Economics of Innovation, Productivity and Growth

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Abstract

This doctoral research studies the deeper drivers of innovation, productivity and growth as well as the interlinkages between these three aspects. The thesis is organized as follows:

Chapter 1 places the motivation of this research within the context of the wider body of research in the fields of economics of innovation, productivity and growth. It sets out the main aspirations of this research, followed by a brief outline of the research.

Chapter 2 explores a wider set of innovation drivers driving firm growth, combining analysis of formal R&D processes promoted by growth theories alongside informal R&D linkages emphasized by national systems of innovation (NSI). The main goal is to distinguish primary drivers from secondary drivers, by examining the differences in key forces driving firm revenue levels versus those driving firm revenue growth. This hypothesis is tested through a dataset of 27 European economies over the period of 1996-2010, controlling also for globalization and industrial organizational drivers. Findings reveal that informal R&D linkages appear to be the primary drivers needed to establish firm revenue levels, while formal R&D investment is needed as a secondary driver to spur firm revenue growth.

Chapter 3 delves into the structural drivers of productivity. Using an adaptation of the economic development framework, the Lewis model, this study proposes that country level labour productivity may be driven structurally by the movement of resources from smaller firm to larger firm-size structures. To enable this analysis, a new database is built up at sector level for the 32 European economies between 2000-2012. The contribution of firm-sizes to country productivity is measured through isolating classifications of small, medium and large firms, alongside control variables capturing growth theory drivers, globalization, credit conditions and monetary lending policies. Large firms are indeed found to be the most significant firm structure shaping country labour productivity.

Chapter 4 examines whether firm independence, previously not considered critical for firm growth, may indeed be an important criterion to enable scale up of innovative firms into successful frontier large firms. To shed light on the role of independence, the study examines the drivers of firm growth and the policy tools used to support firm growth – with innovative independent firms separately assessed from overall innovative firms. Using firm level dataset for all UK sectors between 2006-2016, policy tax and financing tools supporting start-up, growth and merger activity are examined alongside growth theory drivers, globalization and monetary lending policy. The empirical analysis reveals that independent firms reap much higher growth, with age of independence delivering a bonus growth dividend.

Finally, Chapter 5 summarizes the findings of this thesis, listing the limitations of the analysis alongside future potential areas of research.

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I would like to dedicate my thesis to my ever supportive but long-suffering husband, Dave and our amazing children, Saara, Aaliya, and Sayeed. All, who have unfailingly supported me through all my doubts and difficulties and believed in me – especially through periods when this research felt to be a bridge too far.

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Author's Declaration

I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

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Chapter 1 Introduction

'Stay Hungry, stay foolish' Steve Jobs (Commencement speech, Stanford, 2005) A reminder to me to stay true to my outside-the-box training, learned while working in research in frontier edge technology - and now my attempt to apply it also within academic research.

All economies, be they advanced or developing, seek long term sustainable growth to deliver an improving quality of life. The key to sustainable growth has long since been acknowledged as innovation. Yet, innovation does not deliver growth directly, it acts upon growth through raising productivity. The oncoming era of automation and artificial intelligence pose challenges and opportunities for both the advanced and developing economies, with the race on to see which economies will be ahead of this curve in the transition – and how smoothly. Once again innovation has been brought to the fore as a deliverer of growth in this race, raising the importance of understanding the intricacies of the interwound fields of innovation, productivity and growth.

The importance of innovation and its role in economic growth is not new. It can be traced back as early as Adam Smith (1776), who recognized that improvements in technology played an important part in raising worker productivity. After Smith, however there was a period of silence on the role of innovation in economic analysis, till the arrival of the Austrian economist, Joseph Schumpeter, with his influential book "The Theory of Economic Development' published in German (1911) and later in English (1934). However, Soete et al. (2010) give List the credit of being the first economist who advocated the role of the state in creating long-term policies to support industries, emphasizing the importance of interconnectedness of institutional science with technology in industries (List, 1841). Following List, Schumpeter, often acknowledged as the 'father of the field of innovation' (Hall & Rosenberg, 2010), expanded on Lists' importance to the role innovation by focussing on two main themes in his book (1911). Firstly, that innovation lay at the heart of economic development and growth. Secondly, innovation did not just happen, they were created through heroic efforts by entrepreneurs (Schumpeter, 1934). More so, Schumpeter homed in on the importance of understanding and analysing role of firm-structures in developing innovation (Schumpeter J. , 1942). By placing innovation at the heart of the growth process, Schumpeter in essence began a long road of study into innovation and its central connection with growth.

The seminal paper linking the role of innovation as the long-term driver for sustainable growth is attributed to Robert Solow (1957), who attributed innovation or technological change as the only driver to overcome diminishing returns of factors of production. This paper was 'a shot heard around the world that transformed the study of technological change into something more than an obscure sideshow' (Scherer, 1999). Solow's paper sparked a flurry of research into growth, specially the role of human capital in overcoming diminishing returns (Schultz, 1961; Lucas, 1986). However, innovation – which had been promoted as a specific point of focus by Schumpeter- remained still an exogeneous variable, delivered as if it were by manna of heaven. It was not until Romer's seminal paper (1986) that innovation or technology was made endogenous to growth. Romer proposed that innovation in industry required profit-orientated activity to deliver two distinct components: products that could be patented excluding rival firms and knowledge, which is essentially a public good. Alongside this period of growth theories sparked by Solows' seminal paper (1957) leading to Romer's insights into the role of innovation within growth, the field of evolutionary economics – studies of innovation systems- had also experienced a spurt of interest and developed in tandem.

In contrast to growth theories, which concentrate on explaining an output based on inputs, National Innovation Systems (NSI) focus on the process connecting the inputs and outputs. According to Soete et al (2010), the historical foundations of evolutionary economic stream of thought can essentially be traced back to List (1841), who advocated the support to develop systems of innovation, focussed at institutional and country level. These innovation systems, which were alluded to over the early 20th century (Schumpeter, 1939; Rostow, 1952; Kuznets, 1965), were developed further in seminal papers by evolutionary economists highlighting the informal role of R&D linkages or tacit knowledge in National innovation systems (Nelson & Winter, 1982; Freeman, 1987). These papers emphasized linkages between institutions and industry alongside importance of diffusion and skill development and led to a spate of studies on innovation systems (Dosi & Nelson, 1994; Lundvall, 1992; Nelson & Rosenberg, 1993;

Freeman & Soete, 1997), sometimes known as the field of economics of innovation (Verspagen & Werker, 2003). Not only does NSI theory probe into the networks and alignments between the public and private sector, it also includes the emphasis on importance of basic sciences, diffusion of knowledge and skilled workers. In particular, NSI systems differentiated themselves from growth theories by allowing introductions of innovation to be accompanied by initially diverging directions of productivity (Broadberry & Jong, 2000). This somewhat broader approach to the innovation process was complementary to growth theory, adding important understanding to the process of development of innovation. The link of innovation to growth via productivity is however not rooted in NSI, instead it can best be found through linking development economics understanding with growth theory.

A seminal paper in development economics was Lewis's economic development model, which proposed country growth could be linked to accumulation of capital (Lewis, 1954). Adding to this was the influential work of Amsden (2001), analysing newly industrializing economies explaining mechanisms of moving knowledge-based assets from lower skilled sectors towards higher skilled or higher productive sectors. However, it was Gollin (2014) reviewing the Lewis model, who adapted the interpretation of the Lewis model to relate productivity to growth. Building upon the insights in development economics, Gollin (ibid) proposed that productivity caused by the reallocation of resources from lower productive sectors towards higher productive sectors was the key to growth, not capital accumulation as suggested by Lewis. While Gollins' revised interpretation of Lewis model provides a model linking growth to productivity, the model does not make any connection with innovation or firm structures. Despite the oft-repeated insight that innovation is the key to higher productivity, overcoming diminishing returns as proposed originally by Solow (1957). Indeed, while these three disciplines of national innovation systems rooted in evolutionary economics, growth theory rooted in neoclassical economics and development economics offer very fundamental insights – yet, they remain quite apart.

It is this very gap that the thesis aims to bridge. Drawing together insights from these three close yet disparate fields, to find a way to interconnect fundamental concepts on growth: innovation, productivity and growth. In order to do this, a fundamental thread runs through all three papers in this thesis – the importance of the firm in all these three areas. The principle 'vehicle' of innovation as proposed by Schumpeter, who was preoccupied with the role of the firm size in the field of innovation (Schumpeter, 1934; Schumpeter, 1942). To enable this interconnection of innovation, productivity and growth, the thesis breaks up the research into three areas.

Firstly, to enable this, the thesis starts by broadening the analysis of innovation by including growth theory alongside national innovation systems. Following in the footsteps of scholars working on economics of innovation in the 'invisible college' (Verpsagen & Werker, 2003), with an 'evolutionary' paradigm working alongside the more traditional paradigm analysts (Hall & Rosenberg, 2010). This thesis however proposes combining the two paradigms, rather than working alongside the traditional paradigm. Following the seminal work by Lundvall et al. (Jensen et al.,2007) who indeed combine these two paradigms, this thesis examines not only the combined effect of these two paradigms – it seeks to find an order to these influences. Differentiating primary drivers, those needed to initially build innovation, and secondary drivers, those used to spur innovation growth. To avoid using TFP, labelled 'a measure of our ignorance' (Abramovitz, 1956), as growth accounting has pitfalls associated with the increasing difficulty to untangle capital from intangible investments (Hulten et al, 2006), the research used direct innovation survey data. Maintaining Schumpeter's focus on firms, the analysis differentiates these drivers for firm-size classes: small, medium and large. Thus, identifying the innovation drivers most needed per size class. In essence, this is the foundational research setting an understanding of drivers of innovation combining two paradigms, while also laying the groundwork for understanding the importance of structures in the arena of innovation.

Secondly, drawing on development economics' Lewis model, the thesis aims to connect innovation's importance of firm structures with country labour productivity. Influenced strongly by economic development thinking of Lewis (1954), Gollin (2014) and Amsden (2001), all of whom in slightly differing ways explain the mechanisms of moving knowledge-based assets from lower skilled sectors towards higher skilled or higher productive sectors. These higher skilled sectors are associated with higher innovation, which in the long-term generate the higher productivity and growth for economies. Deviating from the norm of considering hindrances to factors of production rooted in neoclassical perspective, as cause of lower productivity – this research explores how firm-structures which channel resources, influences productivity through proposing an adaptation of the Lewis model. This thesis examines through the proposed adapted Leis model whether movement across firm structures, not sectors, could offer important insights to explain country labour productivity. Thereby drawing concepts of innovation into the area of growth and productivity, as productivity is recognized as the sustainable long-term driver of country growth Gollin (2014).

Lastly, proceeding further on Schumpeter's focus of the firm as 'the vehicle' of innovation, this research assesses what drives growth of the firm itself. Tackling one of the very concrete problems hindering growth in the UK economy – scale up of firms. Drawing from evolutionary thought on the influencing role of state policies on innovation, this research aspires to draw as many as possible of the firm-growth policies together, ranging from tax, financing, merger & acquisition supporting policies through to monetary policy. Assimilating an overall view of their realistic influence on the ground through using actual firm data. Combining this analysis with factors of production rooted in neoclassical analysis, alongside variables capturing aspects rooted in systems of innovation.

However, this amalgamation goes further. It draws on understanding rooted in business history of economics and research in finance, management and enterprise literature. These offer valuable insights, which essentially allow the final leap. The leap involving a factor, not rooted in either stream of thought, but debated in economic history – a very prevalent issue on the ground in firms. That of firm independence. Firm independence as measured in this study, is understood to indicate that the firm is not owned by another business or financial firm, as such it has not been acquired or merged by another firm with controlling shares above 25%. The reason firm independence is of interest is the debate between some economic business historians claim that firms appear to grow sustainably through organic growth, which appears to contradict management literature, which consider acquisition as a path of sustainable growth for firms. While this may not be hard and fast rule, it is interesting to examine whether this characteristic does have any impact on firm growth ,as suggested by business historians. The research revelations are surprising. Independence appears to enable firms to reap more from factors of production, while also delivering an age-related independence bonus-dividend. Firm independence appears to have a strong influence on growth, not yet captured in neoclassical thought nor in evolutionary systems. Leaving the possibility open for new models to be perhaps developed, offering deeper insights into firm growth.

This thesis has thus tried to connect the analyses of innovation, productivity and growth, through merging insights across disciplines ranging from evolutionary economics, growth theory, development economics and business history. That path seems to have delivered new insights on the interconnectedness, as well as offering deeper understanding of structural determinants. Yet, it seems only to be a beginning. It offers insights of what can be gained from merging the field of ‘economics of innovation’ towards a field of ‘economics of innovation, productivity and growth’. It would appear that far more can be interlaced, which could help this paradigm of thought to grow and evolve further.

Despite the new insights yielded in this thesis on innovation, productivity and growth, there are quite a few research topics addressed in this thesis that leave avenues for future research. At its core, the foundational research chapter while shedding light upon the broader set of innovation drivers, only throws indicative light upon the possible mechanism through which these innovation drivers influence firms’ primary and secondary drivers. Detailed research into the various threads would reveal the deeper mechanisms, allowing policy analysis to be tuned accordingly. Similarly, the research on the adapted Lewis model which draws firm structures into productivity analysis, enables examination of importance of firm structures influence on productivity of an economy. However, in terms of sectoral composition it was only indicative of which sectors contribute to growth through employment or through higher productivity. Future research to explore the manner of contribution of sectors to economies, would help device policies to tailor policy to the problem – distinguishing between employment versus productivity. The last research piece of this thesis on scale up of firms, while shedding light on the value of firm independence, leaves questions on the role of the innovator unanswered. Future research, perhaps in close collaboration between historical analysis and economics of innovation, may help unveil the critical role of culture or innovator mind-set to find answers to those queries.

In essence, this thesis has tried to address some of the gaps that exist both in evolutionary stream on empirical analysis on concrete problems (Soete et al., 2010), as well as limitations in neoclassical analysis of analysing innovation at country, sector and firm level ((Dosi & Nelson, 2010). According to Soete et al.(2010) , empirical analysis of concrete problems offering concrete policy advice is a much needed next step for evolutionary economic steam of thought. Soete et al. (2010) observe that the challenges of globalisation and the spread of innovation across services and industry sectors causing shifts in the role of R&D and interconnections with institutions, requires evolutionary economic thought to move towards empirical approach to retain relevance. More specifically, it should move towards policy analysis of concrete problem. This thesis hopes to add towards filling the void as mentioned by Soete et al. (2010), as well as making steps towards overcoming some of the neoclassical limitations raised by Dosi & Nelson (2010). I hope this thesis is indeed one small step in that direction.

Last but not least, my own experiences in innovation on the ground, have left me convinced and strongly supportive of Soete et al.'s (2010) stance – that innovation policy analysis has to tackle concrete problems. Allowing not only this field to remain relevant– but principally also in order to grow.

Chapter 2 Where NSI meets Growth Theory - 'Where do informal R&D processes fit alongside formal R&D investment?'

2.1 Abstract

This chapter explores a wider set of innovation drivers driving firm growth, combining analysis of formal R&D processes promoted by growth theories alongside informal R&D linkages emphasized by national innovation systems (NSI). Although both R&D aspects are well researched for their importance towards innovation, this study proposes that there is an order to this contribution. The informal R&D process of linkages works on building the foundational levels of innovation, while R&D investment appears to spur additional growth of these innovation levels. Thus, informal R&D processes such as linkages and tacit knowledge constitute the primary driver, while formal R&D processes such as R&D investment acts as a secondary driver.

The main goal of this study is to distinguish primary drivers from secondary drivers, by examining the differences in key forces driving firm revenue levels versus those driving firm revenue growth. This hypothesis is tested through a dataset of 27 European economies over the period of 1996-2010, controlling also for globalization and industrial organizational drivers. Findings reveal that informal R&D linkages appear to be the primary drivers needed to establish firm revenue levels, while formal R&D investment is needed as a secondary driver to spur firm revenue growth.

Furthermore, the findings reveal that drivers for small and medium (SMEs) firms including both skilled human capital and linkages with academia, are significant. Additionally, linkages with government institutions were found relevant for medium size firms, reflecting the contribution of organisations like the Fraunhofer institutes in Germany on innovation.

2.2 Introduction

Economies across the world seek policies to stimulate sustainable growth and improve productivities. Ever since Solow demonstrated that technology contributed more than capital towards long-term growth (Solow, 1956), the countries have focused on innovation as a basis for growth. Since then, the responsive policy focus has predominantly been driven by an emphasis on R&D investment. While policy response has been dominated by a focus on R&D investment, historical analysis of innovation across the two industrial revolutions draws emphasis towards another aspect – the role of collaboration (Mokyr, 2010). According to Mokyr, the key to economic growth in the west such as UK's innovative reign as the first Industrial nation and Germany's dominance in chemicals in the second Industrial revolution, can be found in the "international cooperative agenda for useful knowledge" (ibid). Perhaps, policy focus may not only have missed capturing the wider drivers of innovation; more importantly it may have overlooked the most critical of drivers.

Understanding the drivers of innovation not only helps tailor policy to support innovation delivering long-term growth in an economy; moreover, economies in the vanguard of innovation appear to dominate globally, outpacing others in growth. The US, the world's dominant economy, can be considered as the 'cutting-edge global technology leader' in the global arena (Wessner, 2011). Among European economies, the European Union Innovation scoreboard (EIS) ranks Germany alongside Sweden, Denmark and Finland as the Innovation leaders above other European economies (European Commission, 2013). Indeed, Germany's strength in technical machinery allows it to be portrayed as the 'world supplier and equipper' of systems and production technology (Wessner, 2011). Obtaining a better understanding of the drivers of innovation may help explain why some economies outpace others in innovation and how, as Mokyr observed, it may have shaped dominance of historical economic powers.

What are then the wider set of innovation drivers and importantly which are primary drivers acting on innovation levels versus secondary drivers acting on innovation growth? Moreover, do current R&D policy targets represent a sufficient response for driving innovation? Mokyr's historical analysis of innovation (Mokyr, 2010) seems to suggest that the drivers of innovation are complex, requiring more than just a focus on R&D investment. This view has also long been promoted by evolutionary economists (Nelson & Winter, 1982; Freeman,1987; Lundvall, 1992), who emphasise the informal role of R&D linkages or tacit knowledge in national innovation systems (NSI). This paper aspires to answer the first part of the query through using a wider context of analysis, which incorporates drivers of innovation found in growth theories, evolutionary economic theories and industrial organization theories. Through bridging the search for innovation across theories, this paper hopes to deliver a wider set of drivers, but critically also providing comparison, enabling in turn the order of selection of the most crucial drivers. The second part of the query is taken up in the conclusion, based on the findings of the analysis.

Building upon significant body of work assessing the diverse roles of informal and formal R&D processes on innovation, this paper adds to this debate through two dimensions. Firstly, it aims to differentiate between the contribution of a primary and secondary driver role, between informal R&D linkages and formal R&D process, as captured by R&D investment, R&D linkages exemplifying an NSI approach and R&D investment rooted in growth theories. This expands on the work of Jensen et al. (2007), who investigate the isolated and combined effect of R&D linkages and R&D investment on innovation, through differentiating the order of the contribution of informal R&D linkages and R&D investment on innovation. The second dimension is that the paper expands the combination beyond national systems of innovation (NSI) and growth theories to including drivers from industrial organization and globalisation which influence the innovation process.

Apart from the significant work on assessing the formal and informal role of R&D on innovation, there is an abundance of studies analysing the determinants of innovation rooted in assessing Schumpeterian concepts or drivers from growth theories. Growth theories, with technology considered either exogenous to systems as in neoclassical growth theories[1] or technology endogenous to growth[2].

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[1] Growth theory models such as (Solow, 1956), (Mankiew, Romer and Wiel , 1992), (Lewis, 1954), alongside growth determinnat studies (Bosworth and Collins, 2003), (Easterly and Levine 2001) (Klenow and Rodrigues, 1997).

[2] Endogenous growth models as developed by (Arrow, 1962), (Romer 1990), (Romer 1993), (Matsumaya, 1992), recently added by (Aghion & Howitt, 2006)

In fact, Mairesse and Mohnen reviewing innovation determinant studies, observed that studies have tended to concentrate on the analysis of contributions of market concentration, firm size, impact of technology push and pull on demand, foreign ownership and impact of R&D effort on Innovation (Mairesse & Mohnen, 2010). In contrast, Cohen reviewing innovation studies over the last fifty years, found the focus of industrial organization studies moved away over 50 years ago from market concentration and firm size, towards a focus on more fundamental determinants[3] such as firm-level or industry characteristics, explaining industry differences and problems of appropriability (Cohen W. , 2010). Nonetheless, Mairesse and Mohnen observe that despite these numerous determinants studies, the process of innovation is far from clear, with a great portion of innovation remaining unexplained (Mairesse & Mohnen, 2010). Supporting that aspect, Hall et al. (2010) observe that R&D may explain as little as 20-30 percent of the innovation process. Thus, by bridging the analysis in this study across theories, this study aims to not only bring in a wider set of innovation drivers – it aspires to shed a little more light on the actual innovation process.

Previous studies have not only left a large portion of the innovation process unexplained; according to Cohen (2010), they have also suffered from the drawback of lack of direct innovation data and perhaps most seriously, from the absence of an innovation measure itself. Total factor of productivity (TFP) an oft used measure of innovation obtained through growth accounting, was very early on characterised by Abramovitz as a 'measure of our Ignorance' (Abramovitz, 1956). While growth accounting techniques have developed a lot since then, the fact that capital has become more inter-twined with productivity has essentially made the separation of influence of innovation from capital through growth accounting even more difficult (Hulten C. , 2010), making the capture of as technology in TFP through growth accounting more problematic. More so, growth accounting is essentially based on a production function approach rooted in growth theories, whereas this study aims to take a wider approach incorporating growth theories as well as the informal role of R&D linkages or tacit knowledge

[3] Pioneered by Schmookler (Schmookler 1962) , Arrow (Arrow 1962), Nelson (Nelson, 1959), Griliches (Griliches, 1979), Rosenberg (Rosenberg, 1974), Mansfield (Mansfield 1968) and Scherer (Scherer, 1980).

in national innovation systems (NSI). This suggests seeking an alternative measure to TFP for capturing innovation.

This leads to the choice by many scholars of another measure of innovation, patents. The weaknesses, however, associated with the use of patents as a measure of innovation have also been highlighted earlier on by Griliches and Pakes (Pakes & Griliches, 1980)), supported by findings of Achs and Audretsch (Achs & Audretsch, 1988). Given these challenges, the innovation manual (Eurostat, 1997) advocated the choice of measuring outputs of innovation, where invention has been commercialized into an output, a concept used in Community Innovation Surveys (CIS). Mairesse and Mohnen (2010) find that Community Innovation Surveys provide studies with access to both direct innovation data and a reliable innovation measure, enabling cross comparisons (Mairesse & Mohnen, 2010). Through choosing to use both innovation data and innovation measure from CIS for this analysis, this study hopes to avoid some of the earlier drawbacks associated with use of indirect data or the absence of a specific innovation measure.

Additional to calling for an avoidance of these pitfalls, Cohen pointed out 'a major lacuna in the understanding of drivers of innovation', is the lack of awareness of the contribution of innovation from the service sector (Cohen, 2010). This study goes a step further and looks at all innovative sectors, be they service or industry, as defined by the Organization for Economic Co-operation and development in their move to help standardize innovation terminology (OECD, Innovation Manual, 2005). Such a wider incorporation of sectors, essentially also assessing the contributions of innovation importantly taking place in design and engineering, is again one more step in the direction towards improving our understanding of innovation through a wider approach

Thus, with the aspiration of shedding greater light on the innovation process through finding a wider set of drivers and adding robustness through use of direct innovation data as a direct innovation measure, this study focuses on 27 OECD countries using EU CIS survey data to perform a country level panel data innovation driver analysis covering a period from 1996-2010. For this analysis, the unit of analysis is at aggregated innovative core sector level for each of the 27 EU economies - with the aggregation capturing innovation across both industry and services, avoiding the pitfall of restricting innovation to industry only sectors.

Following on from the empirical section, this study offers insights into the mechanisms through which these drivers could exert influence on the innovation process illustrated through German context, given Germany's strong standing across drivers and innovation.

Although the drivers in this study are sourced from across a slightly wider set of theories than previous cross-theory studies, the results support earlier findings of those theories: significance was found for industry linkages with academic institutions and importance of public funding for industry, along with supplier linkages and skilled human capital. The linkages were measured through CIS innovation surveys, based on firms rating the working relationship with the respective body as the most valuable cooperation influencing their innovations. Interpreted through the workings in Germany, these drivers influence innovation through mechanisms enhancing commercialization of research, reduction of funding gaps and promotion of longer-term decision-making. Though surprisingly, R&D investment is not found to be significant as a primary driver for innovation, it is found significant as a secondary driver working on innovation growth. This seems to signify that it requires the foundations of innovation to be laid by the wider set of primary drivers and uses them to thereupon build innovation growth. This differentiation may be an important insight for policymaking, by calling into question the current focus on R&D investment, which seems to be a secondary driver, and asking whether innovation may not be better served if greater focus is brought to bear also upon the use of a wider set of primary drivers to lay the foundations of innovation in the first place.

