☐
InterTradeIreland (location of partner, not agency)	☐	☐

6. Funding for growth and development

***22. Has your company sought external funding for R&D or wider innovation activity in the last 3 years?**

- ◯ Yes
- ◯ No

7. Funding for development and innovation

23. With respect to external funding in the last three years:

Approximately what proportion of overall R&D/innovation related spending was externally funded? _____

Have you had any request for R&D/innovation related funding rejected (yes/no)? _____

***24. How easy was it for your company to access the following sources of funding for innovation in the last 3 years?**

	1 Difficult	2	3	4	5 Easy	N/A
Business Expansion Scheme	◯	◯	◯	◯	◯	◯
Angel Investment	◯	◯	◯	◯	◯	◯
Bank Capital	◯	◯	◯	◯	◯	◯
Venture Capital	◯	◯	◯	◯	◯	◯
Hire purchase/Leasing	◯	◯	◯	◯	◯	◯
EI (Enterprise Ireland) equity investment	◯	◯	◯	◯	◯	◯
EI grants e.g. R&D funding/RTI, Innovation vouchers, FP7, EI Stabilisation funding	◯	◯	◯	◯	◯	◯
County Enterprise Board funding	◯	◯	◯	◯	◯	◯
R&D Tax Credits	◯	◯	◯	◯	◯	◯

***25. How important were these sources of funding to support innovation in your company over the last 3 years?**

	1 Not at all	2	3	4	5 To a large extent
Business Expansion Scheme	○	○	○	○	○
Angel Investment	○	○	○	○	○
Bank Capital	○	○	○	○	○
Venture Capital	○	○	○	○	○
Hire purchase/Leasing	○	○	○	○	○
EI (Enterprise Ireland) equity investment	○	○	○	○	○
Innovation vouchers	○	○	○	○	○
R&D funding/RTI Grant	○	○	○	○	○
Stabilisation funding	○	○	○	○	○
R&D tax credits	○	○	○	○	○
European Framework Programmes (e.g. FP7)	○	○	○	○	○
InterTrade Ireland (e.g. Fusion)	○	○	○	○	○
Retained earnings/reinvesment of profits	○	○	○	○	○

***26. Indicate the approximate proportion of revenue generated by the following in the last financial year [should total 100].**

% Export Sales	
% Sales to Irish-owned enterprises	
% Sales to foreign-owned multinationals in Ireland	

27. Indicate the approximate proportion of the last financial year's revenues generated by products/services that did not exist 3 years ago?

	approximate %
Revenue from products/services developed in the last 3 years	

28. As an approximate % of revenue, indicate your company's spend in the last financial year on:

	% revenue spent:
Research and Development	
Broader spend on activities to support innovation (non R&D)	

***29. Please estimate your company's turnover [excluding VAT] for the years:**

2008	
2009	
2010	

8. Summary and thank you

*** 30. To what extent did the following hamper your innovation in the last 3 years?**

	1 Not at all	2	3	4	5 To a large extent
Lack of funds	○	○	○	○	○
Lack of engineering/technical talent	○	○	○	○	○
Lack of sales/marketing talent	○	○	○	○	○
Lack of managerial/leadership talent	○	○	○	○	○
Lack of information on technology	○	○	○	○	○
Lack of information on markets	○	○	○	○	○
Lack of tax incentives	○	○	○	○	○
Lack of intellectual property protection	○	○	○	○	○
Difficulty in finding co-operation partners	○	○	○	○	○
Cost of labour	○	○	○	○	○
Inadequate/costly infrastructure	○	○	○	○	○

Please make any additional comments regarding innovation enablers and constraints here:

31. Thank you sincerely for completing this survey.
A donation to Saint Vincent de Paul will be made in appreciation of your time.
If you would like to receive a summary of our aggregate findings, please provide your details.

Name

Company

E-mail address

Phone-number

Other