The analysis concludes with a reversal of Schumpeter's Hypothesis: instead of using firm-size as a driver, it differentiates the drivers for varied firm sizes. The results indicate that skilled human capital and linkages to academia remain key in driving innovation for SMEs, with the added significance of linkages with government institutions for medium sized firms. The loss of significance of public funding or supplier collaborations as drivers for small and medium size firms invites further research. A last, but perhaps not insignificant aspect, is that large firms appear to dictate a substantial portion of innovation measure.

While SMEs may be called the hidden growth champions of Germany, their share of innovation turnover is by virtue of their size limited. Hence in the long run, economies or indeed sectors may be inhibited in innovation as a consequence of a reduced share of presence of large firms.

The rest of this article is structured as follows. Section 2 gives a short background covering an overview of the Innovation studies and their findings on determinants, accompanied with a brief outline of the theories governing the various studies and their respective drivers. Section 3 describes the model and data. Section 4 interprets the mechanisms of influence of these drivers using insights gained from the Germany economy, with Section 5 listing the empirical results. The concluding section 6 offers insights from the empirical results into the innovation process, along with listing of some possible implications for policy makers.

2.3 Brief Overview of theories and Innovation studies

2.3.1 The dominant theories influencing growth and innovation and their consequent specific innovation drivers

Before we proceed to the overview of innovation determinant studies, it may be helpful to briefly outline the prevalent dominant theories and their accompanying influence on innovation. As this study's main contribution centres on the importance of selecting drivers sourced across a wider range of theories rather than proving the theories themselves, this section provides only a very preliminary sketch of these theories. The reader wishing to pursue these theories in greater detail may access the listed references to obtain a more in-depth understanding of these theories.

It is perhaps also important to clarify that these theories are not innovation specific theories; instead they are the prevalent theories regarding growth, trade and industrial organization. Indeed, these are areas in an economy that, in some way or another, are critically dependent upon the path of innovation. Hence, they tend to include some determinants or influences pertaining specifically to innovation. Aspects of these theories that influence innovation are incorporated in this study as a set of innovation drivers originating from that theory, with each set of drivers thus representative of a particular theory, as illustrated in Figure 2.1. Thus, keeping in mind that the theories itself have a wider composition pertaining to other areas of influence, the following theories will be considered for their influence on innovation: Growth theory; National innovation systems; Cluster theory; and Globalization. Though this selection can by no means be considered to cover the entire range of theories touching upon innovation, their selection is dictated by the prevalent dominance of these theories in influencing various innovation studies.

Let us start with growth theory. At its very simplest, growth theory may be understood as a set of models and theories that attempt to interpret the process of growth in economies, accommodating various combinations of factors of production in their models.[4] Solow, in developing a growth model, with technology exogenous to it, illustrated that the factors of production such as physical and human capital are limited in their contribution to growth and long-run sustainable growth may only achieved by virtue of technology (Solow, 1956). In exogenous growth systems, technology increasing productivity through an upward shift of the production function and endogenous growth systems maintaining an increasing-returns to scale through knowledge capital[5]. Although growth models have continued to develop, some with technology exogenous and others with technology endogenous to them, the main assertion of Solow's remains relevant even today: technology or innovation still appears to drive long-term growth.

While the development of growth models has led to varied sets of drivers, including the distinction of tangible from intangible capital (Hulten, Corrado, & Scihel, 2006), growth theory drivers essentially originate from the supply or input side of the process, with varying emphasis on the degree of contribution of human and physical capital in delivering growth and innovation. The inherent assumption is that the introduction of innovation is accompanied by productivity increases.

[4] A good overview of growth models may be found in (Jones, 2002) , as well as (Thirlwall, 2002)

[5] Some overviews of exogenous and endogenous growth theories may be found in (Broadberry & Jong, 2000), (Winter, 1994), (Jones, 2002) (Meier, Rauch, 2005)

As the focus of this study remains on innovation, the drivers selected from growth theory for this research have been restricted to those influencing innovation, i.e. skilled human capital and R&D investment, including external outsourcing of R&D. Given the restriction of data availability, this smaller subset of drivers pertinent to innovation, is considered for the remainder of this research as appropriately representative of growth theory drivers influencing innovation.

In contrast to growth theories, which concentrate on explaining an output based on inputs, National Innovation systems focus on the process connecting the inputs and outputs. Developed by evolutionary economists, the National Innovation Systems (NSI) approach emphasizes linkages between institutions and industry alongside importance of diffusion and skill development (Schumpeter, 1939; Rostow, 1952; Kuznets, 1965; Nelson & Winter, 1982; Nelson & Rosenberg,1993). Not only does NSI theory probe into the networks and alignments between the public and private sector, it also includes the emphasis on importance of basic sciences, diffusion of knowledge and skilled workers. It also differentiates itself from growth theories in allowing introductions of innovation to be accompanied by initially diverging directions of productivity, with productivity initially reducing at introductions of innovation and only rising after period of diffusion (Broadberry & Jong, 2000). This somewhat broader approach to the innovation process may be viewed as defining the groundwork through which innovation could flourish within the boundaries of a nation state[6]. The selection of NSI drivers impacting the process of innovation for this research have been restricted to those available in CIS data: linkages between industry, public institutions and educational sector, representing alignment between industry, academia and government institutions and commercialization of research; as well as a measure of the influence of skilled human capital, as well as a measure of contribution of firm access to public funding on innovation.

Whereas growth theory and NSI deal with the supply side or process aspect of innovation, Cluster theory has a different angle of contribution to innovation, rooted in its origins in cities and industrial organization (Marshall, 1920; Arrow, 1962). While Marshall (1920) emphasized the decrease in labour and input costs

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[6] Explanation of National Innovation systems have been documented by the OECD (OECD, 1997)

to firm co-location, Hotelling (1929) emphasized co-location as a competitive advantage for profitable business locations. Jacobs (1969) promoted the idea that city size and diversity lead to industrial agglomeration, a concept also recognized earlier by Marshall (1920). These concepts of co-location received greater traction across the policy world, when Porter related the advantages of industrial conglomeration and localization towards spurring of competitive advantage of nations (Porter M. , 1990). Indeed there is an abundance of studies in agglomeration, a review of which was conducted by Rosenthal & Strange (2004), however for this study we focus on the cluster concept promoted by Porter (1990) as it influenced industrial agglomeration.

While not without critique[7], this resurgence of cluster theory has influenced policy widely, both at international and national forum-levels. It combines drivers from growth theory and NSI to bring emphasis on skilled human capital, as well as infrastructure and importance of institutions. While it emphasizes institutions, it differs from NSI that it focuses on the expertise and not the relationships of institutions within the innovative networks. Instead, the key emphasis of relationships for industry is directed towards supplier and clients, based on geographic proximity and the influence of home markets. Competitive advantage is based on inter-firm rivalry within the domestic markets. As before due to data limitations, the drivers representative of cluster theory for this research have been restricted to skilled human capital, supplier linkages measured through collaborations and home market focus of enterprises.

[7] Some recent critique of Porters work may be found in (Martin & Sunley, 2003) (Taylor, 2010) (Swords, 2013).

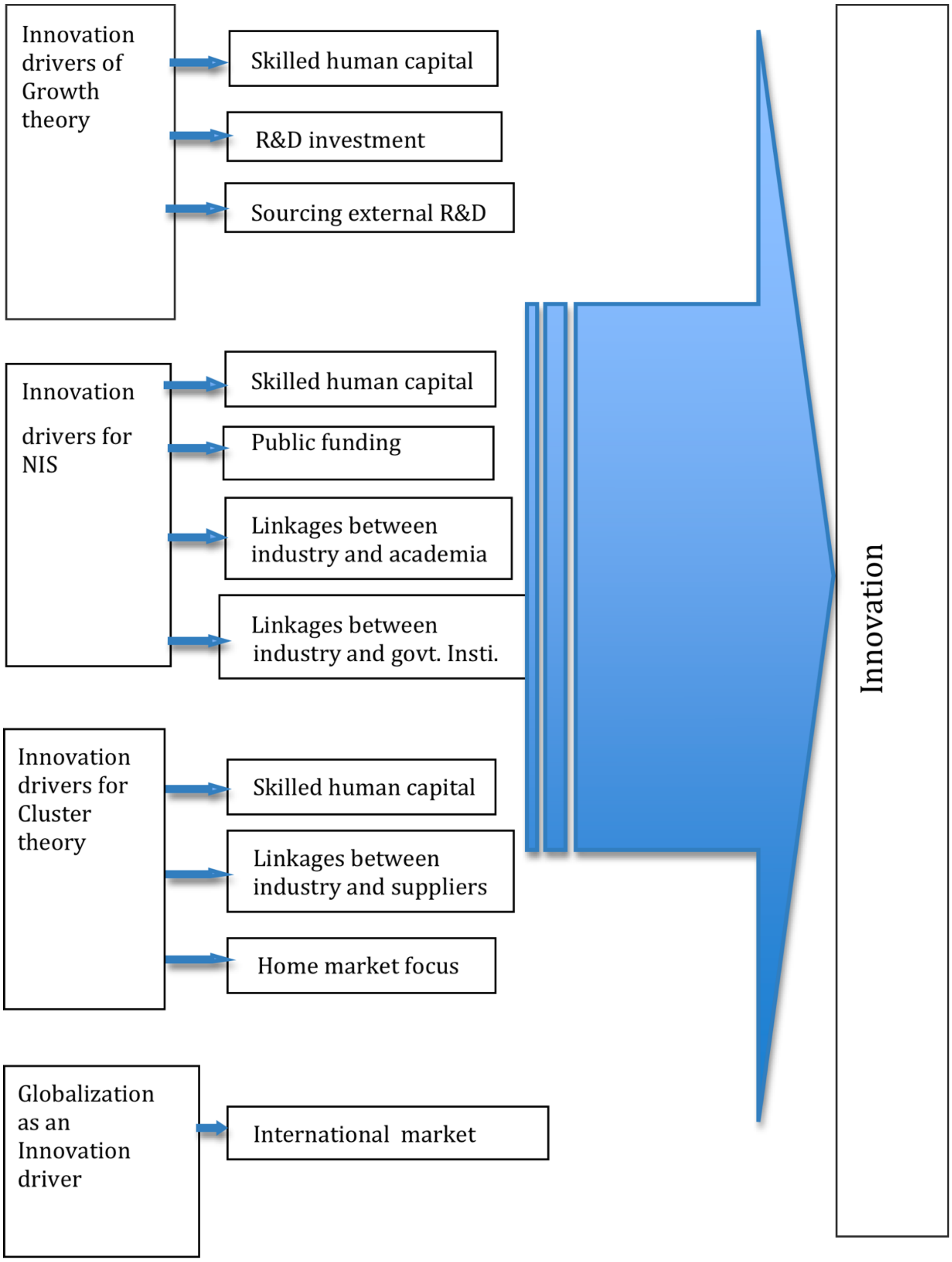

Diagram 1: The different innovation drivers associated with Growth theory, NIS , Cluster theory and Globalization

Figure 2.1: The different innovation drivers associated with Growth theory, NSI, Cluster theory and Globalization, source (author)

In comparison to the above brief overview of dominant theories influencing innovation, globalization may perhaps not be labeled as a theory. Rather it can be described as an aspect of trade, which has shaped innovation through the diffusion of knowledge and enabled transfer of technology across national boundaries, a consequence of multinational enterprise cooperation with local organizations (Frankel & Romer, 1999; Feyrer, 2009). Though globalization and trade may not always have been beneficial for growth[8] or for fuelling innovation, its impact on innovation through global competitive pressures and wider skill-base draw focus on globalization as a driver of innovation in its own right (Grossman & Helpman, 1994; Bailey & Gersbach, 1995; Scherer, 1992). Thus, within the boundaries of this research and data availability, to determine whether it is a primary driver, the importance assigned by innovative enterprises on global markets is considered a driver representative of globalization influence on innovation.

The above thus lists the theories influencing innovation, whose drivers pertinent to innovation will be explored empirically further on in this study. However, there is another theory that has considerably influenced innovation studies – that of Schumpeter's Hypothesis (Schumpeter, 1934; Schumpeter, 1942)[9]. It basically evaluates the contribution of firm-size and market concentration as drivers on innovation. Although has there been considerable research about these two aspects as drivers[10] of innovation, this study seeks to actually refine the Hypothesis. Instead of viewing firm-size as a driver, it seeks to differentiate the drivers for varied firm sizes, as there is a growing preoccupation in the policy world that stimulation of small and medium firms (SMEs) may be important for growth and innovation in economies (Wessner, 2011).

The above remains a very rough outline of theories, describing the main direction of thought of dominant theories influencing innovation and a simplified selection due to data limitation, of the related drivers influencing innovation. Within these boundaries, the empirical analysis that follows in section 4, reviews the contributions of these drivers, representative of these theories on innovation. Before however exploring the empirical analysis, however, the next section lists previous research on determinants of innovation.

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[8] Wacziarg and Welsch found that though average affects of trade on growth are positive, certain economies did not benefit and local context may be important to consider, while reviewing impact of globalization and trade (Wacziarg & Welsch, 2008)

[9] Schumpeter started the debate on whether large size firms and monopoly was good for innovation, as it to an extent reduced the appropriability problem versus the potential of smaller and medium firms being more innovative and nimble in research (Schumpeter, 1934) (Schumpeter, 1942).

[10] See Cohen who lists the large extent of studies in this area (Cohen, 2010)

2.3.2 Innovation Determinant studies

As mentioned earlier, although there has been an abundance of studies into aspects of innovation, puzzlingly a large part of the innovation process remains largely unexplained. Mairesse and Mohnen observe reviewing innovation determinant studies, observe that the predominant focus in analysis has been around some key aspects, such as market concentration, firms size, technology push-pull effects on demand, foreign ownership and influence of R&D efforts (Mairesse & Mohnen, 2010). In contrast, Cohen reviewing industrial organization studies on innovation, found that there has been movement away over the last 50 years from Schumpeter's Hypothesis on firm-size and market concentration, towards a broader research agenda delving into the deeper impacts, such as firm level and industry characteristics, alongside technology and appropriability issues (Cohen W. , 2010). Cohen attributes this broader movement away from Schumpeterian hypothesis to pioneers such as Schmookler (1962), Arrow (1962), Nelson(1959), Griliches (1979), Rosenberg (1974) , Mansfield (1968) and Scherer (1980). According to Cohen's review, the evaluation of firm level characteristics includes appraising influence of attributes such as cash flow, user needs, marketing, various management and governance methods and product diversification on innovation, whereas industry characteristics focus on the innovation differences in industries covering impacts on demand through income and price elasticity, market size, technological opportunities impacted by collaborations with suppliers and universities, along with connections to basic sciences and role of public scientific institutions. Notwithstanding this variation in their viewpoints, both the studies of Mairesse and Mohnen (2010) and Cohen (2010) acknowledge that despite the extensive studies the process of innovation remains largely unexplained.

This lack of understanding of the innovation process is further underscored by Hall et al. (2010), who observe that despite the concentrated focus in innovation studies on R&D, R&D explains only 20-30 percent of the innovation process. It appears that despite this promulgation of studies into these wider drivers and aspects of innovation, 'there is considerable distance to go' in terms of explaining innovation, as succinctly put by Cohen (Cohen, 2010. P.194). This study seeks therefore, not to further increase the depth of study into the same aspects, but instead it considers the option of going across various theories, evaluating their combined effect on innovation, aiming in the process to explain a somewhat larger share of the innovation process.

While this is indeed not the first of innovation determinant studies going across theories, there are not many studies that have attempted a similar approach to innovation analysis. Achs and Audretsch combined growth theory elements alongside Schumpeter's Hypothesis to deliver important insights, when they evaluated innovation determinants at firm level within US (Achs & Audretsch, 1988). Though they found a monotonic relationship between firm-size and R&D, they found no significant effect of firm size on innovation and found importance of market concentration (but not firm dominance) important for innovation. Their study was however limited in comparability, as it was based on a specific US business administration data. Romijn and Albadejo went quite a bit further and combined aspects of cluster theory, NSI and growth theory when exploring firm level innovation in for a particular UK region (Romijn & Albadejo, 2002). Using experimental measures of innovation, they found support for most of their drivers, except that intra-firm networking, customer proximity or geographic proximity were not found to be significant. They also yielded important insights on the significant bearing of previous inter-firm and inter-personnel relationships and experiences on future collaborations and the process of innovation. Their study again lacked ease of comparability, as it was based on a specific innovation survey.

In a similar vein of innovation studies going across theories, but enabling comparability across countries, Furman, Porter and Stern (2002) again explore similar comparisons of theories but enhance the analysis through use of panel data looking across 17 OECD countries and time period between 1973 and 1996. Their results attribute the greater share of innovation to a growth theory attribute of R&D investment and an attribute of all three theories - skilled human capital - with certain aspects of NSI also finding significance, though with lesser impact. Their study is however limited by the use of patents as an innovation measure and the lack of innovation specific data. Mairesse and Mohnen explore an experimental version of a growth accounting technique to determine innovation, using cross-country analysis of 7 OECD countries (Mairesse & Mohnen, 2002). Using a combination of drivers from cluster theory, Schumpeters Hypothesis of firm size, industry characteristics and R&D effort, they find significance for R&D effort and industry characteristic. This analysis provides a valuable alternative approach towards innovation analysis and also uses direct innovation data, providing further reliability of results. They however, critically miss out on skilled human capital contribution, a key driver found across most theories, and so run the risk of capturing contributions of skilled human capital in their other drivers.

Continuing to combine across theories for innovation determinants, but at firm level analysis, Bhattacharya and Bloch use cross-theory analysis for a firm level Australia survey-specific study (Bhattacharya & Bloch, 2004). Reviewing drivers across theories such as Schumpeter's hypothesis of firm size and market concentration, growth theory attribute of R&D investment, globalization drivers of trade, as well as firm-characteristics of profits, their findings attribute the largest significance to R&D investment, with less but still significance for Schumpeter's hypothesis. This analysis adds value through adding globalization as an additional aspect to cross-theory studies., which helps broaden the analysis, but has limitations of cross-country comparison due to the use of Australian-specific survey data from Australian Bureau of Statistics. However, the larger limitation is caused due to the absence of skilled human capital, a vital driver across theories, its absence risking an incorrect significance attribution to other drivers. Jong and Vermeulen combine aspects of linkages, which include management leadership, education and experience, linkages to universities and cluster aspects of intra-firm working for a Netherlands-specific firm-level study (Jong & Vermeulen, 2006). Their results find significance for all except education. Their analysis offers insights into deeper aspects of type of skills of management, employee connections and intra-firm influence. Their study, though, again suffers from the absence of skilled human capital, a key driver across theories, along with absence of R&D investment, a driver usually included. Furthermore, the use of country specific survey data makes comparison across countries of similar drivers more difficult. Valuable as the insights are from these studies, especially as they highlight the potential strengths of various combined approaches, as enumerated above they each suffer from certain shortcomings.

Table 2.1 Summary oversight of literature review , source (author)

Summary of literature overview	
Papers reviewing a set of studies	• Review of Innovation determinant studies (Mairesse & Mohnen, 2010) • Review of Industrial organization studies (Cohen, 2010) • Review of literature measuring returns on R&D (Hall et al, 2010)
Papers going across theories - that enable comparison across countries	• Combining cluster theory, growth theory and aspects of NSI, Panel data looking across 17 OECD countries and time period between 1973 and 1996 (Furman et al, 2002) – find R&D investment, skilled human capital and certain aspects of NSI. Shortcoming - use of Patents • Combining across cluster theory, Schumpeters Hypothesis of firm size, industry characteristics and R&D effort, cross-country analysis of 7 OECD countries (Mairesse & Mohnen, 2002). Findings - R&D effort and industry characteristics, shortcoming – miss out on skilled human capital
Papers going across theories – country specific, but at firm level analysis	• Combining aspects of growth theory and Schumpeterian hypothesis for US (Achs & Audretsch, 1988). Found a monotonic relationship between firm-size and R&D. Shor-coming, not comparable, as specific study • Combining aspects of cluster theory, NSI and growth theory for UK (Romijn & Albadejo, 2002). Found support for most of their drivers, except that intra-firm networking, customer proximity or geographic proximity were not found to be significant. Shortcoming – not comparable, as specific survey • Combining theories across Schumpeter's hypothesis of firm size and market concentration, growth theory, globalization, as well as firm-characteristics of profits - at firm level analysis Australia survey-specific study (Bhattacharya & Bloch, 2004). Find significance to R&D investment and

	Schumpeter's hypothesis. Shortcoming – no skilled human capital • Combining aspects of linkages of innovation systems as well as management aspects and cluster theory for a Netherlands-specific firm-level study (Jong & Vermeulen, 2006). Find significance for all except education. Shortcoming – no skilled human capital

Indeed, this brief overview summarized in Table 2.1, only reaffirms Cohen's observation that part of the problem with innovation studies is either the use of indirect innovation data or an absence of a specific innovation measure or the lack of use of historical insights to supplement explanations of empirical research (Cohen, 2010).. Nonetheless, they have pioneered an approach that has much merit and it is in their footsteps that this study hopes to proceed further, aiming to add value through avoiding the weaknesses highlighted by Cohen as well as going a bit wider across theories for drivers. Our nest section will outline the choice of models and the drivers associated with it, before proceeding to the empirical analysis in section 5.

2.4 Model and data

2.4.1 Model

Having considered both the prevalent dominant theories influencing innovation and their relevant drivers for innovation, the model evaluating the contribution of these drivers on innovation can now be built. As pointed out earlier, the significance of contribution of this model is based on a few simple premises. Firstly, it combines the drivers from a spectrum of theories spanning growth theory, evolutionary theory, cluster theory and impacts of globalization. Secondly, this study refines Schumpeter's hypothesis which seeks to identify the firm-sizes driving innovation, instead this paper reverses this thought process – initially seeking to define innovation drivers for all firms and then differentiating the drivers specific to firm-size: small, medium and large firms. Thirdly, it uses direct innovation firm data and a corresponding innovation measure to increase the relevance of drivers specific to innovation. Lastly, the unit of analysis is at aggregated innovative core sector level for each of the 27 EU economies - with the aggregation capturing innovation across both industry and services, avoiding the pitfall of restricting innovation to industry only sectors.

Based on above mentioned premises, the model is listed in equation 1 :

$INNOVATION_{i,t} = \beta_0 + \alpha$ (innovation drivers of Growth theory) $_{i,t}$ + β (innovation drivers of national innovation systems) $_{i,t}$ + δ (innovation drivers of Cluster theory) $_{i,t}$ + η (drivers of globalization) $_{i,t}$ + γ (country-specific effects) $_{i,t}$ + $\mu_{i,t}$
(1)

Where i – identifies the aggregated innovative core sector level for each EU economy and t – identifies year

Previous innovation studies have varied model specifications, differing between log-log form or linear combinations, based on differing innovation measures (Cohen W. , 2010). Based on the choice of innovation measure and to avoid capturing any of the variables from combining across theories, this model proposes a linear combination of drivers. Essentially, assuming the drivers' contribution is additive on innovation, not multiplicative with each other. While this may be a simplified and conservative estimation of the drivers' separate influences, it avoids overlooking contributions by possibly non-multiplicative drivers. Hence, the above model uses a linear form to assess the various influences of these individual drivers originating from various theories on innovation.

Representing the theories by their driver contributions, the analysis can be rewritten, as specified in equation (2).

$INNOVATION_{i,t} = \beta_0 + \beta_1$(Skilled human capital and Investment) $_{i,t}$ + β_2(Skilled human capital, public funding, linkages to universities and linkages to government institutions) $_{i,t}$ + β_3 (Skilled human capital, linkages with suppliers and home market focus) $_{i,t}$ + β_4 (enterprises focused on international markets) $_{i,t}$ + γ_5 (country-specific effects) $_{i,t}$ + $\mu_{i,t}$ (2)

Innovation measure is represented by firm turnover of innovative firms, with classification of innovative firms based on innovation in product, process, marketing or organizational aspects (Eurostat, 1997; EUROSTAT CIS, 2013).

As skilled human capital is common to several, its influence needs to be only evaluated once. Hence, the final shape of the equation is shown in equation (3):

$INNOVATION_{i,t}$ = β_0 + β_1(Skilled human capital)$_{i,t}$ + [β_2 (R&D Investment)$_{i,t}$+ β_3 (R&D external)$_{i,t}$+ β_4 (R&D internal)$_{i,t}$] + [β_5(public funding)$_{i,t}$ +β_6 (linkages to universities)$_{i,t}$ + β_7(linkages to government institutions)$_{i,t}$} + [β_8(linkages with suppliers)$_{i,t}$ +β_9(home market focus)$_{i,t}$] + [β_{10} (enterprises focused on international markets)$_{i,t}$] + γ_6 (country-specific effects)$_{i,t}$ + $\mu_{i,t}$ (3)

Including, time effects, the equation is listed in (4), with the square brackets denoting the separate variables representing drivers for growth theory, NSI, cluster theory and globalization respectively, as listed in Table 2.2:

$INNOVATION_{i,t}$ = β_0 + β_1(Skilled human capital)$_{i,t}$ + [β_2 (R&D Investment)$_{i,t}$+ β_3 (R&D external)$_{i,t}$ + β_4 (R&D internal)$_{i,t}$] + [β_5(public funding)$_{i,t}$ +β_6 (linkages to universities)$_{i,t}$ + β_7(linkages to government institutions)$_{i,t}$} + [β_8(linkages with suppliers)$_{i,t}$ +β_9(home market focus)$_{i,t}$] + [β_{10} (enterprises focused on international markets)$_{i,t}$] + γ_6 (country-specific effects)$_{i,t}$ + β_7 (time dummies)$_{i,t}$ + $\mu_{i,t}$ (4)

Table 2.2 : List of drivers used in model, associated with main strands of theories influencing innovation, source (author)

The theories specific to drivers	The drivers associated with the innovation theory
Driver common to 3 of 4 strands	• Skilled human capital
Additional drivers specific to growth theories	• R&D investment (including acquisition of external knowledge and capital) • Enterprises engaged in Internal R&D • Enterprises sourcing external R&D
Additional driver specific to National Innovation system	• Access to public funding for enterprises with some form of state support • Linkages between industry and academia, supporting commercialization of research • Linkages between industry and government institutions and laboratories
Additional drivers specific to Cluster theory	• Linkages between industry and suppliers, aligning research and upstream suppliers • Enterprises with Home market focus, home influences shaping innovation
Globalization	• Enterprises focused on international markets

2.4.2 **Sources of data and definition of key measures and terms**

Having defined the model, it is important to explain the sources of data and the definitions of some measures of variables, as that also forms an important aspect of contribution for this research. As highlighted in the overview of previous innovation determinant studies, amongst the various challenges facing cross-country innovation studies, there are possibly two key issues: firstly, access to data that actually reflects innovation; and, secondly, the choice of an accurate and comparable measure of innovation across varied national innovation systems. To attempt to bridge these two gaps, based upon previous research into the reliance of innovation data (Mairesse & Mohnen, 2010; Johansson & Loof, 2009), this research turned to Community Innovation Survey (CIS) data in order to access direct innovation data and a direct innovation measure.

Innovation database: CIS innovation data is specific innovation data collected across EU economies, providing a source of direct measures for most of the innovation variables used in this research. This facilitates a specific measure of innovation through turnover of classified innovative firms along with other variables associated with innovation, as well as avoids the inaccuracies that may accompany the use of general economic variables when applied as proxies for specific innovation issues. The European Commission initiated the first CIS direct innovation data for Europe in '93 with a pilot community innovation survey (CIS) (EUROSTAT CIS, 2013). This was further developed to form the basis of CIS innovation data, leading to the first official CIS survey in '96 and thereafter to the availability of innovation data every two years, with the last available data for 2010. This survey provides data for varied types of indicators related to innovation: products, processes, marketing and organizational and has been closely developed following the guidelines in the Oslo manual (Eurostat, 1997). While not without criticism, as it mixes quantitative and qualitative measures (Mairesse & Mohnen, 2010), with the qualitative measures being vulnerable to certain amount of subjectivity, this research is based upon the quantitative measures available in this data.

Innovation measure: In this study, the dependent variable is the revenue or turnover of innovative firms. This choice of innovation measure needs some elaboration, as Kuznets mentioned as early as in 1962 that 'the lack of meaningful measures of innovation input and output remain great obstacles to understanding the role of innovation in economic progress' (Kuznets, 1962) and continues be a challenge (Achs & Audretch, 1988; Mairesse and Mohnen, 2010). The characterization of TFP as 'a measure of ignorance" (Abramovitz, 1956), underscored by the challenge of separating capital from the increasingly inter-twined capital with innovation (Hulten C. , 2010) highlights the weakness of use of TFP as a measure of innovation. Similarly, the use of patents as a measure of innovation has also been questioned by Griliches and Pakes (Pakes & Griliches, 1980)), supported by findings of Achs and Audretsch (Achs & Audretsch, 1988). The use of R&D expenditure or R&D intensity, another used measure for innovation, was specified by the Oslo manual, as 'one of the range of input activities that generate innovation' (Eurostat, 1997; OECD, 2018, p 46). The Oslo manual goes on to identify that 'innovation needs to be implemented… distinguishing it from invention' (OECD, 2018, p 47), seeming to underscore that innovation should be measured based on output or successful translation of input.

Mairesse and Mohnen (2010) following that line of thought suggest that firm revenue of an innovative firms could be an output measure which successfully measures innovation, capturing the translation of an invention or R&D input into gain. As Community Innovation Surveys (CIS) classify firms as innovative or not and measure revenue, these surveys provide studies with access to direct innovation data and various reliable innovation measures, enabling cross comparisons (Mairesse & Mohnen, 2010). A firm is considered innovative, if it has incorporated innovative products or processes within the last 3 years, in accordance with definitions of innovation as listed in the Oslo manual (Eurostat, 1997; OECD, 2005). Although, the revenue measure has similar disadvantages of measures associated with survey errors, though it appears to reflect reasonable accuracy based on comparisons with sales and balance sheets of firms (Johansson & Loof, 2009; Mairesse & Mohnen, 2010).

While CIS surveys provide total revenue of innovative and non-innovative firms, they also try to identify the percentage of turnover of firms relevant to new innovations introduced over 3 years prior to surveys. However, in the harmonized and anonymized datasets provided by the EU, with requisite firm classifications and sector identification, this separation of turnover related to innovation is not available. Given the differing focus of various innovation studies using CIS datasets, innovation measures have varied ranging from a dichotomous binary variable identifying a firm as innovative or not, to various usages of quantitative data (Mairesse and Mohnen, 2010). This study chose not to use a dichotomous variable instead choosing firm revenue, as this variable could offer insights regarding growth and firm classification.

Albeit, this choice is accompanied by the limitation that this innovation measure does not separately identify the exact contribution of the innovation towards overall revenue. Nonetheless, it was felt that this variable could offer more insights than a purely dichotomous binary variable distinguishing a firm from being innovative or non-innovative, while reflecting as much as possible of actual innovation within firms. Henceforth, the dependent variable in the model is firm revenue of innovative firms, with firms being classified innovative based on CIS definition.

Understanding of Innovation and innovative firms itself: As innovation is a widely used term, it is also perhaps best to define the boundaries of this term for this research. Innovation or innovative firms, as used by this research are in accordance with the classifications of CIS, which are aligned with definitions in the Oslo manual (Eurostat, 1997; OECD, 2005). According to the Oslo manual, innovation is interpreted as either a new or significantly improved set of goods and services brought by a firm to the market. Innovative firms are thus defined as those introducing a new process or product, be it new to the market or only new to the firm, in line with the Oslo manual definition of innovation. This differentiation of innovation from invention, with innovation being the activity that actually is translated to profit in the market, echoes Schumpeter's interpretation of innovation. In his view, innovations took place only when inventions were accompanied by entrepreneurship: '… As long as they [inventions] are not carried into practice, inventions are economically irrelevant' (Schumpeter, 1961, pp 88-89). Hall and Rosenberg (2010) also define similar concepts of innovation, encompassing technical change in both products as well as organization.

Core-innovative sectors: Another key aspect of this research is the width of sectors analysed for innovation, incorporating both service and industry sectors, as innovation in current day digital economies bridges both categories. This research seeks to overcome previous restrictions of innovation studies to industry sectors only, which Cohen (2010) found contributed to the weaknesses of previous innovation studies (Cohen W. , 2010). Hence, this study seeks to include all 'core-innovative' sectors as defined in CIS data[11], including both

[11] These core-innovative sectors of an economy thus follow the classification as specified by CIS (Eurostat, 2013). According to CIS, the core innovative sectors classified within industry are mining and quarrying, manufacturing, electricity, gas, steam and air conditioning and water supply; while services include wholesale trade, except motor vehicles, transportation and storage, publishing activities, computer programming and related consultancies, information's services, financial and insurance services, architectural and engineering activities, technical testing and analysis. The actual activity classification is according to

services and industry. CIS defines these core innovative sectors to include both manufacturing and services ranging from B till M 71 sectors. The possible importance of extending this innovation research to all 'core innovative sectors' across both services and industry is not to be underestimated. This extension is necessary to capture analysis of technical frontier firms, classified varyingly under R&D, computer or information services, which are delivering design solutions but not necessarily manufacturing them. To restrict studies of innovation to manufacturing industries risks missing innovative firms in new emerging sectors and thus not capturing the essential drivers in the ever-changing landscape of innovation. Hall and Rosenberg underscore the importance of this wider concept of innovation to 'encompass research carried out in universities and industrial and government labs … or [even just] which Romer (Romer P. , 1990) labelled as new ideas' (Hall & Rosenberg, 2010). According to Hall and Rosenberg (ibid), this wider understanding of innovation evolved with time to reflect the importance of productivity and welfare-enhancing technical change emanating across sectors.

Firm-sizes: As this research uses firm sizes to distinguish turnover for small and medium firms (SMEs) from large firms and this definition differs across continents, it is also worthwhile to define the basis for this differentiation. The classification of firm sizes in CIS innovation data follows the recommendations of European Commission (Commission, 2003), defining small and medium-sized enterprises (SMEs) as having less than 250 employees and an annual turnover of up to 50 million Euros. It is though worth noting that the differentiation in CIS data between small, medium and large is based only on employee numbers, with small firms having 10-49 employees, medium firms having 50-249 employees and large firms having above 250 employees.

Skilled human capital: Data on skilled human capital was not available in CIS and has been sourced from another data set, also provided by Eurostat, the Human Resources in Science and Technology (HRST) database (EUROSTAT HRST,

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NACE system of classification, a "statistical classification of economic activities in the European Community" (Eurostat, 2008)

2012). This database measures the stock and flows of human resources across the EU and is based on European labour force surveys and UNESCO/OECD/Eurostat questionnaires. This dataset provides a measure of the scientists and engineers in employment in the economy across all sectors, not only innovative sectors. However, as scientists and engineers can be assumed work in innovative sectors, this measure may still be considered relevant. While this is also only a partial measurement of the innovative skill force in an economy, in the absence of further detailed skilled human capital working in economies, this is used as a variable to proxy the skill base of innovative human capital.

Definitions of CIS variables: Though the variables in CIS have matured and developed in the CIS surveys in order to allow greater accuracy and differentiation of data over the years between 1996 and 2010, this study has attempted to choose the variables across the years closely aligned to their initial starting point in 1996 to try to minimize discrepancies. Most of these variables assumed the definitions in 2000, which are listed still as the definitions in 2010.

Total innovation expenditure (R&D investment): In 1996, this is defined as total innovation expenditure. By 2010, this is explicitly defined as total innovation expenditure, capturing R&D investment, as well as costs for acquisition of external knowledge and capital.

Enterprises sourcing external R&D: There is no data in 1996 or 1998, 2000 onwards it is defined as innovative enterprises engaged in external R&D activities.

Enterprises engaged in internal R&D: In 1996, this was obtained as innovative enterprises with R&D expenditure. In 2010, this variable represents innovative enterprises engaged in in-house R&D activities.

Access to public funding for enterprises with some form of state support: In 1996, this is defined as innovative enterprises supported by government. In 2010 this represents the innovative enterprises that receive any form of public funding.

Linkages between industry and academia, supporting commercialization of research: Linkages between academia and industry are considered a critical linkage in national innovation systems. In 1996, CIS defined this as innovative enterprises with universities or other higher education institutes as partners. By 2010 this represents innovative enterprises co-operating with universities or other higher education institutes.

Linkages between industry and government institutions and laboratories: This linkage captures external R&D collaboration for firms in national innovation systems. CIS defined this in1996 as innovative enterprises with government or private non-profit research institutes as partners. By 2010 this represents innovative enterprises co-operating with government or public research institutes.

Linkages between industry and suppliers, aligning research and upstream suppliers: Perhaps also a critical linkage, as an important linkage in national innovation systems as well as cluster theory, CIS defined this in 1996 as innovative enterprises with suppliers as partners in equipment, materials, components and software. By 2010 this represents innovative enterprises co-operating with suppliers of equipment, materials, components and software.

Linkages between industry and any form of development partners: In 1996, this is defined as innovative enterprises with any form of innovative cooperation. By 2010 this represents innovative enterprises engaged in any type of innovative cooperation.

Enterprises with Home market: In 1996 this was classified as innovative enterprises with no exports. By 2010 this had matured into a variety of classes with the study restricting the variable to innovative enterprises that sell goods and/or services in the national markets.

Enterprises focused on international markets: In 1996 this was classified as innovative enterprises with exports. By 2010, the variable chosen for this class is defined as innovative enterprises that sell goods and/or services to other EU, EFTA and EU candidate countries. To avoid overlaps, this study chose not to add further classes of exports to different regions, as it could be the same enterprises with further expansions of exports. While this may reduce the total level of innovative firms with exports and may err on the side of conservative estimates, it attempts to capture the first level of exports for firms – through their expansion in the closest regions outside their national borders.

In the above listed variables (except for investment and revenue variables), the study lists the number of firms making these choices and not the aggregate turnover, as it is not available for such measures, unfortunately a limitation of CIS survey data. Basically, these variables are dichotomous qualitative variables indicating use or not of the wider aspects of National innovation systems.

This study hopes to explore the importance of these above linkages, enabling some prioritisation of these linkages for innovation, differentiated for firm-size classes.

2.4.3 **Interpretation of the coefficients of drivers:**

As the model is a linear model of innovation, the regression will yield coefficients for each driver, which may need to be clarified, as they will represent the proportional ratio of change in output per unit change of the particular driver. These are outlined below:

Dependent variable (all firm-sizes): The dependent variable, innovation output is measured in quadrillion (million billion) Euros to enable readable coefficients in regression tables, is the average turnover of all innovative firms.

Dependent variable (small/medium/large): The dependent variable, innovation output measured in quadrillion (million billion) Euros, is the average turnover of small/medium/large firm-sizes.

Skilled human capital proportional ratio: This parameter would relate innovation output (measured in quadrillion of Euros) per number of scientists and engineers representing skilled human capital unit (measured in the 1000's). Hence unit for parameter would be billions of Euro innovation output per 1000's engineers/scientists.

R&D investment proportional ratio: This parameter would relate innovation output (measured in quadrillions of Euros) per R&D investment unit, represented by total innovation expenditure (measured in millions of Euros). Hence unit for parameter would be billions of Euro output per millions of Euro R&D investment.

Internal R&D proportional ratio: This parameter would relate innovation output (measured in quadrillions of Euros) per number of firms engaged in internal R&D unit (measured in 1000's). Hence units would be billions of Euro output per 1000's of firms engaged in internal R&D.

External R&D proportional ratio: This parameter would relate innovation output (measured in quadrillions of Euros) per number of firms sourcing R&D externally unit (measured in 1000's). Hence units would be billions of Euro output per 1000's of firms sourcing R&D externally.

Public funding proportional ratio: This parameter would relate innovation output (measured in quadrillions of Euros) per number of firms with access to public funding unit (measured in 1000's). Hence unit for parameter would be billions of Euro output per 1000's of firms with public funding.

Linkages between industry and academia proportional ratio: This parameter would relate innovation output (measured in quadrillions of Euros) per number of firms with cooperation between industry and academia unit (measured in 1000's). Hence unit for parameter would be billions of Euro output per 1000's of firms with linkages to academia.

Linkages between industry and government institutions proportional ratio: This parameter would relate innovation output (measured in quadrillions of Euros) per number of firms with cooperation between industry and government institutions unit (measured in 1000's). Hence unit for parameter would be billions of Euro output per 1000's of firms with linkages to government institutions.

Linkages between industry and suppliers proportional ratio: This parameter would relate innovation output (measured in quadrillions of Euros) per number of firms with cooperation between industry and suppliers unit (measured in

1000’s). Hence units would be billions of Euro output per 1000’s of firms with linkages to suppliers.

Linkages between industry and any form of development partner’s proportional ratio: This parameter would relate innovation output (measured in quadrillions of Euros) per number of firms with any form of external collaborations (measured in 1000’s). Hence unit for parameter would be billions of Euro output per 1000’s of firms with any collaboration.

Home market proportional ratio: This parameter would relate innovation output (measured in quadrillions of Euros) per number of firms with sales focus on domestic markets (measured in 1000’s). Hence unit for parameter would be billions of Euro output per 1000’s of firms focused on domestic markets.

International market proportional ratio: This parameter would relate innovation output (measured in quadrillions of Euros) per number of firms with sales focus on international markets (measured in 1000’s). Hence unit for parameter would be billions of Euro output per1000’s of firms focused on international markets.

Having outlined the basic definitions, sources of data and interpretation of coefficients, the next section describes the model and lists the empirical results for this study.

2.5 Empirical Analysis

2.5.1 A panel-data analysis of innovation and its drivers

The empirical analysis is based on the model described in equation 4 in section 3 and the drivers enumerated in Table 2.2, the possible mechanisms of influence for those drivers on innovation as proposed in the above section. Proceeding now to the empirical analysis, the regression is based initially on two Eurostat data sets, CIS and HRST, which cover 27 countries across the EU over the period 1996-2010. Reiterating the earlier equation 4 below, which is used for the regression:

$INNOVATION_{i,t} = \beta_0 + \beta_1(\text{Skilled human capital})_{i,t} + [\beta_2 (\text{R\&D Investment})_{i,t} + \beta_3 (\text{R\&D external})_{i,t} + \beta_4 (\text{R\&D internal})_{i,t}]] + [\beta_5(\text{public funding})_{i,t} + \beta_6 (\text{linkages to universities})_{i,t} + \beta_7(\text{linkages to government institutions})_{i,t}\} + [\beta_8(\text{linkages with suppliers})_{i,t} + \beta_9(\text{home market focus})_{i,t}] + [\beta_{10} (\text{enterprises focused on international markets})_{i,t}] + \gamma_6 (\text{country-specific effects})_{i,t} + \beta_7 (\text{time dummies})_{i,t} + \mu_{i,t}$ (4)

For the regressions, panel datasets covering 27 countries are used, which offer the advantage of capturing both cross-sectional as well as time-series data, while minimizing impact of omitted variables in regressions (Hsiao, 2005). Given this advantage of panel data sets, nonetheless the regression estimation has to be careful to avoid country specific and sector specific effects, as they could distort regression results. Hence, based on the panel data sets selected for this study, this study found Fixed effect (FEM) estimation to be the most appropriate econometric analytical tool of choice to remove country specific effects from across the 27 country data, as FEM removes time invariant mean effects from the correlation of regressor with explanatory variables (ibid).

The regression results for equation 4 are listed in Table 2.3 for period '96-2010 covering 27 European countries. Innovative firm turnover as defined earlier as the innovation measure, is used as the dependent variable on the L.H.S. Columns numbered (1) – (5) list the various regressions independently initially for each theory as listed in Table 2.3 and then the combined regression of all drivers – the model for our research. Consequently column (1) lists the regression with only the independent drivers from growth theories on R.H.S.; column (2) lists results for NSI drivers only on R.H.S; column (3) shows results for cluster theory drivers only; column (4) lists globalization only drivers; with column (5) depicting results due to the combined effect of drivers, as proposed by this theory in equation (2). However, these initial separate regressions for each separate theory from column 1-4 may suffer from problem of omitted variable regressions, as we exclude combining these theories which this research considers jointly significant. As such, the result and consequent insights of the initial regression results from column 1-4 should be treated with caution.

Table 2.3:Regression results for initially step-wise theories and their drivers, lastly with combined drivers in accordance with proposed model, with dependent variable – annual innovative turnover of firms in quadrillion Euros

Strands of theories:	(Period 1996-2010)	(1) Growth theories	(2) Nat. Innov. Systems	(3) Cluster Theory	(4) Globali-zation	(5) All combined – as per model	(5) Previous combined – as per model
	Observations	109	100	103	107	89	90
	No. of groups	30	29	28	29	27	27
	Obs per group:	min = 1, avg = 3.6, max = 5	min = 1, avg = 3.4, max = 5	min = 1, avg = 3.7, max = 5	min = 1, avg = 3.7, max = 5	min = 1, avg = 3.3, max = 5	min = 1, avg = 3.3, max = 5
Common driver	No. of Scientists/ Engineers (Skilled human capital)	2.04*** [0.34]	1.49*** [0.32]	3.29*** [0.40]	3.22*** [0.31]	1.82*** [0.53]	2.83*** [0.05]
Drivers specific to growth Theories	Total Innovation Expenditure (R&D investment)	.000013 [0.000012]				0.000022 [0.000015]	-0.000012 [0.000014]
	Enterprises with internal R&D	-0.039 [0.027]				-0.12 *** 0.03	
	Enterprises with external R&D	0.11 * [0.056]				0.23 *** [0.06]	0.037 [0.049]
Drivers specific to NSI	Enterprises with public funding		0.081*** [0.019]			0.075 *** [0.02]	0.07 *** [0.022]
	Enterprises with any collaboration		-0.062 * [0.032]			-0.2 *** [0.045]	-0.22 *** [0.050]
	Enterprises with govt. Insti. Collaboration		0.123 [0.15]			-0.32 ** [0.16]	-0.068 [0.16]
	Enterprises with University collaboration		0.145* [0.08]			0.44 *** [0.086]	0.25 *** [0.08]
Cluster Theory	Enterprises focused on National markets			-0.003 [0.008]		0.009 [0.017]	0.025 [0.019]
	Enterprises with Supplier collaboration			-0.048 [0.038]		0.138 ** [0.06]	0.15 ** [0.069]
Globalization	Enterprises focused on International markets				-0.02 ** [0.009]	-0.014 [0.025]	-0.045 * [0.027]

Strands of theories:	(Period 1996-2010)	(1) Growth theories	(2) Nat. Innov. Systems	(3) Cluster Theory	(4) Globali-zation	(5) All combined – as per model	(5) Previous combined – as per model
Constant	constant	-4.87e+02***	-3.91e+02***	-6.11e+02***	-5.84e+02***	-4.8e+02***	-5.9e+02***
	Corr(μ_i, X_b)	-0.9493	-0.8844	-0.9568	-0.9476	-0.9441	-0.9212
	F-test that all μ_I = 0; Prob > F	0.0128	0.0003	0.000	0.0000	0.0000	0.0001
	R^2	within = 0.5135 between = 0.9455 overall = 0.9018	within = 0.6828 between = 0.9387 overall = 0.9080	within = 0.6171 between = 0.8924 overall = 0.8471	within =0.6278 between =0.8802 overall = 0.8385	Within =0.8658 between = 0.9464 overall = 0.9219	Within =0.8220 between = 0.8793 overall = 0.8540

Note: p-values: *** denoting significance at 1%, ** significance at 5% and * 10% significance. Std.errors are in square brackets. Data sources are CIS and HRST databases

Table 2.3, shows these combined drivers with time dummies. The regressions provide for some interesting results, which are explored briefly further below.

Before we interpret results, it is also important to note that the correlation coefficient for μ_I and X_b for both regressions is reasonably high, affirming that use of fixed effects estimation is justified. Also, the probability for F-test in all regressions shows that all variables are jointly significant.

2.5.2 Initial analysis of innovation drivers separately by theory

Growth theories innovation drivers regression only: The regression with innovation drivers only associated with growth theory, as listed in column (1), is unexpected and quite surprising. R&D investment and internal engagement of R&D both do not appear to be significant, while external sourcing of R&D is significant and positive. The positive and significant external R&D driver may reflect that it may be positive for firms to outsource R&D work, reducing the burden of costs of carrying internal R&D effort. This advantage seems to outweigh the possible loss of internal technology development associated with outsourcing of R&D, which appears to be more closely linked with growth of firms, such as from medium to large, rather than innovation fundamentals itself. Keeping in mind that drivers may differ for growth in firm-sizes from innovation drivers, human capital is also seen as significant and positive, thus seeming to affirm the importance of skilled human capital also as a key driver for innovation. If this result is valid, then it provides some support for endogenous growth theory in terms of innovation, but negates the importance of R&D investment, which includes capital and knowledge acquisition, as a main driver for innovation. Removing skilled human capital from this regression immediately assigns significance to both these R&D drivers, indicating that absence of skilled human capital in innovation regressions may assign mistaken significance to other drivers.

NSI innovation drivers regression only: The regression of innovation drivers part of National Innovation Systems as listed in column (2), appears to negate the importance of linkages with government institutions. Indeed cooperation in general, appears to generate a negative contribution for innovation. Instead, positive contribution towards innovation is specific to industry linkages with universities and to firms access to public funding, thus affirming importance of certain linkages within NSI for innovation, along with signifying importance of public funding for firms for innovation.

Cluster theory innovation drivers regression only: Column (3) lists the contributions from cluster theory, surprisingly also only finding significance for skilled human capital. Home market focus and supplier cooperation do not appear significant.

Globalization as an innovation driver regression only: The results of column (4) show the regression results for globalization as an innovation driver along with skilled human capital. Again, unexpectedly international market focus, though significant is negative towards innovation, thus, seeming to indicate that export may not be an essential driver for innovation on its own.

Before moving onto the analysis of combined drivers, the proposed model of this research, it suffices to say that some of these results are unexpected. While empirical errors may never be totally ruled out, it may be that the use of a wider set of innovation drivers based on direct innovation data reduces both a possible problem of omitted variables as well as reduces errors from usage of indirect proxies, providing a result more accurately representative of the actual determinants of innovation.

2.5.3 Analysis of combined innovation drivers, the proposed model for this research:

Combined innovation drivers regression: The model as proposed by this research, incorporating drivers from across the theories, as listed in column (5) in Table 2.3 is also displayed in column (1), Table 2.4. The results reveal quite a few intriguing differences from the previous separate regressions: while R&D investment remains insignificant and external R&D investment stays significant, internal R&D which was negative earlier now turns significant. The government linkage variables turn significant, but they also become negative. Additionally, international markets turn insignificant though remaining negative, in contrast to supplier linkages, which turns significant and positive. The rest of the results remain similar. To understand the results of this combined driver regression, the next subsections offers insights and explanations for each of the drivers used in this model, interpreting R&D investment last as it requires more detailed investigation. Indeed, to make sense of the absence of significance of R&D investment as a primary driver of innovation, further regressions are performed and listed in Table 2.4. These regressions are listed in column (2-4) check for specification error: column (2) examines an oft used model without human capital and column (3) evaluates if R&D could have a non-linear component. Thereafter, out of concerns of collinearity, two mirroring variables home market and international market are interchangeably removed in column (4) and (5) and accordingly assessed.

Table 2.4:Regression results for combined drivers in accordance with proposed model in column 1, with additional regressions column 2-4 for further checks on model specification and column (5) listing regression on innovation growth, with time dummies.

Dependent variable for column 1 -4: annual innovative turnover of firms in quadrillion Euros

Strands of theories:	(Period 1996-2010)	(1) Proposed model, as per paper – with variables from merged theories	(2) Without human capital – an oft missed variable in prior analyses	(3) An additional non-linear R&D -to check for specification error	(4) Reduced collinearity (1) – no home market and no internal R&D	(5) Reduced collinearity robustness check - with home market, but no international market
	Observations	89	91	89	90	90
	No. of groups	27	28	27	27	27
	Obs per group:	min = 1, avg = 3.3, max = 5	min = 1, avg = 3.2, max = 5	min = 1, avg = 3.3, max = 5	min = 1, avg = 3.3, max = 5	min = 1, avg = 3.3, max = 5
Common driver	No. of Scientists/Engineers (Skilled human capital)	0.182 *** [0.53]		1.64 *** [0.54]	2.50 *** [0.48]	2.49 *** [0.5]
Drivers specific to growth Theories	Total Innovation Expenditure (R&D investment)	.000021 [.000015]	.000052 *** [.000013]	.000004 [.000019]	.000001 [.000011]	0.00000092 [0.000012]
	(Total Innovation Expenditure)∧2			3.02e-13 [1.96e-13]		
	Enterprises with internal R&D	-0.12 *** [0.03]	-0.16 *** [.000015]	-0.12 *** [0.029]		
	Enterprises with external R&D	0.23 *** [0.06]	0.34 *** [0.059]	0.23 *** [0.06]	0.018 [0.05]	-0.002 [0.044]
Drivers specific to NSI	Enterprises with public funding	0.076 *** [0.02]	0.084 *** [0.02]	0.093 *** [0.022]	0.085 *** [0.019]	0.093 *** [0.017]
	Enterprises with any collaboration	-0.196 *** [0.045]	-0.20 *** [0.049]	-0.158 *** [0.051]	-0.229 *** [0.051]	-0.223 *** [0.051]
	Enterprises with govt. Insti. Collaboration	-0.315 ** [0.155]	-0.28 * [0.168]	-0.35 ** [0.155]	-0.094 [0.162]	-0.085 [0.164]
	Enterprises with University collaboration	0.443 *** [0.085]	0.56 *** [0.084]	0.408 *** [0.087]	0.255 *** [0.255]	0.232 *** [0.08]
Cluster Theory	Enterprises focused on National markets	0.009 [0.016]	-0.02 [0.016]	-0.013 [0.02]		-0.003 [0.008]
	Enterprises with Supplier collaboration	0.14 ** [0.06]	0.148 *** [0.067]	0.116 * [0.062]	0.165 ** [0.069]	0.157 ** [0.07]

Globalization	Enterprises focused on International markets	-0.014 [0.026]	0.026 [0.025]	0.007 [0.029]	-0.012 [0.012]	
Constant	constant	-4.8e+02 ***	-2.6e+02 **	-4.6e+02 ***	-5.62e+02 ***	-5.52e+02 ***
	Corr(μ_i, X_b)	-0.9441		-0.9505	-0.9412	-0.9371
	F-test that all μ_i = 0; Prob > F	0.0000		0.0000	0.0000	0.0001
	R^2	Within =0.8658 between = 0.9464 overall = 0.9219		Within =0.8719 between = 0.9445 overall = 0.9175	Within =0.8159 between = 0.9146 overall = 0.8861	Within =0.8128 between = 0.9102 overall = 0.8816

Note: p-values: *** denoting significance at 1%, ** significance at 5% and * 10% significance. Std.errors in square brackets. Data sources are CIS and HRST databases..

Overall, these results are interesting yet surprising - the lack of significance for R&D expenditure, the negative significance of internal R&D, the lack of significance of domestic market focus – balanced against strong positive significance of skilled human capital, public funding, collaboration with suppliers and linkages with universities. These results are explained further below, but detailed analysis to explore how these drivers vary for firm-sizes, is explored in sub-section 2.5.7 as well as a separate sub-section 2.5.4 to understand lack of R&D expenditure significance, as some of these surprising results are quite significant.

Skilled human capital as driver: This is quite a strong result, emphasizing the importance of skilled human capital as an innovation driver, as it shares importance across theories - a driver common across growth theories, NSI and cluster theory – is found consistently significant and positive. Indeed, it is one of the highly robust drivers. As will be shown in section 2.6, based upon literature on Germany explaining mechanisms of influence on innovation, skilled human capital as a driver may be made more effective through the provision of a highly skilled and diverse education sector incorporating vocational programmes, closely aligned with industry. Thus, though skilled human capital significance for innovation is found across all economies, its effectiveness in delivering innovation may be increased through additional focus in policy on the diversity of the skilled educational sector and its alignment with industry.

R&D internal and external focus of firms: As in the separate growth theory, the driver capturing the firms' outsourcing of R&D externally appears to be significant and positive. In contrast the choice by firms to undertake internal R&D is shown to be negative. This is a surprising result, if internal R&D is viewed separately. However, as suggested earlier, these two results in tandem may represent the reduced burden of cost of internal R&D, which would impact innovation turnover negatively. Also, as mentioned earlier, maybe this driver would be significant for growth of firms rather than innovation fundamentals, differentiating growth from small to medium-sized firms and medium to large-sized firms. This variation is explored in depth in sub-section 2.5.7, where drivers are differentiated for firm-size classes.

Public funding of firms as driver: The next listed driver, public funding of firms, is another remarkably consistent and robust positive driver on innovation. Its influence on innovation may well work through the mechanism highlighted in section 2.6 on Germany, through encouraging longer-term decision-making and stable governance structures, while reducing funding gaps for firms. Despite the robustness of this driver, the data of economies reveals some anomalies. There is quite a lot of variation in the use of this driver and the delivery of innovation. A possible interpretation of the varying effectiveness of this driver on innovation may take us back to the original proposal of this paper – the delivery of innovation may be better achieved through a wider tool-kit, which in turn may increase effectiveness of individual drivers.

Nonetheless, future research on ownership structures and decision –making using demographic data of firm birth and death rates, as started by EU in 2008, may provide further insights into understanding the workings of this driver.

Linkages with academia and government as drivers: We proceed now to the three drivers capturing varying forms of linkages: various sorts of collaborations of firms with other enterprises, institutions, academia, suppliers and/or clients; collaborations of firms specifically with government institutions; collaborations of firms specifically with academia for research. Out of these linkages, the first driver representing any type of linkage is significant but negative, whereas the second driver of industry linkages with governmental institutions is significant but negative. Only the last driver representing linkages with academia is significant and positive.

The insignificance of the first driver may capture possible losses incurred to innovation turnover in short-term, as it also captures effort with clients, customers and other agencies. The second linkages driver representing collaborations with government institutions, may specify that this association is not necessarily fruitful for all firm sizes. Indeed, this is later affirmed, when differentiating these drivers for different firm sizes, where it is found significant for medium sized firms. While the underlying mechanism for this relationship would need further research, it appears that driver differentiation for specific firm sizes helps clarify this result. In addition to differentiation of drivers for varied firm-sizes, this insignificance may also suggest that collaborations in industry may only benefit innovation when focused on specific partnerships. However, the last driver representing linkages between industry and academia is highly robust, even later irrespective of firm sizes, staying significant and positive. As will be explored in section 2.6 on this particular drivers' influence in Germany, it appears conceivable that linkages with academia exerts a positive influence on innovation through enhancing commercialization of research for all firm-sizes, forged through collaborations between research and entrepreneurs.

International market and home market focus drivers: Turning to also the surprising negative and insignificant influence of international market focus on innovation and positive but still insignificant significance for home market focus of firms. As home market focus of firms is considered quite necessary for innovation in the cluster theory concept as promoted by Porter, (Porter M. , 1990), two further regressions are analysed in order to rule out correlation mistakenly influencing results, removing higher correlation variables of internal R&D and home market. To avoid mistaken results due to imperfect collinearity, the significance of international market focus as a driver and home market as a driver are assessed separately in regressions listed in Table 2.4 in column (4) and (5) respectively. Interchanging either driver in these two regressions does not influence the significance of other drivers, though it changes the borderline significance of internal markets to insignificant. These additional regressions seem to affirm the insignificance of both globalization and home markets as a primary driver of innovation. There may however be scope for market influence

– be it home market or globalization - to perhaps exert a secondary influence on innovation. In other words, markets may be important after innovation has taken place to expand future profits. On the other hand, a specific focus on markets before knowing the suitability of markets to target, may be an added burden detracting finances away from innovation. To differentiate and properly understand the order of inter-workings between globalization and innovation, further analysis with specific innovation and market data would be required.

Linkages with suppliers as driver: Supplier collaboration is found positive and significant as expected with cluster theory, contrary to the results found earlier in the step-wise analysis. This may be as a result of improved analysis through inclusion of a more complete set of drivers. The importance attributed by cluster theory on the relationship of innovators with suppliers is widely acknowledged in policies and is apparent in policy incentives around the world.

R&D investment driver: The second listed driver, R&D investment, as pointed out earlier is a key driver for innovation policy targets and an important component in growth theories. Nonetheless, it was found insignificant for innovation in the separate theory analysis and continues to be insignificant in the combined driver regression.

Although data inaccuracies cannot be totally excluded, a few aspects of R&D investment driver, which seem plausible given the data, may explain this insignificance. Firstly, R&D investment is recognized in practice to be quite a stable figure in firms (Hall, Mairesse, & Mohnen, 2010, p. 16), only changing gradually over time. This attribute may influence the significance of this drivers' correlation with variations in innovation turnover. Secondly, and perhaps more significantly, it appears that economies most effectively using this driver to deliver innovation do not turn out to be the most innovative of economies. This anomaly is evident in the figures in table A3 in Annexe, which lists the proportional ratios for R&D (innovation output per R&D input, measured in billions output per millions R&D input) for the top 10 economies with the highest R&D investments: Spain having the highest proportional ratio (2x of Germany), yet Germany having the highest turnover (5x of Spain). This lack of correlation between the highest proportional ratio of this driver and the highest innovation turnover, seems to signify that other drivers may need to be present in an economy, which when working together deliver a total innovation much higher than that of this individual driver. This implies that possibly other drivers drawn from informal R&D drivers as captured in national innovation systems and not R&D investment in particular, may explain the differentiation in innovation levels performance of economies. This result is further investigated for model robustness in more regressions listed in Table 2.4 above and explained in greater detail in the next subsection.

2.5.4 **Further regressions to investigate lack of significance of R&D investment driver:**

In order to make more sense of this result, additional regressions are undertaken, which are also listed in Table 2.4, to check for specification error or possible collinearity. The regressions listed in column Table 2.4 columns (2-3) explore regressions to check for specification, while column (4-5) remove closely correlated variables to reduce collinearity errors.

To first and foremost check the robustness of model specification, the proposed complete model as suggested by the merging of theories in this paper is listed in column (1), this is compared it to the oft-used model without human capital as listed in column (2) of Table 2.4. As this model without human capital is a model quite prevalent in innovation analysis with direct innovation data, it is important to examine if it can lead to mistaken conclusions due to specification error. Furthermore, in order to check our own model for specification error, column (3) adds a non-linear component of R&D investment to the proposed model of column (1). Non-linear component of R&D is considered, in case there is a curved non-linear relationship between R&D and innovation, possibly a tapering impact of increasing R&D on innovation, which our model fails to incorporate. More so, to alleviate concerns of collinearity, Column (4) and (5) remove higher correlated variables, in order to check if that may influence significance of R&D investment. Finally, column (6) investigates the possibility of R&D investment as a secondary driver, working on innovation growth instead of innovation fundamentals depicted by levels. The detailed interpretations are listed below, but these regressions appear to show that R&D investment only becomes significant as a primary driver when skilled human capital is excluded. On the other hand, it does remain significant as a secondary driver, so indeed important for spurring growth of innovation once fundamentals of innovation in place.

Column (2) results: Regression without skilled human capital: This regression is to allow comparison of the proposed model as in column (1) with on oft used models in innovation analysis, omitting skilled human capital. The results are interesting, as it seems to indicate that misleading significance may be attached to other variables, if models omit skilled human capital. Setting aside small changes in extent of significance, this regression shows similar results for all drivers as in the papers proposed model - except one, R&D investment. It becomes highly significant and positive. This appears to indicate that exclusion of skilled human capital from this model could lead to mistaken results as a result of omitted variable problem, an important aspect that may explain the difference of results in this study from previous studies.

Column (3) results: Regression with additional non-linear component of R&D investment: To ensure there is no specification error in papers proposed model as listed in column (1), this regression adds a non-linear component of R&D investment, as R&D investment itself was not significant. The results again show barely any changes in significance for drivers and both R&D investment driver, as well as the non-linear component of R&D investment remain insignificant.

Column (4) and (5) results- To reduce collinearity, two regressions with removal of two mirroring variables: To reduce possible errors due to imperfect collinearity, the two variables that seem to be mirrored by their counterpart, Internal R&D and National markets, are removed. Based on the assumption that these two variables reflect their counterparts to a large extent: Internal R&D with External R&D and National markets with International markets; and as they appear to be highly correlated with these counterparts, the two variables may reliably be removed without losing fundamentals of specification. The results do capture two differences from our initial proposed model in column (1): significance is lost for external R&D outsourcing and government collaboration. This appears to be a robust result, as the switch between National markets and International markets, column (4) and (5) respectively, shows no change in significance to other drivers. Most importantly, it shows no change in significance for R&D investment.

To assess whether R&D investment may be a secondary driver, instead of primary driver, the combined drivers model is regressed on innovation growth, which is examined in the following section.

2.5.5 Analysis of secondary innovation drivers – on innovation growth, rather than innovation level:

So far, the study has focussed on determining on finding a complete set of primary innovation drivers, to understand what drives the foundation of innovation – measured by innovation levels. In order to avoid attributing misleading significance to variables due to omitted variable problems, it has chosen drivers across a range of theories to provide as holistic a set of innovation drivers as is possible within the dataset. While this has yielded valuable insights as explained in previous section, it is important to seek to put this in context with secondary drivers – those innovation drivers that spur growth, after innovation foundation has been laid in the economy.

Towards this end, it would appear important to apply the same approach of regressing a wider set of innovation drivers on innovation growth, to try to obtain a holistic set of secondary drivers spurring innovation growth.

Thus, a regression is now performed on innovation growth (biannual growth, due to data availability) instead of innovation level, using the same wider set of innovation drivers combining theories, over the same time period 1996-2010. Choosing the model of reduced correlation drivers as listed in column (4) in Table 2.4, the regression on innovation growth for these same drivers is listed in Table 2.5.

Table 2.5:Regression of combined drivers on innovation growth - not innovation level, to determine how secondary drivers may differ from primary drivers

Strands of theories:	(Period 1996-2010)	Dependent variable: biannual innovation growth (6) Reduced correlation regression with time dummies
	Observations	86
	No. of groups	26
	Obs per group:	min = 1, avg = 3.3, max = 5
Common driver	No. of Scientists/Engineers (Skilled human capital)	-70*** [25]
Drivers specific to growth Theories	Total Innovation Expenditure (R&D investment)	.000005 *** [.0000002]
	(Total Innovation Expenditure)^2	
	Enterprises with internal R&D	
	Enterprises with external R&D	14.6*** [.000007]
Drivers specific to NSI	Enterprises with public funding	-1.335 [0.97]
	Enterprises with any collaboration	-5.97* [3.09]
	Enterprises with govt. Insti. Collaboration	-19.6** [8.1]
	Enterprises with University collaboration	19.2*** [7.37]
Cluster Theory	Enterprises focused on National markets	
	Enterprises with Supplier collaboration	7.37*** [3.82]
Globalization	Enterprises focused on International markets	-3.34*** [0.709]
Constant	constant	1.47e+4***
Time dummies	2004	-6.8e+03* [3.86e+03]
	2006	-7.1e+03* [4.13e+03]
	2008	-9.8e+03 ** [3.96e+03]
	2010	-7.1e+03 * [4.01e+03]
	Corr(μ_i, X_b)	-0.1589
	F-test that all μ_i = 0; Prob > F	0.0000
	R^2	Within =0.9926 between = 0.6792 overall = 0.8797

Note: p-values: *** denoting significance at 1%, ** significance at 5% and * 10% significance. Std.errors in square brackets. Data sources are CIS and HRST databases..

This regression again provides interesting insights. Perhaps the most important insight is that R&D investment appears to be a secondary driver influencing innovation growth, as R&D investment is significant and positive. Thus, underscoring the importance of understanding that the same variables exhibit different influences as primary drivers as opposed to secondary drivers. In terms of secondary drivers not only is R&D investment significant, but also external R&D is positive and significant, while interestingly skilled human capital turns negative and public funding loses significance. Exploring these results in further detail is currently out of the scope of this study, however there is one important understanding highlighted by this regression - an innovation policy should carefully distinguish the target of its policy from fostering the foundations of innovation to spurring innovation growth, as then it can accordingly choose the appropriate drivers to influence to achieve that goal.

Within this boundary of understanding, this regression seems to confirm that different secondary drivers such as R&D investment are needed to grow innovation, after primary drivers have laid the foundation to create innovation levels. Thus, accommodating and indeed understanding this differentiation of both primary and secondary drivers may be an important insight gained for tailoring effective innovation policies.

Though each driver's significance or lack of significance does provide further opportunities for research, the possible mechanisms of influence of this wider set of drivers are explored through exploiting the understanding gained on their workings in Germany in Section 5.

Another perhaps equivalently important message from this analysis is that no driver in isolation can be as effective as a wider mix of these drivers. Indeed, if this is valid, then it may be possible for economies to boost innovation within current capital limitations, purely through applying these wider set of innovation drivers in tandem.

2.5.6 **Robustness checks for innovation drivers:**

To ensure robustness in empirical analysis, some further regressions are undertaken and listed in Table 2.6: column (1) lists the regression of reduced set of combined drivers as some drivers were excluded due to concerns of collinearity, as listed originally in column (3) of Table 2.4. This is supplemented in column (2) in Table 2.6, with the addition of time-dummies. Then column (3) in Table 2.6 displays results of regression for robustness check, with substitution of international market driver with home market driver and external outsourcing of R&D replaced with internal R&D driver. As these two pairs of reasonably highly correlated with each other, their substitution could highlight weakness in regression results. Reviewing the results in column (3) indicates the regression to be reasonably robust, as the substitution of these drivers causes no change in significance of other drivers, though it does add significance of time dummies. Column (4) lists the heteroskedasticity and autocorrelation (HAC) robust corrected standard errors. There is one change in the significant variables, which is that significance of suppliers is reduced to 13%. This implies that the earlier higher significance of the supplier variable at 5% may have been influenced erroneously through heteroskedasticity and autocorrelation. Nonetheless, though lower in significance, its effect on innovation may be still be evaluated within this lower significance level.

Last, but not least, these regressions could not rule out endogeneity, as due to shortages of time period data, these regressors could not be instrumented to ensure there was no reverse causality between drivers, such as linkages between academia or linkages between government institutions and innovation measure as dependent variable.

Table 2.6:Robustness checks for Fixed Effects regression results with reduced set of drivers to avoid collinearity

Dependent variable – annual innovative turnover of firms, measured in quadrillion Euros

Strands of theories:	(Period 1996-2010)	(1) Reduced regression – with no home market	(2) Reduced regression – but with added time dummies	(3) Robustness check , substituting international market with home market	(4) Further robustness check, (autocorrelation and heteroskedasticity) Reduced regression – but with added time dummies
	Observations	90	90	90	90
	No. of groups	27	27	27	27
	Obs per group:	min = 1, avg = 3.3, max = 5	min = 1, avg = 3.3, max = 5	min = 1, avg = 3.3, max = 5	min = 1, avg = 3.3, max = 5
Common driver	No. of Scientists/Engineers (Skilled human capital)	2.5*** [0.48]	3.04*** [0.56]	3.325*** [0.45]	3.038*** [0.91]
Drivers specific to growth Theories	Total Innovation Expenditure (R&D investment)	0.000001 [0.000011]	-0.000007 [0.000012]	-0.000009 [0.000011]	-0.000007 [0.000015]
	Enterprises with external R&D	0.018 [0.048]	-0.009 [0.05]		-0.009 [0.058]
	Enterprises with internal R&D			-0.049 *** [0.018]	
Drivers specific to NSI	Enterprises with public funding	0.0849*** [0.019]	0.085*** [0.020]	0.090*** [0.016]	0.085*** [0.03]
	Enterprises with any collaboration	-0.229 *** [0.051]	-0.29*** [0.058]	-0.289*** [0.053]	-0.289*** [0.107]
	Enterprises with govt. Insti. Collaboration	-0.094 [0.162]	-0.066 [0.158]	-0.183 [0.156]	-0.066 [0.28]
	Enterprises with University collaboration	0.255*** [0.255]	0.247*** [0.079]	0.268*** [0.07]	0.245*** [0.085]
Cluster Theory	Enterprises focused on National markets			0.010 [0.008]	
	Enterprises with Supplier collaboration	0.165 ** [0.069]	0.247*** [0.083]	0.28*** [0.074]	0.247 ([0.159]
Globalization	Enterprises focused on International markets	-0.012 [0.012]	-0.002 [0.013]		
Constant	constant	-5.62e+02***	-4.9e+02***	-3.99e+02***	-4.9e+02***
Time dummies	2004		-1.9e+02** [94.4]	-2.31e+02*** [85.8]	-1.88e+02* [109]
	2006		-1.33e+02 [99.6]	-1.91e+02 ** [90.2]	-1.33e+02 [99.6]
	2008		-1.34e+02 [96.4]	-1.8e+02 ** [92.6]	-1.34e+02 [95.7]

Dependent variable – annual innovative turnover of firms, measured in quadrillion Euros					
Strands of theories:	(Period 1996-2010)	(1) Reduced regression – with no home market	(2) Reduced regression – but with added time dummies	(3) Robustness check , substituting international market with home market	(4) Further robustness check, (autocorrelation and heteroskedasticity) Reduced regression – but with added time dummies
	2010		-1.93e+02* [99.9]	-2.45e+02*** [92.6]	-1.93e+02* [103]
	Corr(μ_i, X_b)	-0.9412	-0.9323	-0.9412	-0.9323
	F-test that all μ_I = 0; Prob > F	0.0000	0.0001	0.0000	0.0000
	R^2	Within =0.8159 between = 0.9146 overall = 0.8861	Within =0.8388 between = 0.8769 overall = 0.8528	Within =0.8159 between = 0.9146 overall = 0.8861	Within =0.8388 between = 0.8769 overall = 0.8528

Note: p-values: *** denoting significance at 1%, ** significance at 5% and * 10% significance. Std.errors in square brackets. Data sources are CIS and HRST databases..

2.5.7 **Differentiating innovation drivers for firm-sizes: small, medium and large firm-sizes:**

Thus far, the Innovation drivers have been evaluated for firms across the board. Now, however we refine Schumpeter's hypothesis on impact of firm size on innovation (Schumpeter J. , 1942), instead performing regressions to differentiate innovation drivers for small, medium and large firm-sizes. It should also be clarified that firm-size turnover for each firm-size class is the average turnover of small/medium/large firms. To enable differentiation of innovation drivers for each firm-size class, the innovation measure on the left-hand side of the equation (4) is changed from measuring innovative turnover for all firms to average innovative turnover for small firms initially, then medium firms and then large firms. The regression analysis with these changes is listed in Table 2.7 below. Thus, column (1) lists the combined drivers regression for all firm-sizes, whereas column (2) is specific to small firms , column (3) is relevant to medium firms and column (4) for large firms.

The results indicate differing drivers for small and medium firms from the general drivers for all firm sizes are interesting and somewhat difficult to interpret, without further in-depth data. Noticeably, public funding and supplier collaboration are both found not significant for either small or medium sized firms. The loss of significance of linkages to suppliers could indicate that small and medium firm products may not be mature enough to benefit from supplier collaboration. Albeit, the lack of significance for public funding for SMEs remains puzzling and invites further research.

Table 2.7:Regression results with reduced correlation terms and time dummies, for differing firm-sizes

Dependent variable: annual innovative turnover (measured in quadrillion Euros) of all firms for column 1; annual innovative turnover of small firms for column 2, medium sized firms in column 3 and large sized firms in column 4

Strands of theories:	(Period 1996-2010)	(1) Reduced correlation regression –with added time dummies – for all firm-sizes	(2) Reduced correlation regression –with added time dummies – for small firm-sizes	(3) Reduced correlation regression –with added time dummies – for medium firm-sizes	(4) Reduced correlation regression – with added time dummies – for large firm-sizes
	Observations	90	89	89	89
	No. of groups	27	27	27	27
	Obs per group:	min = 1, avg = 3.3, max = 5	min = 1, avg = 3.3, max = 5	min = 1, avg = 3.3, max = 5	min = 1, avg = 3.3, max = 5
Common driver	No. of Scientists/Engineers (Skilled human capital)	3.038*** [0.56]	0.439*** [0.13]	0.27*** [0.08]	2.639 *** [0.48]
Drivers specific to growth Theories	Total Innovation Expenditure (R&D investment)	-0.000007 [0.000012]	-0.000002 [0.000002]	0.00000015 [0.000001]	-0.000009 [0.000009]
	Enterprises with external R&D	-0.009 [0.05]	-0.01086 [0.011]	-0.015** [0.003]	-0.0009 [0.041]
Drivers specific to NSI	Enterprises with public funding	0.085*** [0.02]	-0.0037 [0.004]	-0.004 [0.003]	0.09*** [0.016]
	Enterprises with any collaboration	-0.289*** [0.058]	-0.0029 [0.0136]	0.004 [0.008]	-0.32*** [0.049]
	Enterprises with govt. Insti. Collaboration	-0.066 [0.158]	-0.08** [0.035]	0.047** [0.022]	-0.0245 [0.125]
	Enterprises with University collaboration	0.247*** [0.08]	0.054*** [0.018]	0.034*** [0.011]	0.148** [0.06]
Cluster Theory	Enterprises focused on National markets				
	Enterprises with Supplier collaboration	0.247*** [0.08]	0.0068 [0.02]	-0.005 [0.013]	0.299*** [0.07]
Globalization	Enterprises focused on International markets	-0.002 [0.01]	-0.002 [0.003]	0.002 [0.002]	0.002 [0.01]
Constant	constant	-4.9e+02***	-3.11e+01	-3.18e+01	-3.77e+02
Time dummies	2004	-1.9e+02** [94.4]	-1,7e+01 [26.9]	-2.47e+01 [16.7]	- 2.52e+02** * [96.8]
	2006	-1.33e+02 [99.6]	-3.3e+02 [28.5]	-2.13e+01 [17.7]	- 2.22e+02** [10.3]
	2008	-1.34e+02 [96.4]	-8.4 [28.6]	-1.24e+01 [17.1]	- 2.22e+08** [99.3]

Dependent variable: annual innovative turnover (measured in quadrillion Euros) of all firms for column 1; annual innovative turnover of small firms for column 2, medium sized firms in column 3 and large sized firms in column 4					
Strands of theories:	(Period 1996-2010)	(1) Reduced correlation regression –with added time dummies – for all firm-sizes	(2) Reduced correlation regression –with added time dummies – for small firm-sizes	(3) Reduced correlation regression –with added time dummies – for medium firm-sizes	(4) Reduced correlation regression – with added time dummies – for large firm-sizes
	2010	-1.93e+02* [99.9]	-1.88e+01 [28.6]	-1.64e+01 [17.7]	-2.71e+02*** [103]
	Corr(μ_i, X_b)	-0.9323	-0.7626	-0.7972	-0.925
	F-test that all μ_I = 0; Prob > F	0.0001	0.0000	0.0016	0.0000
	R^2	Within =0.8388 between = 0.8769 overall = 0.8528	Within =0.6744 between = 0.4296 overall = 0.4875	Within =0.9227 between = 0.8675 overall = 0.8516	Within =0.8372 between = 0.7934 overall = 0.7640

Note: p-values: *** denoting significance at 1%, ** significance at 5% and * 10% significance. Std.errors in square brackets. Data sources are CIS and HRST databases.

Further differences specific to their firm sizes are listed below:

Innovation drivers for small-sized firms: For small firms, skilled human capital and linkages with academia remain the positive and significant drivers, with linkages to government institutions turning significant but negative. The continued significance of linkages with universities seems to support commercialization of research through start-ups and spin-offs. The negative but significant impact of linkages with governmental institutions is not easily explained and should be followed with research into specific data, to understand the mechanisms through which this driver influences small firms.

Innovation drivers for medium-sized firms: Medium firms show a similar positive significance of skilled human capital and linkages with academia. At the same time, there is the added negative significance of sourcing R&D externally. Contradicting this driver slightly is the positive significance of linkages to governmental institutions. The negative significance of sourcing R&D externally may be indicative of difficulties of bearing cost burden for medium sized firms, while the positive significance of collaborations with governmental institutions may capture the reverse – that of reduced cost of R&D when collaborating with a government institution, as reflected in German economy with the use of Fraunhofer institutes or in the US through use of extension services by SMEs. Further exploration with specific data would yield clearer insights into the mechanism of this drivers influence on innovation.

Innovation drivers for large-sized firms: Large firms are similar to small and medium sized firms in the positive significance of skilled human capital and linkages to academia. However, they show additional positive significance for public funding, as well as suppliers and negative significance for linkages to government institutions. The positive significance of public funding and supplier relationships appears to reflect that large firms use access to public funding and relationships of co-development with suppliers to aid their growth, while the negative association with government institutions reflects their lack of need to subcontract research externally, as large firms usually have significant R&D teams internally.

Innovation turnover size of SMEs: A last but perhaps not insignificant aspect is that SMEs innovative turnover is reasonably small compared to large firms, which appear to dictate a substantial portion of innovation measure. Looking at descriptive stats listed in table A1 in appendix, small-size firms mean innovative turnover is 11 % of total firm-sizes mean turnover and medium-size firms mean innovative turnover also only reaches 19%. Thus, while SMEs may be called the hidden growth champions of Germany, their share of innovation turnover is by virtue of their size limited. Hence in the long run, economies or indeed sectors may be inhibited in innovation as a consequence of a reduced share of presence of large firms.

In brief, some results for these SME drivers remain puzzling and do invite further research. It may reflect a step-wise process to building innovation, and that order and type of drivers may be important to build differing type of innovative economies. If this is indeed the case, then policy makers may need to account for these variations when designing specific policy incentives for SMEs. Following Cohen’s line of thinking that historical and case-study literature can provide rich insights to supplement interpretation of empirical analysis (Cohen W. , 2010), the following section explores the experiences in Germany to illustrate possible mechanisms through which drivers may influence innovation.

2.6 Germany, as a case in point, for the workings of these drivers

2.6.1 Possible mechanisms through which drivers may influence innovation

The choice of an apt case study to provide hypotheses for the workings of these drivers appears best suited to fall upon Germany. Not only is it the highest performing economy according to our innovation measure as listed in Table 2.8 below, it is also an acknowledged successful innovative economy according to other measures. As mentioned earlier, Germany ranks alongside Sweden, Denmark and Finland as an Innovation leader above other European economies according to the European Innovation Union scoreboard (EIS) (European Commission, 2013). Though Germany's particular type of innovation as a 'world supplier and equipper' of systems and production technology, integrating newer technologies in traditional industries, may not equate it to a globally innovative leader as US, which is considered a 'cutting edge technology leader' (Wessner, 2011), the economy could highlight workings relevant to other economies. Thus, acknowledging that varying economies may evolve diverse patters of innovation, nonetheless some useful insights may perhaps be gained by understanding the mechanisms through which these drivers exert influence on German innovation. Further cementing Germany's high performance in this study's innovation measure is also the remarkably consistent and high performance of Germany across the wider set of drivers[12]: skilled human capital, R&D investment, external sourcing of R&D, public funding for enterprises, firm linkages with academia, firm linkages with governmental organizations, firm linkages with suppliers, national market focus for enterprises and Enterprises focused on International markets. Drawing on previous research, the next few subsections offer a brief summary of the mechanisms through which these drivers may have worked to enhance innovation in Germany.

[12] The tables listing the top 10 economies for each driver are in Appendix section 1.3, tables A4 and A5

Table 2.8:Top 20 EU economies ranked in order for mean innovative turnover in absolute value (in billions of Euros) for all firm-sizes, covering the period 1996-2010

Countries	Mean Innovative turnover (all firms) – main innovation measure	Mean innovative turnover (for only small firms)	Mean innovative turnover (for only medium firms)
Germany	2.99	0.23	0.48
France	1.33	0.11	0.19
UK	1.00	0.13	0.23
Italy	0.92	0.16	0.21
Spain	0.63	0.08	0.12
Turkey	0.62	0.27	0.14
Netherlands	0.38	0.05	0.092
Belgium	0.29	0.048	0.067
Sweden	0.26	0.04	0.048
Poland	0.24	0.019	0.046
Austria	0.23	0.029	0.057
Ireland	0.18	0.02	0.055
Finland	0.16	0.015	0.025
Czech Repiblic	0.15	0.015	0.032
Norway	0.14	0.019	0.03
Denmark	0.13	0.023	0.031
Portugal	0.12	0.023	0.032
Hungary	0.08	0.006	0.013
Romania	0.062	0.006	0.011
Luxembourg	0.057	0.008	0.013

CIS database, Eurostat

Commercialization of research through: aligned skilled human capital and linkages to research Germany's ability to commercialize its research, a mechanism quite vital for innovation, appears to be facilitated by the presence of two drivers in particular. According to Soskice, the highly skilled and diverse German work force, a distinguishing feature of German economy, delivered by the strength of its diversified education sector, combined with the strong linkages between research and industry, appear to enhance Germany's ability to commercialize its research (Soskice, 1997). The linkages not only align government policy with industry interests and research institutions through industry-wide associations, they also help tailor skills and research to industry needs (Burton & Hansen, 1993). The heavy investment of industry in both the educational sector and the funding of specialized vocational programmes ensures continued alignment and channelling of the workforce in accordance with demands in industry (Soskice, 1997). From this very brief synopsis, it appears that these drivers work in tandem to stimulate innovation through encouraging the commercialization of research.

Longer-term decision-making and reduced funding gaps through: public funding: The long-term governance and public financing of firms, another quite distinct feature of German firms (Soskice, 1997), appears to be supported through one driver in particular – public funding. It seems that public funding influences this characteristic of the German industry, through encouraging longer-term decision-making, with the provision of long-term finance for firms over longer periods relative to commercial loans, (Buiguis & Sekkat, 2009). The provision of long-term loans for firms in Germany may be as long as 20 years, though typically 10 through the German state investment bank Kreditanstalt fur Wiederafbau (KfW) and regional Sparkassen banks (Buiguis & Sekkat, 2009). These longer periods of loans seem to allow firms greater time periods for recovery of profits, reducing short-term pressures and encouraging innovation of products which may have longer lead times. The availability of public finance not only influences innovation through encouraging these longer-term governance and decision-making structures, but may also impact the funding gap in R&D investment (Buiguis & Sekkat, 2009; Soskice, 1997). The presence of funding gaps in R&D, or rather the difficulties associated in financing R&D are well recognized and were raised early on by Schumpeter (1942), Nelson (1959) and Arrow (1962). R&D investment may be inadequate because of in ability of firms to appropriate knowledge or avoid leakages (Schumpeter, 1942; Nelson, 1959; Griliches, 1992). However, R&D investments could suffer due to the gap between private rate of return and external cost of capital (Schumpeter, 1942; Arrow, 1962; Hall & Rosenberg, 2010). In competitive markets, Hall and Lerner recognize that either of these aspects could combine to create a funding gap for R&D investments in firms (Hall & Rosenberg, 2010). A study in Finland was shown to demonstrate that public funding helped bridge funding-gaps for firms, avoiding constraints on growth and innovation investments (Hyytinen & Toivanen, 2005). Through having a provision of public financing for firms, minimizing some of these funding gaps and encouraging longer-term governance structures, public funding appears to provide a strong support for innovation in Germany.

Concentrated ownership and governance structures enhanced through public funding: Public funding appears to encourage another aspect in German industry, that of a more concentrated form of ownership structures. It appears that the long-term governance and financial planning in firms enhanced through public funding, seems also to be associated with a smaller group of stable shareholders in contrast to the Anglo-Saxon dispersed shareholder value model (Soskice, 1997). Buigues and Sekkat also associate the provision of long-term loans for firms in Germany, with longer-term planning and governance structures (Buiguis & Sekkat, 2009). Such ownership structures appear to forge relationships with banks, allowing easier monitoring by banks, enhancing longer-term financial agreements. Perhaps this concentrated form of ownership structures allied to longer-term financial agreements, augmented through public funding, is another mechanism through which public funding has worked to influence innovation in Germany.

Diffusion of knowledge and technology through inter-industry linkages: Not only do linkages enhance commercialization of research, they also appear to enhance diffusion of technology within industries. According to Burton and Hansen, Germany's industry-wide linkages are important to innovation, as they encourage the dissemination of new technologies by pooling of resources and allow industry as a whole to remain competitive (Burton & Hansen, 1993). Soskice suggests that these linkages between industry and research embed links, which encourages investment by firms and in turn enhances technology diffusion (Soskice, 97). This diffusion of knowledge allowing industry as a whole to remain competitive may be another mechanism through which these industry-wide linkages shape innovation in Germany.

Reduction of costs for firms through linkages with research: It appears that industry-wide linkages with external contract centres such as Germany's Fraunhofer institutes and research units, which in turn link up with university research, may additionally work on enhancing innovation in the economy through reducing the burden of funding for R&D for firms (Burton & Hansen, 1993; Martin & Scott, 2000). This may be similar to the provision in the US, where extension services have helped reduce R&D burden on small firms (Nelson & Rosenberg, 1993). This may be another aspect through which linkages with research may enhance innovation in Germany.

SMEs - growth champions for Germany: Though not considered a driver for this study, it appears that SMEs are an important aspect of growth and innovation in the German economy. According to Schutte, Germany's State Secretary for Education and Research, Germany's hidden growth champions are its SMEs, (Wessner, 2011). This focus on SMEs appears to be re-iterated in Germany's Federal government white paper on innovation policy, the High-tech Strategy 2020, where financing of innovation for SMEs receives high prominence (Rammer, 2011). The earlier analysis distinguishing the drivers for small and medium firm sizes throws some light on the varying drivers needed in an economy to stimulate wide-spectrum of firms.

Although this is a very brief synopsis of the conceivable mechanisms through which drivers may influence innovation in Germany, it does appear to offer insights on the possible workings of these drivers. Brief as it is, it does seem to validate Cohen's suggestions that historical and case study literature can be a source of hypotheses aiding the interpretation of empirical research. With these interpretations in mind, the next section summarizes the key findings of this study.

2.7 Conclusion

Let us return to the main queries of this research: What is the wider set of innovation drivers that may address the innovation process more completely and importantly, what is the order of these drivers, differentiating primary drivers from secondary? More so, how do these drives differ for different firm-sizes. This wider set of drivers is sourced from combining analysis of formal R&D process promoted by growth theories, alongside informal R&D linkages emphasized by national innovation systems. This study also sought to query whether current R&D policy targets, based on formal R&D process, are a sufficient response for driving innovation?

There were varied regressions undertaken, in order to seek answers to the above queries. A short summary of the key findings of the regressions are listed in Table 2.9 and thereafter, the outcomes are described in greater length.

Table 2.9:Summary table of overall key findings

Focus of analysis	The key drivers found significant
Primary innovation drivers – driving innovation levels – all firm sizes	• Skilled human capital • Access to public funding for enterprises with some form of state support • Linkages between industry and academia, supporting commercialization of research • Linkages between industry and suppliers, aligning research and upstream suppliers
Primary innovation drivers – driving innovation levels – small firm-size	• Skilled human capital • Linkages between industry and government institutions and laboratories (negative) • Linkages between industry and academia, supporting commercialization of research
Primary innovation drivers – driving innovation levels – medium firm-size	• Skilled human capital • Enterprises sourcing external R&D (negative) • Linkages between industry and government institutions and laboratories • Linkages between industry and academia, supporting commercialization of research
Primary innovation drivers – driving innovation levels – large firm-size	• Skilled human capital • Access to public funding for enterprises with some form of state support • Linkages between industry and academia, supporting commercialization of research • Linkages between industry and suppliers, aligning research and upstream suppliers
Secondary innovation drivers – driving innovation growth	• Skilled human capital (negative) • R&D investment (including acquisition of external knowledge and capital) • Enterprises sourcing external R&D • Linkages between industry and government institutions and laboratories (negative) • Linkages between industry and academia, supporting commercialization of research • Linkages between industry and suppliers, aligning research and upstream suppliers

<u>**Primary drivers versus secondary drivers**</u>:

The results from this empirical analysis covering 27 EU economies over the period 1996-2010 appear to negate the latter part of the query. Importantly, R&D investment is not found significant as a primary driver working on innovation levels. Instead the primary drivers found significant and positive for innovation are based on the informal R&D linkages emphasized in national innovation systems: industry linkages with academia, public funding of firms, industry collaborations with suppliers and importantly skilled human capital. These findings seem to provide partial support for Mokyr's historical analysis for building up innovation in an economy – importance of collaborations or rather linkages - though in this case not only restricted to academia, but instead extending to other institutions, firms and bodies, as is well acknowledged in national innovation systems. The mechanisms through which these drivers may influence innovation are drawn from a brief analysis on Germany and are touched upon briefly below.

Linkages with academia as a primary innovation driver: Basing our interpretation on previous research on Germany, it appears that the driver representing linkages with academia could exert influence on innovation through two facets: aligning education sector with industry to deliver skilled human capital in accordance with demands of industry; and facilitating commercialization of research through forging collaborations between entrepreneurs and educational sector, working beyond geographic proximity and helping spawns the creation of spin-offs and start-ups.

Public funding as a primary innovation driver: Public funding as a driver of innovation, as understood from the workings in German economy, may shape innovation through encouraging longer-term decision-making and reduction of funding gaps for firms, along with supporting more stable ownership structures. This driver would benefit from future research using firms birth demographic and ownership data, as started in Eurostat for CIS since 2008, as it would yield clearer insights into ownership patterns and governance structures.

Industry collaborations with suppliers as a primary innovation driver: The impact of linkages with suppliers on innovation as stressed by cluster theory, appears to work through enhancing incremental innovation through joint collaborations with suppliers.

Skilled human capital as a primary innovation driver: Skilled human capital, along with linkages to academia are probably the two most robust drivers for innovation, affirming the central role of skilled human capital in innovation, working in tandem with alignments of industry with academia. The importance of a diversified education sector, including the offering of vocational programmes to help deliver the skilled work force is highlighted through German analysis. This delivery of skilled human capital in line with the needs of industry seems too encourage investment from industry into educational sector. in Germany. Mayhap this alignment in educational sector across economies, could thus not only fine-tune the training of the skilled human capital, but perhaps even provide an alternative source of funding for institutions.

Lack of significance of R&D investment as a primary innovation driver: The absence of significance for R&D investment as a primary driver on innovation levels was surprising and unexpected. While this result invites further research specially into drivers of innovation growth, there are certain aspects evident in the data, which may explain this insignificance. Firstly, R&D investment is recognized in practice to be quite a stable figure in firms (Hall, Mairesse, & Mohnen, 2010, p. 16), only changing gradually over time periods. Secondly, it appears that economies most effectively using this driver to deliver innovation do not turn out to be the most innovative of economies. This is evident in the lack of correlation of highest proportional ratios of R&D investment to highest innovation turnovers. Seeming to signify that presence of other drivers in an economy, working in tandem may deliver a total innovation level higher than that of this individual driver. Thirdly, and perhaps more significantly, R&D investment appears significant as a secondary driver when regressed on innovation growth, thus validating the difference between secondary drivers from primary drivers for a process. This innovation growth regression seems to confirm that secondary drivers, such as R&D investment, are needed to grow innovation after primary drivers have laid the foundation to create innovation levels. This result also invites further research into the wider set of innovation growth drivers itself.

Accommodating and indeed understanding this differentiation of both primary and secondary drivers may be an important insight gained for tailoring effective innovation.

This also appears to support previous findings that innovation growth may initially diverge from productivity growth (Tunzelmann G. V., 2000), thus growth drivers may differ somewhat from innovation drivers in initial stages of technology generation. Further reiterating the need for policymakers to acknowledge this differentiation and ensure that policies target both innovation drivers as well as growth drivers in the long run.

Lack of significance for globalization as an Innovation driver: Globalization is also not found significant as a driver, nor is the driver representing home markets focus found significant. The absence of both these market drivers on innovation may reflect that the focus on markets may follow innovation, when the product may determine the choice of markets and not the other way around. This would again imply that time periods necessary for technology maturing and diffusion, as also referred to by Tunzelmann (Tunzelmann G. V., 2000), may explain these differences between drivers of growth from drivers of innovation.

Differences in innovation drivers for firm-sizes:

Innovation drivers for small-sized firms: For small firms, skilled human capital and linkages with academia were found positive and significant drivers, with linkages to government institutions surprisingly significant but negative. However, linkages with universities continues to be found significant and positive, seeming to support commercialization of research through start-ups and spin-offs. The negative but significant impact of linkages with governmental institutions is not easily explained and should be followed with research into specific data, to understand the mechanisms through which this driver influences small firms.

Innovation drivers for medium-sized firms: Medium firms similarly found skilled human capital and linkages with academia positive and significant. However, external sourcing of R&D was found negative. Contradicting this driver slightly is the positive significance of linkages to governmental institutions. The negative significance of sourcing R&D externally may be indicative of difficulties of bearing cost burden for medium sized firms, while the positive significance of collaborations with governmental institutions may capture the reverse – that of reduced cost of R&D when collaborating with a government institution, as reflected in German economy with the use of Fraunhofer institutes or in the US through use of extension services by SMEs. Further exploration with specific data would yield clearer insights into the mechanism of this drivers influence on innovation.

Innovation drivers for large-sized firms: Similar to small and medium sized firms, large firm analysis found skilled human capital and linkages to academia positive and significant. However, they show additional positive significance for public funding as well as linkages to suppliers and negative significance for linkages to government institutions. The positive significance of public funding and supplier relationships appears to reflect that large firms use access to public funding and relationships of co-development with suppliers to aid their growth, while the negative association with government institutions could reflect their lack of need to subcontract research externally, as large firms usually have significant R&D teams internally.

Firm eco-sphere for innovation*:*

Importance of large firm presence for innovation: A last but perhaps not insignificant aspect is that large firms appear to dictate a substantial portion of innovation measure. While SMEs may be called the hidden growth champions of Germany, their share of innovation turnover is by virtue of their size limited. Hence in the long run, economies or indeed sectors may be inhibited in innovation as a consequence of a reduced share of presence of large firms.

German insights:

The brief analysis of Germany helped offer insights into the mechanisms through which these wider sets of drivers may influence innovation: commercialization of research; alignment of industry, academia and government policy; and encouragement of longer-term decision-making, along with the reduction of funding gaps. Apart from offering insights into the mechanisms through which these drivers exert influence on innovation, Germany also shows that the use of a wider tool kit of innovation drivers may allow different drivers to drive different segments. It that is indeed the case, then policy makers in other economies may enhance the delivery of innovation across a range of firms sizes, through setting up structures and regulations that encourage the creation of this wider mix of drivers in economies.

Thus, by no means complete and with some results remaining puzzling and inviting further research, this wider analysis of drivers highlights the importance of increasing the toolkit to analyse influences on innovation and paves the way for further research into understanding the mechanisms through which these drivers shape innovation. Germany's consistent high usage of these other innovation drivers provides some affirmation of this wider tool kit of innovation drivers. Perhaps, the most important message is that no driver in isolation may be as effective compared to using a mix of drivers, while distinguishing primary drivers from secondary drivers enables policy tools to effectively target required outcome. If the results of this analysis are indeed valid, then it appears that innovation may be increased in economies without expanding capital investment – through just widening the toolkit to incorporate the primary drivers.

Chapter 3 Are firm-size structures important for Productivity? - An adapted Lewis model to draw firm-sizes into the arena of productivity analysis

3.1 Abstract

UK labour productivity levels have lagged well below US, Germany and France since the 70's, something often cited as a productivity conundrum for the economy (FT, 2016). This study explores whether deeper determinants may explain productivity levels. In particular, this chapter explores the structural compositions of the economy, which may influence productivity. Using an adaptation of the economic development framework, the Lewis model, this study proposes that country level labour productivity may be driven structurally by the movement of resources from smaller firm sizes to larger firm-size structures. To enable this analysis, a new database is built up at sector level for the 32 European economies between 2000-2012. The contribution of firm-size to country productivity is measured through isolating classifications of small, medium and large firms, alongside control variables capturing growth theory drivers, globalization, credit conditions and monetary lending policies. Large firm sizes are indeed found to be the most significant structure for country labour productivity. These findings underscore the fact that focus on factors of production alone, be it firm investment or skills shortage, may not be sufficient to enable productivity improvements – understanding the firm-landscape composition may be as essential.

Additionally, this chapter examines whether sectoral composition of an economy can shape country labour productivity levels. The findings from sector composition analysis are less clear. Some sector productivities were found significant for country productivity, while revenue-size was found significant for some sectors. These results suggest that firm structures may not be an equally sensitive issue over all sectors.

3.2 Introduction

Office of National Statistics (ONS) analysis showed UK labour productivity to have grown by 0.9% for the second quarter in 2015 (ONS, 2015), though this decreased in 2016 to 0.4% (Harari, Briefing paper, n0 06492, 2017). While these figures indicate some recovery of productivity growth, productivity levels remain below the pre-financial 2008 crisis trend. According to ONS figures, productivity growth was indeed flat between Q3 2013 and Q2 2014. Bank of England (BoE), undertaking an analysis in 2014 into UK labour productivity, concluded that alongside cyclical factors, two persistent non-cyclical factors could perhaps better explain UK's lower labour productivity growth: reduced investment and impaired resource allocation (Barnett et al., 2014). While these figures are specific to UK productivity growth and productivity levels related to 2008 crisis, an equivalently if not more worrying aspect is that UK's productivity levels have lagged well below Germany, France and US since the '70's (Harari, Number 06492, 2016). Indeed, productivity levels and not only productivity growth, remains and has been a key focus of concern for advanced economies, but specially for UK.

The roots of the BoE productivity analysis lie in the long-advocated Lewis development model (Lewis, 1954), which emphasizes resource allocation as key to growth. This line of thought provides the theoretical grounding for the BoE analysis, which focuses on explaining constraints on factors of production influencing resource reallocation. These theories on factor constraints could be broadly grouped in two camps. The first one centres on distortions, which hinder capital investment flows and the consequent impact on skills shortage (Bannerjee & Duflo, 2005; Hsieh & Klenow, 2009). The second related camp targets the time lag or slow diffusion of technology as an explanation for slower resource reallocation (Tunzelmann, 2000; Klenow & RodriguezClare, 2005; Caselli & Feyrer, 2007). The core focus of both these camps, as reflected in the BoE analysis, remains on identifying constraints or distortions in credit and labour market - the removal or reduction of which could encourage resource reallocation. Notwithstanding, an analysis of constraints on resources without assessing the underlying structures that channel these resources, appears incomplete. Understanding the role structures play in determining productivity could perhaps be as significant in identifying the hindrances on productivity.

Gollin's review of the Lewis model (Gollin, 2014), proposes that productivity and not capital, as assumed by Lewis, may be the long run driver for growth (Gollin, 2014). Importantly, he attributes growth through productivity to be driven structurally, through the movement of resources to higher productive sectors. While Gollin focuses on the movement of resources between sectors as the means to raising productivity, there could perhaps be another equivalently important structural aspect governing higher productivity from resources – that of movement of resources across firm structures.

Why firm structures, instead of sectors? This draws on the linkage of productivity to innovation, where innovation is recognized as the long run driver of growth, through increasing productivity (Solow, 1956; Romer, 1990). The emphasis on firm structures in innovation is rooted in the theories promoted by one of the earliest innovation economists, Joseph Schumpeter, who drew attention to the structures prevalent in economy through which innovation is channelled. Schumpeter questioned which size of firm could best function as the principal engine of innovation, initially emphasizing the role of small firms (Schumpeter, 1934), later singling out the presence of large firms as critical to long run technological progress (Schumpeter, 1942). It would appear that firm structures play an important role in driving innovation. Given the intricate linkage of innovation with productivity and building upon Gollin's review, the question arises: Could lack of country level labour productivity be driven through hindrances of moving resources, not only across sectors as implied by Gollin's review of Lewis model – but also across firm structures? That is the key question this thesis aims to address.

This thesis develops this insight through offering a structural model for country level labour productivity, building upon Gollin's review of Lewis's model of growth, remodelling the resource movement across firm structures – not sectors, as in Gollin's work (Gollin, 2014). In other words, could a country's lack of productivity levels be hindered by constraints on moving resources to larger firm structures? A focus on importance of firm-size structures on country productivity, irrespective of firm productivity or sectors. To this end, the study assesses whether firm structures are significant for a country's labour productivity economy, and if so, which firm-size structures. Identifying the firm-size structures most significant for labour productivity, enables an assessment of the influence of expansion or reduction of that firm-size structure on productivity levels of an economy. In particular, it may offer clues to the productivity puzzle in the UK, whose productivity levels remain towards the bottom of the G7 league table (Financial Times, 2018). In essence, this study aims to show the linkage between firm structures and country productivity, offering a theoretical framework through the further adaptation of the Lewis model.

To demonstrate this linkage, this study focuses on how differing firm-sizes may influence country labour productivity. Firms are classified into firm-size groupings based on size of average revenue (turnover) to enable initial assessment of importance of firm size on an economy – irrespective of the firm productivities. Later, firm sizes are also assessed through average firm productivity's influence on country productivity. This differentiation is to enable insights on whether just sheer presence of particular firm sizes is important or not for an economy, irrespective of whether those firm-sizes are productive or not. Reason for this focus on firm size, irrespective of firm productivity, is to recognize that certain firm sizes may be lifting country productivity through other channels such as best practices, R&D spill-overs, skills training – and as such may be valuable for an economy in their own right, irrespective of their productivity.

Nonetheless, firm productivity is of importance, which though assessed also in this study, has already been documented at varied aggregate levels previously by a valuable body of research. The seminal paper linking firm productivity to aggregated sector productivity in this field was by Bailey et al. (1992), who examined the empirical linkage of plant productivity to sector level aggregate productivity. Examining 23 manufacturing sectors, they found an econometric positive correlation between productivity of plants and sector productivity, thus, establishing an empirical base line linking productivity of plants with an aggregated sector productivity. Developing this theme further, further research has shown that reallocation of resources from lower to higher productive firms largely influenced sector-level labour productivity growth (Olley & Pakes, 1996; Griliches & Regev, 1995). Following a slightly different theme, using cross-country data Bartelsman et al. (2013) examine entry/exits of firms impact on country labour productivity and find that country-level labour productivity can to a large extent be explained by within-firm productivities. These studies provide significant evidence underscoring the relationship between firm productivity and either sector-level productivity or country-level productivity, yet there appears to be far less research on the link between firm size and country level labour productivity. The only previous study on this topic is by Leung et al. (2008), who find that the reallocation of labour towards larger firm structures appears to have a positive correlation on country level productivity Building upon this theme using econometric analysis, this thesis seeks to examine the influence of the varied firm-size structures on country-level labour productivity for 32 European economies between 2000-2012. More so, it aims to offer an explanation for the mechanisms by which firm sizes may impact on country labour productivity, through an adapted form of the Lewis model.

The adapted Lewis model, introducing Schumpeterian innovation concepts of firm structures, essentially explains the impact of varied firm size landscapes on the labour productivity of an economy. By necessity, models are simplifications in order to clarify a mechanism. Thus, to enable this study to focus on a model to highlight the relationship between firm-size and country labour productivity, it is not possible to include all other heterogenous firm aspects well-acknowledged in industrial organizational literature. Hence, within these limitations and keeping view of the insights sought by this study, the question arises - does the data corroborate this adaptation of the Lewis model and do firm-size structures indeed dictate productivity for an economy?

The findings from this study support the proposed adaptation of the Lewis model, with some caveats. It would appear, based on average firm turnover shares, that only large firms' structures were found to impact country level productivity significantly and positively, with small and medium sized firm structures seeming to have a negative influence. More so, only large firm productivity was found robust and significant for country level productivity. This overlaps with recent research by ECB, which found that though small and medium sized firms (SMEs) employed nearly 70 percent of the workforce in the EU business economy in 2012; they generated only 60 percent of the value added (ECB, 2013). Further, if measured by number of firms, though SMEs accounted for 99.8 percent of the firms in the business economy, large firms comprising only 0.2 percent of the total, generated 40 percent of the value added

(Eurostat, 2012). That roughly translates to a factor 330 times higher value added per large firm compared to SMEs, indicating larger firms appear to have much higher productivity. However, it should be kept in context with the fact that despite lower productivity, SMEs are found to be an important source of employment and country growth (Beck et al., 2005). Similarly, both small and large firms were found critical for innovation (Bradley, 2014), bearing in mind that innovation is a critical element for long-term productivity. Keeping sight of the varied value of the different firm-size structures, it would appear that moving resources from SMEs over to larger firm structures for purposes of raising country level labour productivity, could be beneficial. That is essentially the main insight for the model.

In particular, interpreted in UK's case, this could be a problem, as on average the UK appears to have a declining large firm density trend since the 70's (Bradley, 2018). This would require policy makers to look beyond constraints on factors of production, looking to devise policies to increase or support large firm presence in the economy.

This study also examined sector influence on country productivity, aspiring to shed some insights on Gollin's view that moving resources to higher productivity sectors could help lift the country level productivity of an economy. However, findings in this area were more mixed. It appears that some sectors influence country level productivity through their productivity and others through sector size. Where sectors influence through size, it would appear that such sectors would benefit from presence of all three firm-sizes in those sectors. In contrast, those sectors influencing through productivity may benefit from a larger firm-size presence in those sectors. These findings add some detail to Gollin's interpretation of Lewis model, lending some clarification of the type of structures towards which to move resources in varied sectors. However, these implications would need further detailed corroboration through detailed research, to verify the validity of these implications.

The remainder of this chapter is as follows: the next section 3.3 addresses the theoretical framework and thereafter section 3.4 covers the relevant literature around the questions addressed by this study. Section 3.5 explains the data and methodology. Section 3.6 highlights the main results, concluding in section 3.7 with possible policy implications.

3.3 Theoretical Framework

This study offers insights into the structural drivers of productivity, based on adaptation of Lewis's development model for growth, as interpreted by Gollin (Gollin, 2014). Gollin suggested productivity was the long run driver of growth instead of capital, as proposed originally in Lewis's model (Lewis, 1954). Gollin based this interpretation on Lewis's original dual-sector model, attributing growth through productivity to be driven structurally through the movement of resources to higher productive sectors. This study builds further upon Lewis's model, but with two differences. Firstly, it aims to explain country level labour productivity, not country level growth. Secondly, it proposes that this productivity could be driven structurally, through the movement of resources across firm-structures, irrespective of sectors. The focus is on firm structures, small versus large, deriving from Schumpeterian concepts of innovation (Schumpeter, 1942; Schumpeter, 1934). It simplifies the firm structures into dual-structure concept of small and large, in order to explain the mechanism of shift of resources. Thus, this study not only proposes that country level labour productivity is driven structurally by the movement of resources across firm structures, it proposes a particular direction – movement from smaller firm sizes to larger firm-size structures.

This direction of movement from smaller firm-size structures to larger firm-size structures to enhance labour productivity is based to an extent on simplification of previous research on firm structures and related firm productivities. While research has widely found large firm-size structures to have higher firm productivity (Lucas, 1978; Snodgrass & Biggs, 1996; Van Biesebroeck, 2005; Van Ark & Monnikhof, 1996), there is caution that this could be sector dependent or indeed dictated by various other aspects, including management practices (Bartelsman et al., 2013). Thus, keeping this caveat in mind, the model proposes a direction of resources towards larger firm-size structures for enhancing productivity, based on the assumption that larger firm-size structures are on average associated with higher productivities.

In turn, this movement of resources to larger firms, in effect more highly productive firms, is proposed to deliver higher country level labour productivity. In essence, this proposal is based on the key insights by earlier research that moving resources to higher productivity structures raises sector level labour productivity (Olley & Pakes, 1996; Griliches & Regev, 1996; Bailey et al., 1992). In this study, this same mechanism is proposed to translate to country level labour productivity as depicted in Figure 3.1. In effect, this study builds upon these various insights in literature and pulls them together, to offer an adapted-Lewis model for country level labour productivity.

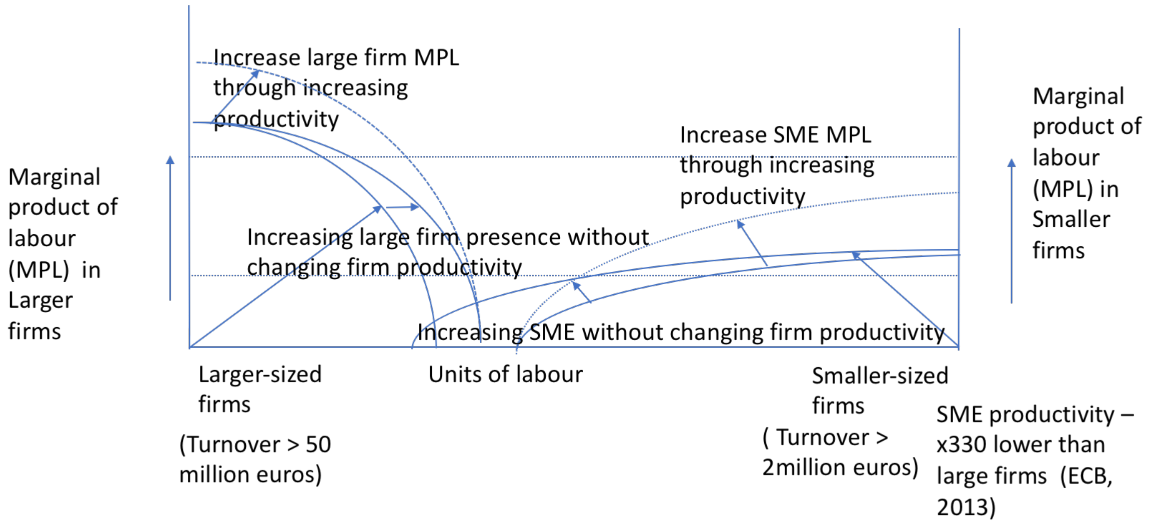

Figure 3.1 Adapted Lewis Model for Productivity, source (author)

This adapted Lewis model, based on simplification of the interrelationship between innovation and productivity, highlights the impact of firm structures on country level labour productivity. Combining various insights from above mentioned previous research, this model proposes that shift from smaller firm structures towards larger firms raises country level productivity - both through channels of firm productivity and firm revenue. The model is explained basically through representations of marginal product of labour (MPL) curves for small and large firms, with shifts in these MPL curves observed for their impact on country level labour productivity.

The proposed mechanism of shifting MPL of large firm rightward or leftward, whilst not shifting left hand corner of MPL curve, in essence represents a firm's capital expansion without productivity shift. On a country level, however, this MPL can be seen as representative of expansion or reduction in the share of large firm presence in an economy. This is however different from a firm productivity shift (due to introduction of a new technology/innovation or efficiency), in which case the entire MPL shifts outwards due to a firm productivity increase. Smaller firms are depicted on the right-hand side of the diagram with on average a much lower MPL than large firms. This follows a similar mechanism as explained for large firms, with a leftward shift of the MPL capturing expansion of the smaller firm-size presence in an economy, but a full outward-shift of the smaller-firm MPL only caused by a productivity increase. However, should the small firms struggle to scale up, as evidenced in UK (Bradley, 2018), then the smaller MPL may not scale up outwards as firms do not appear to last the distance to grow.

The study assesses the data to verify the validity of this adapted Lewis model for productivity, thus assessing the questions of whether firm structures are indeed significant for a country's labour productivity economy, and if so, which firm-size structures? To assess if large or small firm-size structures are indeed relevant for country level productivity irrespective of their firm productivities, firm-size structures are assessed for their influence both through their average turnover share and firm productivity, essentially, allowing a dual-check of relevance of firm-size structures. It uses evidence to identify the firm-size structures most significant for country labour productivity and thereby, examines the validity of the proposed adapted Lewis model. Importantly, if this model is found valid –the expansion or reduction of particular firm-size structures in an economy could be then found to offer clues to the longer-term productivity levels of an economy. This itself could offer vital clues for longer term productivity challenges, for example in the UK economy.

The study examines the evidence through a panel database on firm-sizes and country productivity at sector level for 32 EU economies between 2000-2012. It includes firm size classification (OECD, 2005) of small, medium and large firms at sector level for core innovative sectors spanning manufacturing and services, using both average firm turnover and average firm productivity to assess importance of firm structures (EUROSTAT CIS, 2013).

The findings of this study appear to validate the proposed adapted Lewis model. Large firm structures are indeed found to be an essential positive force on the country level labour productivity. In fact, only large firm turnover share and large firm productivity were found significant and positive. In contrast, firm turnover shares of small and medium sized firms were found to influence country level labour productivity negatively, thus, underscoring the importance of large firm presence in an economy for country level productivity and affirming that a shift of resources towards larger firm structures, which essentially could shift the MPL-curve of large firms rightwards (expansion of firms) or fully outwards (productivity increase for new frontier technology firms), would raise country level productivity. Vice versa, a reduction in large firm presence in an economy would entail a shift of resources away from large firms towards smaller firms, resulting in a lowering of country level labour productivity. Thus, the research emphasizes the importance of including an understanding of firm-structures, alongside constraints on factors of production, into the arena of productivity analysis of an economy.

3.4 Existing Literature.

As noted earlier, excepting that of Leung et al. (2008), previous research is mainly silent on the examination of firm sizes and their influence on country labour productivity. Leung et al. (2008) examine the influence of reallocation of resources towards large firms on country labour productivity, offering insights of the mechanism that increasing employment in large firms appears to raise country level productivity. This study takes this a step further and investigates initially how the varied firm size structures influence country level labour productivity, irrespective of firm productivities, thereafter, also assessing influence of firm productivities on country productivity, for which there is a valuable body of prior research.

There are nonetheless valuable insights in previous literature on the importance of firm-structures, even if they don't specifically relate it to country productivity. This section reviews the existing literature on the relationship of firm-structures, firm productivity, country productivity and growth.

There is a relatively wide range of studies that have investigated the link between firm sizes and firm productivities. Partially inspired by Schumpeter's differing claims of firm-sizes for innovation, Lucas researched movements in firm productivity due to employment shifts of highly skilled managers as a consequence of rising wages and found an association in the US between large firms and higher firm productivity (Lucas R. J., 1978). Lucas, though, indicated this could possibly vary in accordance with the level of advancement of economies, with perhaps smaller and medium sized firms having greater importance for developing economies. On the other hand, Snodgras and Biggs, assessing a wide range of parameters on the role of SMEs in India and newly industrializing economies of the far east, research revealed that on aggregate, firm labour productivity appeared to be positively correlated with firm-size (Snodgrass & Biggs, 1996). They cautioned that this could be sector dependent, as a few sectors showed that SMEs had comparable or higher productivity. Supporting Lucas's earlier findings while examining advanced economies, Van Ark and Monnikhof having constructed data sets based on three manufacturing sets in advanced economies between the 60's and late 80's, reported that higher firm productivity appeared correlated with larger firm sizes (Van Ark & Monnikhof, 1996). Assessing developing economies, Van Biesebroek relating firm-size to firm productivity for manufacturing sectors across some African economies, showed that firm-size was positively correlated with both firm growth and firm productivity (Van Biesebroeck, 2005). This supports earlier findings by Biggs et al.(1996) examining manufacturing sectors in African economies, where large firms were found to have higher labour productivities. With some variation for developing economies, this set of research overall seems to support views that higher firm productivity is closely associated with larger firm sizes in advanced economies and some developing economies.

As mentioned earlier, there are valuable studies linking firm productivity with aggregate productivity. The seminal paper linking firm productivity to aggregated sector productivity in this field was by Bailey et al. (1992), who examined the empirical linkage of plant productivity to sector level aggregate productivity. Examining 23 manufacturing sectors, they found a positive econometric correlation between productivity of plants and sector productivity, thus, establishing an empirical base line linking productivity of plants with an aggregated sector productivity. Developing this theme further, further research has shown that reallocation of resources from lower to higher productive firms largely influenced sector-level labour productivity growth (Olley & Pakes, 1996;

Griliches & Regev, 1995). With a slightly different focus, Bartelsman et al. (2013), use firm productivity gaps to capture resource misallocation that explain cross country productivity differences across five advanced and three eastern European economies. These studies provide valuable insights linking firm productivities to aggregate productivity, finding shifts towards higher productive firms reflected in raised aggregate productivity measures.

Furthermore, there is also research assessing total factor productivity (TFP) and its impact on country level productivity. Using TFP to capture some resource misallocation caused by constraints to physical and human capital, a positive association was found between lower TFP and lower country productivity (Klenow & Rodriguez-Clare, 1997). This association of TFP with country labour productivity is supported by findings from Hall & Jones, using growth accounting on extended human capital Solow models to compute TFP (Hall & Jones, 1999). Caselli evaluating country income and TFP through development accounting finds cross-country incomes are not sufficiently explained by factors of production and questions if departure from Cobb-Douglas function may aid future research (Caselli, 2005). As this study does not use growth accounting or TFP to capture impact of technology, instead using firm structures to capture innovative activity, this association is of less direct relevance here.

On another related strand, there is some research assessing firm-size, classified by employment share, and its effect on aggregate country growth. . Historically, there is evidence for the vital role of SMEs on country growth for some developing economies. Indeed SMEs played a critical role in Japan's industrialization after the Meiji revolution and experience of emerging economies like Taiwan seemed to further strengthen these convictions (Snodgrass & Biggs, 1996). However Snodgrass and Biggs(1996) also emphasized that was not the experience of most second tier industrializing European economies, nor of Korea as an emerging economy, showing that variable firm sizes seemed to have suited differing economies to deliver growth. Albeit, the role of SMEs in delivering growth in emerging economies is also supported by the World Bank (World Bank, 2002; World Bank 2004). While recent research by Beck et al. (2005) further supports the correlation of SMEs with growth, they find no empirical support for a causal relationship. Beck et al. (ibid) use national characteristics as instrumental variables to assess this causal relationship, cautioning that this is only indicative of the lack of empirical support for the significance of this relationship, not evidence to support the absence of a causal relationship; which leaves the issue of firm sizes open for further evaluation. Excluding causality, it appears there is quite a significant body of evidence supporting the association of smaller and medium sized firms with country growth. While country growth differs from country productivity, the focus for this current study, nonetheless this strand of research underlines the importance of evaluating all three firm sizes carefully for their impact on country level labour productivity.

This study thus hopes to complement this body of research on firm-structures, through assessing how presence of varied firm-size structures influences labour productivity at country level. Using these insights, it assesses the proposed adapted Lewis model offering a mechanism through which firm-sizes could impact country level productivity. This is followed by an examination of sector sizes and sector productivities, which may shed insights on the differing types of firm-structures needed in sectors for country productivity. The description of the data and methodology follows in the next section.

3.5 Data and Methodology

3.5.1 Measures of Firm-size structures and productivity, as well as Sector share and Sector productivity

To ensure the collection of a comprehensive set of firm size measures, the study uses a newly built database comprising of two types of sector level survey data and one set of country level data. The sector level firm data is sourced from bi-annual community innovation survey data (CIS) for 32 European economies between 2000-2012 (EUROSTAT CIS, 2013) and Structural Business survey data (SBS) between 2008-2012 (EUROSTAT SBS, 2015). Although CIS data covers the period of 2000-2012, as there is often missing sector data for 2002, that year is dropped from the regression analysis. The corresponding country specific control variables between 2000-2012 are drawn from World Bank Development Indicators (WDI) accessed from the World DataBank (World Bank, n.d.).

Using these datasets, a panel database is built, incorporating all firm-sizes, including SMEs and large firms, for 32 European economies over the period of

2000-2012. Moving away from an analysis into either just manufacturing or services sectors, it instead incorporates core innovative sectors within countries, as defined by Eurostat (2013). This includes both manufacturing and service sectors, permitting the study to engage with all sectors contributing to innovation, the key to long run growth and productivity. This panel database has essentially 5 layers of classifications: year, country, sector, type of firm (innovative, non-innovative) and firm size (small, medium and large). The data for sectors is available at aggregated core innovative sector level, sub-aggregated level and detailed sector level.

3.5.1.1 Firm classification and Firm turnover:

To classify firm-size structures influence on the productivity of an economy, this study separates firm turnover and firm productivity at sector level into three OECD-defined groups: small, medium and large firm size class structures (EUROSTAT CIS, 2013; OECD, 2005), with small featuring 0-49 employees, medium between 50-249 employees and large with 250+ employees. Firm turnover is the average turnover of small/medium/large firms, measured by aggregated turnover at sector level for each size class. The firm-size measure is in fact a dynamic measure, as it captures the net firm data bi-annually, including entries and exits of firms at sector level. Though the survey data provides access to invaluable aspects of firm data, it has the associated shortcoming of survey data and thus limited in its coverage of the entire economy. Eurostat attempts to ensure that the population cover is representative of the economy and by measuring both innovative and non-innovative firms, tries to ensure a balanced snapshot of the economy at sector level (EUROSTAT CIS, 2013; EUROSTAT SBS, 2015). Its unique strength lies in its provision of international comparability, an aspect that has seriously hindered previous cross-country studies, opening up the possibility of panel data studies.

3.5.1.2 Firm productivity, Sector productivity and Sector share:

Firm size structures are captured by the associated turnover related to firm-size classes: small, medium and large for the period of 2000-2012. Lacking gross value added per employee data in CIS, the productivity of firm sizes is captured by turnover per employee for the time period 2000-2012, critically with CIS data providing related firm-size information. The study also uses SBS data, which provides accurate productivity measures of gross value added per employee data at sector level, however as it for shorter time period of 2008-2012 and lacks firm-size information, and opportunities for corroboration are limited. Furthermore, as varying sectors will have missing data across the 32 economies for different year groups, the number of actual panel years per sector employed in the analysis is reduced accordingly, with the year 2002 often dropped due to missing sector data. Another limitation of firm size structure data is that it is only available at approximately 10 aggregated sector levels, restricting firm size structures analysis to that level. However detailed sector level turnover and turnover per employee is available, albeit without firm-size classification, allowing detailed sector share and sector productivity analysis. Sector share is defined as the aggregated turnover for firms in that sector, while sector productivity is measured as turnover per employee aggregated at sector level.

3.5.1.3 Level of aggregation of sectors:

As this study focuses on firm-size structures, it is restricted to varying depths of sector level for the regression due to restrictions imposed by availability of data. CIS survey data is the only source of firm-size structures classification data, providing firm-size information either at a fully aggregated sector level defined as 'Innovation Core activities', encompassing all innovative sectors or at sub-aggregated levels of sector aggregation. The 9 sub-aggregated innovative sectors providing firm-size structure classification are as follows: Industry (except construction); Information and communication; Financial and insurance activities; Architectural and engineering activities; technical testing and analysis; scientific research and development; advertising and market research; Electricity, gas, steam and air conditioning supply; manufacturing; Water supply; sewerage, waste management and remediation activities; Transport, storage and communication; Wholesale trade, except of motor vehicles and motorcycles. The firm-size structures and firm-size productivity regressions are of necessity performed at this sub-aggregated level. In contrast, as no firm-size classification is required, the detailed sectors comprising about 60 innovative sectors are used during the examination of sector share and sector productivity influence on country productivity.

The width of sectors chosen for this analysis also deserves some clarification. As innovation over the last few decades has moved away from pure manufacturing and is increasingly wrapped up in the software and design in the services sector, the study uses OECD's grouping of sectors, defined as core innovative sectors (OECD, Innovation Manual, 2005). Though this grouping or classification has thus far not been used widely in studies, the author of this study previously used this grouping in a study on innovation drivers (Bradley, What are the drivers of Innovation and does policy target them?, 2014), and again uses this grouping for this study as it enables to focus the examination on sectors most relevant to innovation across manufacturing and service sectors.

3.5.2 **Measures of Country productivity, alongside country specific control variables**

As the study examines the relationship of firm-size structures on country level productivity, the dependent variable is country level labour productivity measured by Gross Value Added per employee, sourced from WDI. Following this regression, the study assesses the impact of sector level turnover and sector productivity on country productivity, the dependent variable for country level labour productivity again being measured by Gross Value Added per employee.

When assessing impact of sector productivity on country productivity, the sector productivity variable of interest is initially measured by turnover per employee if using CIS data, over the period 2000-2012. However, this is later followed up by an alternative and more accurate measure of sector productivity as measured by Gross value added per employee from SBS data, albeit with a shortened time period of analysis from 2008-2012 due to data availability restrictions. On the other hand, sector turnover is measured only by the size of turnover of corresponding sector each second year over the period 2000-2012.

The level of analysis for firm-size structures is restricted by the availability of firm-size data only at particular sub-aggregated sector level. The sub-aggregated sectors are detailed in the regression. However, regressions analysing sector turnover and sector productivity impact on country productivity are independent of firm-size structures, and thus are implemented at detailed sector level.

To ensure that the regression only captures the firm structure effects, we separately control for country specific growth drivers which influence productivity as per Solow model (Solow,1956): capital formation and labour force participation rates; as well as globalisation growth impact captured by export trade; last but not least, also controlling for differing monetary policy growth impacts through country specific deposit rates alongside lending rates influencing variable credit conditions. Though sourced from World DataBank, they are a mixture of National statistics data, as well as IMF, IFC and ILO collected data statistics (World Bank, n.d.). As the CIS data is only available biannually, the country specific measures are accordingly drawn for a similar period and frequency from World databank. The choice of these control variables is defined in greater length in the sub-section 3.5.3.1

To provide a snapshot of the movement of economies between 2000-2012, Table 3.1 provides a listing of the country labour productivities (derived from WDI, World DataBank) analyzed in this study, initially in 2000 and then 2012.

Table 3.1 GVA per employee (K Euros per Empl) of the 32 economies in this study at 2000 and 2012, derived from WDI indicators sourced from World DataBank

Country	GVA per employee (2000) (K Euros per Employee)	GVA per employee (2012) (K Euros per Employee)
Austria	43.9	82.7
Belgium	47.9	92.3
Bulgaria	3.8	15.04
Croatia	-	33.3
Cyprus	19.3	40.9
Czech republic	11.2	36.8
Denmark	47.9	96.2
Estonia	8.1	30.6
Finland	39.8	75.4
France	45.6	81.2
Germany	45.5	78.6
Greece	26.97	55.97
Hungary	8.97	24
Ireland	46.75	98.77
Italy	47.4	80.5
Latvia	8.7	27.3
Lithuania		29.3
Luxembourg	94.97	193.4
Malta	22.04	-
Netherlands	42.6	81.3
Norway	53.7	148.8
Poland	9.5	26.04
Portugal	19.5	40.1
Romania	2.8	16.4
Serbia	-	15.1
Slovakia	11.2	34.9
Slovenia	18.9	42.1
Spain	32.7	66.4
Sweden	43.8	87.1
Turkey	9.1	23.7
United Kingdom	44.7	71.2
United States (Reference only, not analyzed in regressions)	56.9	92.8

Note: Whist care has to be taken interpreting these nominal values, Luxembourg had the highest labour productivity in 2000 and yet again in 2012. In contrast Romania had the lowest GVA/employee in 2000, yet in 2012 Bulgaria appears to have even lower labour productivity than Romania. Excluding Canada and Japan, the G7 economies listed here vary in their labour productivities with UK with the lowest productivity level, France and Germany virtually equivalent, then Italy and US the highest in 2000. This remains similar in 2012 for UK being lowest and US highest. Inbetween it changes somewhat with France increasing its productivity above Germany, as well as Italy. Though US continues to remain slightly less than half of Luxembourg. Norway stands out in increasing its productivity nearly three-fold from 2000 to 2012.

3.5.3 **Methodology**

3.5.3.1 Country level Productivity and Firm-size Regressions

Measurement of productivity is inherently derived from growth models. Either neoclassical growth models that estimate income of an economy based on a functional form relating human and physical capital with technology exogenous to model (Solow, 1956; Mankiew, Romer, & Weil, 1992). Or endogenous growth models can be used to measure income of an economy, with yet another functional form relating capital, both human and physical, to some measure of technology endogenous to model (Arrow, 1962; Romer, 1990). While labour productvity has many definitions, the most commonly used measure of labour productvity is income of an economy per employee or more specifically income per hour worked (OECD, 2001). This study, due to data restrictions, uses income per employee, as measured by gross value added (GVA) per employee to estimate country labour productvity.

Purpose of regression: As explained earlier, this study assesses the data, to verify the validity of this adapted Lewis model for this measure of country labour productivity, in other words, assessing whether firm structures are indeed significant for a country's labour productivity economy, and if so, which firm-size structures? To initially examine whether large or small firm-size structures are indeed relevant for country level productivity irrespective of their firm productivities, firm-size structures are assessed for their influence both through average turnover share impact on country labour productivity. Thereafter, average firm productivity of the varied firm size structures is assessed for its impact on country labour productivity, essentially, allowing a dual-check of relevance of firm-size structures. The findings are then used to identify the firm-size structures most significant for country labour productivity and thereby, to assess the validity of the proposed adapted Lewis model.

Choice of control variables: Assesment of the validity of the proposed adapted Lewis model, requires examining the impact of the varied firm-sizes on country labour productvity. To ensure the regression captures the correct impact of firm size structures on country productivity, the regression controls for basic drivers of growth, globalization and monetary policy. Growth drivers are represented by human and physical capital, where human capital is captured by employment labour force particpation rate, in order to also assess Becker and Gordon's findings that productvity and employment may move in opposite directions (Gordon & Becker, 2008). Physical capital is proxied by the gross capital formation at country level. Along with these basic elements of productvity analysis, the empirical analysis controls for country specific moneatry policy and financial lending rates, which could influence credit constraints impacting labour productvity. Furthermore, it controls for export, as that aspect of country-specific trade policy may also influence labour productivity. Lastly, time dummies are included to capture any anuual shocks across the panel.

Regression equation: The regression equation used to evaluate the relationship between country productivity and firm-size structures, using panel data over the period 2000-2012 for the 32 European economies, can be defined as follows:

$$y_{ij}= \alpha_1 GCF_{it} + \alpha_2 EMP_{it} + \alpha_3 EXP_{it} + \alpha_4 LEND_{it} + \alpha_5 DEP_{it} + \beta_1 SmallFirm_{ijt} + \beta_2 MedFirm_{ijt} + \beta_3 LgeFirm_{ijt} + \eta \text{year dummies} + \varepsilon \quad (1)$$

where y is the country-level labour productivity measured by GVA per employee, GCF is the gross capital formation at country level, EMP is the country's labour force participation rate measured as Employment to population % ratios, EXP is the country specific export as a % ratio to GDP as proxy for government policy, LEND is the lending interest rate capturing credit constraint conditions, DEP is the deposit interest rate to proxy monetary policy. Year dummies are included to capture any time shocks and ε represents error term. The subscripts in regression following standard notation of 'i' representing country variation, subscript 'j' sector variation and subscript 't' denoting year variation. GCF and EMP chiefly represent country specific productivity factors influencing physical and human capital accumulation. This regression evaluates at the aggregated and sub-aggregated innovative sector levels, as firm-size information is not available at detailed sector level. At these two levels of aggregation, initially the regression examines influence of average turnover of the firm size structures: small, medium and large size class. Thereafter, the regression evaluates these three firm-size structures through average firm-turnover share (firm intensities), with average turnover of each firm-size class as a proportion of total turnover. Lacking data on actual firm numbers, the share in revenue or turnover was proxied to represent firm-intensities. Both regressions offer differing, but equally important insights. Essentially, firm turnover reveals how the average revenue of the small, medium and large firms impacts on country productivity, while average turnover-share examines how the proportions of particular firm-size classes present in an economy can influence country productivity.

As described in the adapted Lewis model, firm structures influence country level productivity either through channels of expanding turnover or through increasing firm productivity. To examine the validity of the proposed adapted Lewis model, firm-size structures are assessed thus additionally through channels of firm productivity as well as turnover. The equation for the regression adding the influence of firm-size productivities on country labour productivity can be listed as follows:

$y_{ij}= \alpha_1 GCF_{it} + \alpha_2 EMP_{it} + \alpha_3 EXP_{it} + \alpha_4 LEND_{it} + \alpha_5 DEP_{it} + \beta_1 SmallFirm_{ijt} + \beta_2 MedFirm_{ijt} + \beta_3 LgeFirm_{ijt} + \gamma_1 SmallFirmProd_{ijt} + \gamma_2 MedFirmProd_{ijt} + \gamma_3 LgeFirmProd_{ijt} + \eta year\ dummies + \varepsilon$ (2)

where SmallFirmProd, MedFirmProd and LgeFirmProd are represented by turnover per employee.

In both these regressions, the coefficient β indicates the ratio of country productivity to firm-size turnover, according to classification of small, medium and large size class. As the β coefficient is the slope response of a unit change of a particular class of firm-size turnover, a higher value of β implies a higher impact on country productivity for a unit change of the associated firm-size turnover.

Similarly, the coefficient γ represents the ratio of country productivity to firm-size productivity, classified again into small, medium and large size grouping. This coefficient γ is the slope response on country productivity for a unit change in firm-size productivity. Again, a higher γ value is suggestive of a greater productivity of that firm-size class, with the sign and significance of the coefficient indicating whether there is any relationship between firm-size productivity of that class and country productivity. A positive sign implies a favourable influence, while a negative sign an adverse effect.

3.5.3.2 Country level Productivity and Sector Regressions

This study also examines the relationship of sector size and sector productivity on country level productivity. As firm-size turnovers determine sector size and firm-size productivities in turn shape sector productivities, this examination in effect allows an alternative cross-check of firm-size influence on country productivity. It offers the added advantage of a lower level of evaluation at detailed sector level, as no firm-size classification is required, increasing the robustness of the regression.

Each sector size is measured by turnover of the corresponding sector for each biannual year, over the period 2000-2012. On the other hand, sector productivity is measured by turnover per employee using CIS data over a panel data period of 2000-2012 biannually. When measuring sector productivity by GVA per employee using SBS data, the period of observation is restricted to 2008-2012. Using this more accurate measure of sector productivity, albeit restricted to a shorter time period, offers a robustness check to the regression.

It is to be noted that as there is lack of firm-size classification, sectors can only be assessed for their relationship of sector size or productivity on country productivity. Not for the makeup of firm-size classes within those sectors on country productivity. The following regression is used:

$$y_{ij} = \alpha_1 GCF_{ij} + \alpha_2 EMP_{ij} + \alpha_3 EXP_{ij} + \alpha_4 LEND_{ij} + \alpha_5 DEP_{ij} + \beta_1 SectorShare_{ij} + \ldots + \beta_{60} Sector\ Share_{ij} + \gamma_1 SectorProd_{ij} + \ldots + \gamma_{60} SectorProd_{ij} + \eta year\ dummies + \varepsilon \quad (3)$$

In this case, coefficient β indicates the ratio of country productivity to sector turnover. As β is effectively the slope response of a unit change of sector turnover on country productivity, a higher β value suggests a larger impact on country productivity for a unit sector turnover. A positive and significant β suggests a beneficial impact of sector size on country productivity, whilst a negative sign would indicate an adverse effect.

In this instance, coefficient γ represents the ratio of country productivity to sector productivity. Thus the coefficient γ is the slope response on country productivity for a unit change on sector productivity. As earlier, a higher γ implies a greater influence on the country productivity, with a positive (negative) sign implying country productivity benefits (adverse effect) from that particular sector's productivity.

In essence, sector size (measured by turnover) could expand without improving sector productivity (turnover per employee) through increasing employment, yet benefitting country productivity by shifting resources from lower productive sectors to employment in higher productive sectors, as proposed in original Lewis model (1954). On the other hand, sector productivity could increase through efficiency in the short term or innovation in the long term shifting the firm technology composition, as per adapted Lewis model – yet again benefitting country productivity.

As both sector sizes and sector productivity are examined, this process is examined comparatively - whether sector sizes or sector productivity have a similar significance of influence. If there is disparity in significance, the predominance of one aspect, either sizes or productivity, is suggestive of a more (less) than proportional influence of that aspect on country productivity.

This initial analysis of sector size as captured by turnover is followed by a set of regressions where sector size is instead represented by sector share, measured with sector turnover as a proportion of total core innovative sectors' turnover. In essence, sector share = sector size (turnover) / total turnover of all innovative sectors, enabling each sectors weight in the whole economy to be determined. Whereas sector size examines sector revenue as an alternative channel of influence on country productivity, sector share assesses whether the proportion of sectors relative to total core innovative sectors is important for country productivity.

3.5.3.3 Descriptive Statistics and Correlations

Table 3.2 lists summary statistics of the variables for . Looking at labour productivity variations of GVA per employee overall, the mean labour productivity across the 32 economies for the period 2000-2012 is measured as 49KEuros per employee. However, looking overall at the 32 countries over the period 2000-2012, there is also substantial variation with the lowest labour productivity of a country recording absolute value of 2.8 K Euros GVA per employee, possibly Romania and the highest labour productivity measuring 215 K Euros GVA per employee, possibly Luxembourg. Sector turnover has a mean of 63 billion Euros, with a maximum turnover of sector reaching 3.2 trillion Euros. Sector productivity, as proxied for this study and defined by turnover per employee has a mean of 300 K Euros per employee, varying between sectors from 103 K Euros per employee to 1, 822 K Euros per employee. These contrasts with Sector productivity figures of gross value added per employee with a mean of 75 K Euros per employee, varying between 27 K Euros per employee to 2197 K Euros per employee. It appears that sector productivity as defined by turnover per employee is approximately factor five higher than sector productivity for the mean as measured by gross value added. The turnover per standard deviation is somewhat higher than standard deviation of gross value added per employee, possibly indicating it is a less sensitive measure of sector productivity.

Table 3.2 Summary Statistics

	Mean	Std dev	Min	Max	Observations
Country GVA/Empl					
(K Euros per	49.3	35.93	2.81	215.3	N= 65520
Employee)		0	49.3	49.3	n = 312
overall		35.9	2.81	215.3	T = 210
between					
within					
Gross cap form					
GCF/Empl (K Euros	6.88	5.27	.104	30.5	N = 66768
per Employee)		0	6.9	6.9	n = 312
overall		5.27	.104	30.5	T-bar = 214
between					
within					
Employment ratio					
(Empl)	53.25	7.13	35.5	72	N= 66456
(Labour %age of		7.1e-15	53.25	53.25	n = 312
Pop)		7.1	35.5	72	T = 213
overall					
between					
within					
Export (Export as					
%age of GDP)	51.9	29.5	9.8	193.3	N = 66768
- overall		0	51.9	51.9	n = 312
- between		29.5	9.8	193.4	T-bar = 214
- within					
Lending interest rate					
- overall	8.6	6.01	.5	53.85	N= 43056
- between		0	8.6	8.6	n = 312
- within		6.01	.5	53.85	T = 138
Deposit interest rate					
- overall	4.8	7.8	.01	78.7	N= 37440
- between		0	4.89	4.89	n = 312
- within		7.86	.01	78.7	T = 120
Turnover Billion					
Euros (of sectors)	63	184	0	3,290	N = 4360
(CIS)		68	0.9	340	n = 60
- overall		170	-273	3,040	T-bar = 72.7
- between					
- within					
Turnover/Empl (K					
Euros per Employee)	300.8	581.15	1.8	22505.7	N = 4125
(CIS)		272.06	103.8	1822.3	n = 60
- overall		524.9	-1512.2	20984.3	T-bar = 68.75
- between					
- within					
Sector GVA/Empl (K					
Euros per Employee)	75.9	349.2	-323.7	18451.6	N = 13788
(Sbs)		283.5	27.9	2197.665	n = 171
- overall		307.8	-2001.1	16329.9	T-bar = 80.6
- between					
- within					

Table 3.3 shows the correlation matrix values between country productivity, GVA per employee, and the independent variables. Country productivity has the highest correlation percentage with gross capital formation, as well as labour force participation rates, with negative correlations for the lending and interest rates. Export, the trade variable is also positive, while sector turnover and sector productivity showing also positive correlation. Interestingly sector

productivity, as measured by turnover per employee, or sector productivity as measured by GVA per employee, show a similar level of correlation.

Table 3.3 Correlation Matrix values

	Country GVA/Empl	GCF/Empl	Empl (%age to Pop)	Export (%age to GDP)	Lending rate	Deposit rate	Sector Turnover	Sector Turnover per Empl	Sector GVA/Empl
Country GVA/Empl	1								
GCF/Empl	.96	1							
Empl (%age to Pop)	.765	.831	1						
Export (%age to GDP)	.187	.109	.305	1					
Lending rate	-.507	-.39	-.44	-.705	1				
Deposit rate	-.036	.06	.17	-.377	.60	1			
Sector Turnover	.217	.17	.18	.097	-.19	-.25	1		
Sector Turnover per Empl	.399	.367	.30	.15	-.25	-.05	.23	1	
11Sector GVA/Empl	.390	.378	.305	.06	-.18	-.0006	.12	.58	

3.6 Empirical Results

3.6.1 Country level Productivity and Firm-size Regressions

3.6.1.1 Firm turnover and Firm productivity:

Using Fixed Effects Estimation (FEM) to minimize country specific effects, as well as controlling for country specific variables influencing productivity, the results for the regression for the 32 European economies between 2000-2012 are listed in Table 3.4. The first two columns report regression results for equation (1). The first column lists the impact of firm-size turnover on country productivity at an aggregated level encompassing all core innovative sectors, with the second column listing results for firm-size turnover at the detailed sub-sector aggregated level. The next two columns list the results of the regression for equation (2). The third column, showing the impact of firm-size turnover and firm-size productivity on country productivity at again the aggregated level encompasses all core innovative sectors, while the fourth column lists results for regression conducted at a sub-aggregated sector level. Due to insufficient data for many sectors in 2002, it appears to drop out of the regressions, with year dummies reflecting shocks relative to reference dummy of year 2000.

Besides the firm-size turnover and firm-size productivity indicators, the regression includes gross capital formation, employment as a percentage of population, export as a percentage of GDP, lending interest rate and deposit interest rates. All control variables are significant in column (1), with employment and lending rate showing a negative coefficient. A negative coefficient on employment seems to support findings of Gordon & Becker (2008) that employment may move in opposite directions to labour productivity. For the rest of the three columns, export is insignificant while employment and lending rate continue to show a negative coefficient.

As this study assesses the importance of firm-size structures on country productivity through the channels of both firm revenue and firm productivity, initially regressions listed in Table 3.4 are only on firm turnover impact on country productivity followed by regressions of both firm-size turnover and firm-size productivity on country productivity. The initial regression examining firm-size turnover in columns 1 and 2 of Table 3.4 is mainly to build an understanding of how firms impacts country productivity through channels of revenue, followed by regressions in column 3 and 4 in Table 3.4 of both channels of revenue and firm productivity influence on country productivity.

Firm-size turnover is significant for all three firm-sizes in all columns 1, 3 & 4 at the one percent significance level. Firm-size productivity is however only significant for the large and small firm-size classification at the aggregated level in column 3, whereas at sub-aggregated level although small and large firm-size productivity is mostly found significant in column 4 , this varies across subsectors.

The firm-size structures in column 1 of Table 3.4 are found to be all significant, while in column 2 all three firm-sizes are also found significant for most sub-sectors, when assessed through impact of firm turnovers on country productivity. As explained earlier, the higher the value of the firm-size coefficient, the greater the impact of turnover of that size class on unit country productivity. At first glance, the findings indicate that large firms appear to have a slope response roughly half to one-third the impact on country productivity compared to small or medium firms for a unit change in large firm turnover. Furthermore, as large firm share of value added was found to be 40 percent on average between 2008-2013 in the EU economy (ECB, 2013), it would appear that the net impact on the economy of large firms is indeed less than that of small or medium sized firms. However, this needs to be assessed in context with the fact that only 0.2 percent of total firms were found to be large firms and they alone made up the 40 percent of value added share. Hence to perceive the actual impact of the creation or loss of a large firm in the economy, this slope response needs to be evaluated in context of the net impact of a firm. Given that this translates to a magnitude of value added per large firm in the EU economy as approximately 330 times higher than an SME firm, then the net impact per creation or loss of a large firm presence could in essence have a much larger significance on the economy at country level than is implied at first glance from the slope response. Based on this wider context of ECB survey that on average the large firms are about 0.2% of total firms, as the data itself does not yield the number of firms making up large firm turnover, it would appear turnover influence per large firm can be estimated by dividing slope by 0.2% - making the actual impact per large firm much larger indeed. Similarly, the effect per firm for smaller and medium sized (SME) firms requires the slope to be divided by their total percentage of 99.8%, which would make the slope of SME firms' influence on country productivity much smaller, thus, establishing an understanding of the much larger scale of influence of large firm-size revenue on country productivity relative to both small and medium sized firms' revenue.

Furthermore, it is notable that R-square is reasonably high in the regression results, yet it is not necessarily a problem as similar high R^2 are found in an OECD study of use of firm structures impact on country level job creation using country panel data (Criscuolo et al, 2014), indicating it is not unusual to find such R^2 values in similar types of studies. Indeed, Goldberger attributes only a modest role to R-square in regressions indicating that '… a high R^2 is not evidence in favour of a model and a low R^2 is not evidence against it' (Goldberger, 1978). In fact, Gujarati (2003) puts the emphasis on ensuring model is correctly specified, which has been attempted in this study.

Table 3.4 FEM of Firm-size Turnover and Firm-size productivity impact on Country Productivity

	(1) – Eq (1)	(2) – Eq (1)	(3) – Eq (2)	(4) – Eq (2)
Aggregation Level of Turnover:	Aggregated all core innovative sectors	Sub- aggregated innovative sectors	Aggregated all core innovative sectors	Sub- aggregated innovative sectors
	Firm-size Turnover	Firm-size Turnover	Firm-size Turnover	Firm-size Turnover
Small Firms	6.98 e-8*** (9.66e-9)		5.38e-8*** (1.18e-8)	5.4e-8*** (4.97e-9)
Medium Firms	6.13e-8*** (8.79e-9)		6.87e-8***(9.95e-9)	5.13e-8*** (4.62e-9)
Large Firms	2.41e-8*** (3.68e-9)		2.07e-8*** (4.02e-9)	1.27e-8*** (1.45e-9)
		Firm-size Turnover (sub-sectors)	Firm-size Productivity (Turnover per Emply)	Firm-size Productivity (Turnover per Emply) (sub-sectors)
Small Firms			.025** (.01)	
Medium Firms			.0009 (.004))	
Large Firms			.015**(.006)	
		Inf & com		Inf & com
Small Firms		1.14e-6***(4.3e-7)		.057 ***(.019)
Medium Firms		1.95e-6***(7.5e-7)		.09*** (.035)
Large Firms		1.37e-6**(5.8e-7)		.07*** (.025)
		Fin & ins		Fin & ins
Small Firms		8.2e-8*(4,5e-8)		.001 (.002)
Medium Firms		8.3e-8**(4.05e-8)		.002(.003)
Large Firms		2.4e-8***(8.6e-9)		.006 (.003)
		Arch & Engg		Arch & Engg
Small Firms		1.4e-6(2.8e-6)		.05 (.06)
Medium Firms		1.3e-6***(5.2e-7)		.053*** (.02)
Large Firms		2.6e-6**(1.07e-6)		.017 (.03)
		Elec & Gas		Elec & Gas
Small Firms		-1.2e-6**(5.9e-7)		-.001 (.002)
Medium Firms		-1.1e-7(3.2e-7)		-0.001(0.002)
Large Firms		-2.5e-8(1,7e-7)		-.00007 (.003)
		Manufacturing		Manufacturing
Small Firms		8.3e-8***(2.1e-8)		.03 ***(.009)
Medium Firms		6.2e-8***(1.6e-8)		.008(.006)
Large Firms		1.5e-8***(4.4e-9)		.01**(.004)

	(1) – Eq (1)	(2) – Eq (1)	(3) – Eq (2)	(4) – Eq (2)
Aggregation Level of Turnover:	Aggregated all core innovative sectors	Sub- aggregated innovative sectors	Aggregated all core innovative sectors	Sub- aggregated innovative sectors
		Mining & Quarrying		Mining & Quarrying
Small Firms		3.9e-7(9.6e-7)		.001(.002)
Medium Firms		-9.7e-7***(3.5e-7)		-.00009(.001)
Large Firms		-1.4e-7***(4.97e-8)		.0003(.002)
		Water,Sew & Waste		Water,Sew & Waste
Small Firms		3.7e-6**(1.9e-6)		.03***(.01)
Medium Firms		3.1e-6***(1.06e-6)		.02**(.01)
Large Firms		2.5e-6**(1.03e-6)		.03**(.013)
		Tranpt, Stor & com		Tranpt, Stor & com
Small Firms		3.2e-7***(9.3e-8)		.03***(.009)
Medium Firms		3.4e-7***(1.1e-7)		.0003(.002)
Large Firms		1.1e-7***(2.98e-8)		.04***(.01)
		Wholesale Trade		Wholesale Trade
Small Firms		1.53e-7***(6.07e-8)		.01(.008)
Medium Firms		1.3e-7**(5.3e-8)		.01(.007)
Large Firms		2.2e-7**(9.4e-8)		.017***(.006)
Observations	192	33,455	186	2,046
No. of groups	3	312	3	57
Obs per group	min = 64	min = 7	min = 62	min = 6
	avg= 64	avg= 107.2	avg= 62.0	avg = 35.9
	max= 64	max= 114	max= 62	max= 80
R-sq	within= 0.97	within= 0.9419	within= 0.9738	within = 0.9605
	between	between = .7147	between	between = 0.6047
	overall = 0.972	overall = 0.9418	overall = 0.972	overall= 0.9571
Corr (u_i,Xb)	-0.0084	-0.0196	-0.0353	-0.0232

Note: The regression equation for column (1) and (2) is country productivity measured by $GVA/Empl_{ij} = \alpha_1 GCF_{ij} + \alpha_2 EMP_{ij} + \alpha_3 EXP_{ij} + \alpha_4 LEND_{ij} + \alpha_5 DEP_{ij} + \beta_1 SmallFirm_{ij} + \beta_2 MedFirm_{ij} + \beta_3 LgeFirm_{ij} + \eta year\ dummies + \varepsilon$ (1). While for column (3) and (4) , the equation is country productivity as measured by $GVA/Empl_{ij} = \alpha_1 GCF_{ij} + \alpha_2 EMP_{ij} + \alpha_3 EXP_{ij} + \alpha_4 LEND_{ij} + \alpha_5 DEP_{ij} + \beta_1 SmallFirm_{ij} + \beta_2 MedFirm_{ij} + \beta_3 LgeFirm_{ij} + \gamma_1 SmallFirmProd_{ij} + \gamma_2 MedFirmProd_{ij} + \gamma_3 LgeFirmProd_{ij} + \eta year\ dummies + \varepsilon$ (2) Country Productivity is represented by gross value added at factor cost GVA/empl, derived from World Bank national accounts data. To control for country specific productivity influencing aspects, a range of variables are used: GCF is country level gross capital formation sourced from World bank national accounts; EMP is employment to population ratios, sourced from ILO; EXP is export as a %age to GDP sourced from World bank National Accounts;

and credit conditions is captured by lending rate sourced from IMF, while monetary policy is proxied by deposit rate derived from interest rate spread sourced from IMF. Small firms refer to firms with less than 49 employees, medium is less than 249 employees and large is 250+ employees – all as defined by OECD.

*** indicates significance at 1% p-value, ** indicates significance at 5% p-value and * indicates significance at 10% p-value. Standard errors are listed in parenthesis.

To complete the analysis, regressions in column 3 and 4 assess influence of firm-size structures on country productivity through both channels: firm turnover and firm productivity, column 3 is aggregated level and column 4 is at sub-aggregated level. In column 3, all three firm-size turnovers are indeed still found significant for their influence on country productivity, whereas only large and small firm-size productivity is found significant. This is to an extent also reflected at sub-aggregated level in column 4, where small and large firm-size productivity are predominantly found significant in sub-sectors, though this is not true for all subsectors. In some subsectors, all three firm-size productivities are significant, in one sub-aggregated sector only medium class is found significant, with more often the small and large firm size class productivity found significant for rest of sub-sectors. These slight variations suggest that different sectors have differences in how firm productivity impacts country productivity, although in general even at sub-aggregated level, it appears that enabling firms to grow to become medium and large firms would be beneficial for country productivity. As noted earlier, these results hold when controlling for country specific aspects influencing productivity including trade policy, credit conditions and monetary policy.

The finding that predominantly small and large firm-size productivity have a significant influence on country productivity at both aggregated and sub-aggregated level, is quite important. This echoes the findings of ECB, which analysed firm-size labour productivity in EU business economy between 2008-2013 and assessed large firms to have 130% productivity compared to SMEs at 87% (ECB, 2013, p. 42). It thus further corroborates the importance of large firm presence for building productivity levels in economies. The fact that both small and large firm productivity is significant underscores Schumpeters' focus initially on small (Schumpeter, 1934) and then large firms (Schumpeter, 1942) as drivers of innovation. Indeed, it appears that the influence of structures on country productivity is quite intricate, with large and small firms seeming to exert their influence in a dual capacity, through both turnover and productivity. However given the ECB (2013) analysis of large firm value-added on average 330 times SME's and large firm productivity 130% relative to SME 87%, it appears important to ensure large firms continue to keep their share in the economic landscape for maintaining high country productivity.

3.6.1.2 Firm turnover-share:

To properly assess how the size (and hence the expansion or reduction) of particular firm-size structures impacts country productivity, firm-size classes' turnover needs to be assessed as a proportion of total turnover. To assess how the size of small, medium and large firm-size presence in an economy impacts country productivity, equation (1) is used to regress firm turnover shares on country productivity. As earlier, these are initially examined separately and then alongside firm-size productivity. The results are listed in Table 3.5.

Table 3.5 FEM of Firm-size Turnover-share impact on Country Productivity

Aggregation Level of Turnover:	(1) – Eq (1) Aggregated all core innovative sectors
Firm-size Turnover	
Small Firms	-15.8 (10.72)
Medium Firms	-34.07*** (12.1)
Large Firms	18.07*** (6.995)
Observations	192
No. of groups	3
Obs per group	min = 64 avg= 64 max= 64
R-sq	within= 0.957 between overall = 0.878
Corr (u_i,Xb)	-0.2877

Note: The regression equation for column (1) is country productivity measured by $GVA/Empl_{ij}= \alpha_1 GCF_{ij} + \alpha_2 EMP_{ij} + \alpha_3 EXP_{ij} + \alpha_4 LEND_{ij} + \alpha_5 DEP_{ij} + \beta_1 SmallFirm_{ij} + \beta_2 MedFirm_{ij} + \beta_3 LgeFirm_{ij} + \eta year\ dummies + \varepsilon$. Country Productivity is represented by gross value added at factor cost GVA/empl, derived from World Bank national accounts data. To control for country specific productivity influencing aspects, a range of variables are used: GCF is country level gross capital formation sourced from World bank national accounts; EMP is employment to population ratios, sourced from ILO; EXP is export as a %age to GDP sourced from World bank National Accounts; and credit conditions is captured by lending rate sourced from IMF, while monetary policy is proxied by deposit rate derived from interest rate spread sourced from IMF. Small firms refer to firms with less than 49 employees, medium is less than 249 employees and large is 250+ employees – all as defined by OECD.

*** indicates significance at 1% p-value, ** indicates significance at 5% p-value and * indicates significance at 10% p-value. Standard errors are listed in parenthesis

The findings are quite suggestive. At aggregated sector level as listed in column 1, only large-sized firm intensity is found to be positive for country productivity, with both small and medium firm-intensities showing a negative contribution towards country productivity. This latter result is intriguing, as in terms of actual revenue, small and medium sized firms appear to have about 3 times larger impact per unit turnover compared to large firms, as listed in Table 3.4. Yet, perhaps as a consequence that net revenue generated by SMEs is so much lower on average than large firms (ECB, 2013), their expanded share in the total economy may not be that positive for country productivity. Perhaps that could serve to explain the negative impact on country productivity of SMEs, though it is to be noted that small sized firm intensity is found to be statistically insignificant. Essentially at aggregated levels, these findings reveal that the size of large firm presence in an economy, captured through its turnover share, is the most significant influence on country productivity.

In contrast, the size of the smaller and medium sized firms' presence in an economy appears to have a negative influence on country productivity. This finding, nonetheless has to kept in perspective, as SMEs are well recognized for their importance on the economy through channels of growth or employment. Indeed, Beck et al. (2005) found that SMEs play a positive role in delivering country growth.

These two insights - positive impact of size of large firm presence in an economy on country productivity versus negative impact of size of smaller and medium sized firms on country productivity – seem to validate the proposed adapted Lewis model. This model essentially demonstrates that the size of the large firm presence in an economy is critical for its influence on country productivity and that reduction (or expansion) would lead to consequent fall (or rise) of country productivity. The findings from these regressions appears to support this proposed mechanism of working of the adapted Lewis model.

In the same vein, further to firm-size structures, the question arises whether specific sectors or industries could be more relevant for country productivity. Furthermore, is it the size of sectors or rather sector turnover as determined by firm structures important, or is sector productivity of greater import for country productivity? To seek answers to this query, the next section examines the impact of specific sectors both for their turnover and productivity on country productivity. This not only could shed some light through isolating industries and their channel more pertinent to country productivity, it may also provide an alternative examination at sector level of the influence of firm-sizes structures on country productivity.

3.6.2 **Country level Productivity and Sector Regressions**

3.6.2.1 Sector Size and Sector productivity:

The FEM results of analysing specific sector sizes and sector productivities on country level productivity are listed Table 3.6. Column (1) lists the sectors turnover coefficients and column (2) lists the coefficient for sector productivities, measured by turnover per employee. As these variables use CIS data, the analysis is conducted over the time period of 2000-2012 for the 32

European economies. Sectors found significant for both aspects are highlighted in column 3.

Table 3.6 FEM of Sector turnover and Sector turnover/Employee on Country Productivity

Sectors	-1 Sector turnover coefficients	-2 Sector Productivity (turnover/Empl) coefficients	Sectors found significant for both aspects
Activities auxiliary to financial services and insurance	8.9e-7*** (2.07 e - 07)	.0132* (.006)	√
Advertising and market research	1.41e-6* (8e-07)	.0089 (,0197)	
Air transport	3.9e-6*** (6.86e-07) (6th highest)	-.0022 (.003)	
Architectural, engineering and technical activities	1.06e-6*** (1.55e-07)	.004 (.014)	
Collection, purification and distribution of water	1.12e-6** (5.04e-07)	.038*** (.0117)	√
Computer programming, consultancy and related activities	6.89e-7*** (9.47e-08)	.015 (.0104)	√
Electric power generation, transmission and distribution	-6.6e-8(2.93e-07)	.001 (.004)	
Electricity, gas, steam and air conditioning supply	1.51e-7(1.65e-07)	.0002 (.005)	
Extraction of crude petroleum and natural gas	-7.16e-8 (5.82e-08)	.0032*** (.0013)	
Financial service activities, except insurance and pensions	1.81e-7*** (3.83e-08)	.006(.0045)	
Insurance, reinsurance and pension funding	1.10e-7*** (2.69e-08)	.005** (.002)	
Land transport and transport via pipelines	6.83e-8 (5.66e-08)	.078*** (.016) (2nd highest)	
Manufacture of basic metals	4.74e-7*** (1.41e-07)	.018*** (.004)	
Manufacture of basic pharmaceutical products	1.96e-6** (8.91e-07) (10th highest)	.017 (.014)	√
Manufacture of beverages	1.34e-6 (1.15e-06)	.024*** (.008)	
Manufacture of chemicals and chemical products	1.43e-7*** (3.74e-08)	.019*** (.005)	√
Manufacture of coke and refined petroleum products	2.53e-7*** (8.72e-08)	.00003 (.001)	
Manufacture of computer, electronic and optical products	-6.15e-7** (2.21e-07) (negative)	.053*** (.011) (8th highest)	√
Manufacture of electrical equipment	5.48e-7 (3.52e-07)	.03** (.013)	√
Manufacture of fabricated metal products, except machinery	2.88e-7*** (8.9e-08) (7th highest)	.06*** (.011) (4th highest)	√
Manufacture of food products	2.71e-7*** (6.55e-08)	.003 (.011)	
Manufacture of furniture	4.01e-6*** (1.62e-06) (5th highest)	.03 (.023)	
Manufacture of gas; distribution of gaseous fuels	3.7e-7 (5.37e-07)	-.001 (.002)	
Manufacture of leather and related products	2.98e-6*** (9.4e-07) (8th highest)	.064*** (.008) (3rd highest)	√
Manufacture of machinery and equipment n.e.c.	3.54e-7*** (7.66e-08)	.028*** (.009)	√
Manufacture of motor vehicles, trailers and semi-trailers	2.08e-8 (4.26e-08)	.037*** (.007)	
Manufacture of other non-metallic mineral products	5.42e-7*** (1.75e-07)	.050*** (.009) (10th highest)	√
Manufacture of other transport equipment	3.91e-7*** (1.56e-07)	.037*** (.007)	√
Manufacture of paper and paper products	5.49e-7*** (1.84e-07)	.035*** (.007)	√
Manufacture of rubber and plastic products	2.7e-7 (1.13e-07)	.059*** (.01) (6th highest)	

Sectors	-1 Sector turnover coefficients	-2 Sector Productivity (turnover/Empl) coefficients	Sectors found significant for both aspects
Manufacture of textiles	8.41e-7** (3.78e-07)	.081*** (.01)	
Manufacture of tobacco products	5.4e-7 (1.12e-06)	.006*** (.002)	√
Manufacture of transport equipment	5.22e-8 (1.96e-07)	.018 (.021)	
Manufacture of wearing apparel	9.59e-7*** (3.72e-07)	.053*** (.006)	
Manufacture of wood and products of wood and cork	7.21e-7* (4.12e-07)	.055*** (.011)	√
Mining of coal and lignite	2.56e-7 (5.34e-07)	.024*** (.006)	√
Mining of metal ores	1.76e-6 (3.58e-06)	.009 (.019)	
Mining support services	-1.38e-6*** (4.41e-07)	.023*** (.005)	
Motion picture, video and television	.000018*** (3.9e-06)	-.023 (.015)	
Other manufacturing	5.05e-6*** (8.82e-07) (4th highest)	-.019 (.024)	√
Other mining and quarrying	2.97e-6*** (9.49e-07) (9th highest)	.032*** (.005)	√
Other professional, scientific and technical activities	2.36e-6 (2.01e-06)	.003 (.027)	
Postal and courier services	3.8e-6** (1.73e-06) (7th highest)	-.005 (.011))	√
Printing and reproduction of recorded media	3.62e-7** (1.72e-07)	.082*** (.013) (Highest)	
Professional, scientific and technical activities	6.27e-7*** (1.02e-07)	-.025** (.011)	√
Programming and broadcasting activities	.000012** (4.93e-06) (3rd highest)	-.0003 (.03)	√
Publishing activities	2.06e-6* (1.25e-06)	.022 (.032)	
Remediation activities and waste management	.000052*** (.000018) (Highest)	-.018 (.02)	
Scientific Research and development	3.16e-6*** (6.76e-07)	.05*** (.013) (9th highest)	
Sewerage	.000024*** (6.4e-06) (2nd highest)	.003 (.022)	√
Telecommunications	1.01e-6** (4.91e-07)	-.002(.007)	
Transportation and Storage	3.12e-7*** (8.31e-08)	.0007 (.024)	
Warehousing and support activities for transportation	9.61e-7*** (2.17e-07)	-.01 (.013)	
Waste collection, treatment and disposal activities	2.07e-6*** (4.15e-07)	.022*** (.005)	
Water collection, treatment and supply	1.82e-6(2.08e-06)	.033*** (.009)	√
Water transport	1.94e-6*** (3.86e-07)	.003 (.0058)	
Wholesale and retail trade, repair of motor vehicles	1.62e-8*** (4.48e-09)	.023*** (.004)	
Wholesale trade, except of motor vehicles and motorcycle	7.85e-8*** (1.40e-08)	-.0004 (.005)	√
No. of Obs	2,313		
No of groups	59		
Obs per group	Min = 8		

Sectors	-1 Sector turnover coefficients	-2 Sector Productivity (turnover/Empl) coefficients	Sectors found significant for both aspects
	Avg = 39.2		
	Max = 61		
	Within = 0.9743		
R-sq	Between 0.8581		
	Overall = 0.9711		
Corr (u_i, Xb)	-0.0442		

Note: The regression equation for this regression is $y_{ij} = \alpha_1 GCF_{ij} + \alpha_2 EMP_{ij} + \alpha_3 EXP_{ij} + \alpha_4 LEND_{ij} + \alpha_5 DEP_{ij} + \beta_1 SectorShare_{ij} + \ldots + \beta_{60} Sector\ Share_{ij} + \gamma_1 SectorProd_{ij} + \ldots + \gamma_{60} SectorProd_{ij} + \eta year\ dummies + \varepsilon$ (3) , with similar control variables as explained in previous regression

*** indicates significance at 1% p-value, ** indicates significance at 5% p-value and * indicates significance at 10% p-value.

The coefficient or slope-response of sector turnover measures the ratio of country productivity to sector turnover or size of revenue, whilst the sector productivity coefficient or slope-response measures the ratio of country productivity to sector productivity. For both coefficients, the higher the coefficient value, the greater is the impact on country productivity for a unit change of sector turnover (or sector productivity).

As in the earlier regressions, alongside sector turnover and sector productivity indicators, the regression includes controlling variables of gross capital formation, employment as a percentage of population, export as a percentage of GDP, lending interest rate and deposit interest rates. All controlling variables are found significant in the regression, again with employment and lending rate having a negative coefficient for their impact on country productivity. A negative coefficient on employment yet again appears to supports propositions by Gordon & Becker (2008) that employment for advanced economies may move in opposite direction to labour productivity.

The overview reveals that sectors differ in their contributions to country productivity. The sectors found significant for turnover listed in column (1) are not necessarily accompanied by significance of that sector's turnover per employee listed in column (2). The sectors with both overlapping sector turnovers contribution, as well as sector productivity as measured by turnover per employee, are indicated in column (3). Observing the higher impact sectors, as suggested by the coefficient size, the difference in sector results suggests that the channels through which sectors influence the economy may be different. The coefficient size can suggest the relative influence level of sectors in terms of either size of revenue or productivity on country productivity. Furthermore, it is to be noted, that no comparisons may be drawn from these results differentiating the impact of these two channels on country productivity.

To evaluate net responses of sectors on country productivity, a similar caution has to be exercised by placing coefficients in context alongside the actual size of sectors. Sectors with smaller coefficients or slope responses may exert a larger influence on country productivity based on the net impact incorporating size and slope response. While the listing of the net impact of sizes of sectors for the 32 EU economies for the time period 2000-2012 is outside the current scope of this study, it implies there should be caution in drawing conclusion based on coefficients alone. However, it is somewhat surprising that sectors, such as financial services, basic pharma, transport and storage and telecommunication sectors are not found significant for their productivities. In contrast, their sector turnovers are found significant. This implies they do not seem to exert influence on country productivity through firm productivities, rather only through their turnover. Given that all three firm-sizes are important for turnover, in particular with large firms found to contribute disproportionately higher magnitude of turnovers, this invites further research on the role of structures in these particular sectors.

These sector results may be contrasted with slightly different FEM sector turnover and productivity results displayed in Table 3.7. Although this regression covers the 32 European economies again, it is regressed over a shorter time period, i.e. 2008-2012. Further, this regression measures sector productivity more accurately through the measure GVA/employee through use of SBS data. However, as SBS data is restricted to 2008-2012, the period of analysis is shorter and certain sectors are dropped as data not available in SBS data, the comparison should be viewed with caution. Column (1) lists the sector turnover coefficients and column (2) the coefficients of sector productivity as measured more accurately by GVA per employee. Column (3) again indicates sectors found to be significant in both sector turnover and sector productivity to country productivity.

Table 3.7 FEM of Sector turnover and Sector GVA/emp on Country Productivity

Sectors	-1 Sector turnover coefficients	-2 Sector Productivity (GVA/Empl) coefficients	Sectors found significant for both aspects
Advertising and market research	5.85e-7 (4.35e-07)	.3604** (.08) (6th highest)	
Air transport	2.94e-6** (1.33e-06) (7th highest)	.0856*** (.024)	√
Architectural, engineering and technical activities	1.25e-6*** (2.67e-07)	.123*** (.033)	√
Computer programming, consultancy and related activities	7.67e-7*** (1.96e-07)	.1922*** (.034)	√
Electricity, gas, steam and air conditioning supply	-4.05e-8 (7.37e-08)	.0579*** (.008)	
Extraction of crude petroleum and natural gas	-8e-7 (5.44e-07)	.0119*** (.002)	
Financial service activities, except insurance and pensions	-6.23e-7*** (2.5e-07)	.1389*** (.023)	√
Land transport and transport via pipelines	5.56e-7** (1.04e-07)	.2661*** (.021)	√
Manufacture of basic metals	6.46e-8 (2.03e-07)	.2025** (.064)	
Manufacture of basic pharmaceutical products	1.86e-6 (1.4e-06)	.1247** (.021)	
Manufacture of beverages	-1.55e-7 (9.73e-07)	.168*** (.019)	
Manufacture of chemicals and chemical products	2.16e-7*** (8.26e-08)	.0854*** (.023)	√
Manufacture of coke and refined petroleum products	-2.24e-7 (1.99e-07)	.1109*** (.024)	
Manufacture of computer, electronic and optical products	2.74e-7 (1.96e-07)	.1866*** (.022)	
Manufacture of electrical equipment	2.01e-7 (2.93e-07)	.285*** (.032)	
Manufacture of fabricated metal products, except machinery	2.12e-7 (1.74e-07)	.296*** (.043)	
Manufacture of food products	1.46e-7 (1.15e-07)	.247*** (.070)	
Manufacture of furniture	1.7e-6 (1.4e-06)	.3586*** (.057) (8th highest)	
Manufacture of leather and related products	2.4e-6 (1.99e-06)	.3606*** (.035) (5th highest)	
Manufacture of machinery and equipment n.e.c.	4.15e-7*** (1.4e-07)	.147*** (.029)	√
Manufacture of motor vehicles, trailers and semi-trailers	-9.45e-8 (6.87e-08)	.335** (.033) (9th highest)	
Manufacture of other non-metallic mineral products	4.08e-8 (3.34e-07)	.3865*** (.043) (3rd highest)	
Manufacture of other transport equipment	3.53e-7 (4.83e-07)	.2379*** (.041)	
Manufacture of paper and paper products	7.69e-7 (6.5e-07)	.2886*** (.051)	
Manufacture of rubber and plastic products	-4.63e-8 (2.08e-07)	.323*** (.037)	
Manufacture of textiles	7.58e-7 (9.15e-07)	.374*** (.038) (4th highest)	
Manufacture of tobacco products	4.85e-7 (1.11e-06)	.1530*** (.022)	
Manufacture of wearing apparel	3.13e-7 (9.21e-07)	.3602*** (.038) (7th highest)	
Manufacture of wood and products of wood and cork	-3.95e-7 (6.66e-07)	.4295*** (.0411) (2nd highest)	

Sectors	-1 Sector turnover coefficients	-2 Sector Productivity (GVA/Empl) coefficients	Sectors found significant for both aspects
Mining of coal and lignite	8.05e-8 (8.41e-07)	.134 (.083)	
Mining of metal ores	-.0002 (.000017)	-113 (.19)	
Mining support services	8.37e-7*** (2.55e-07)	.0462***(.004) (4th highest)	√
Motion picture, video and television	.000022*** (3.64e-06) (2nd highest)	-.036 (.04)	
Other manufacturing	1.87e-6* (1.14e-06) (9th highest)	.3198*** (.054)	√
Other mining and quarrying	2,41e-7 (2.97e-06)	.194*** (.043)	
Other professional, scientific and technical activities	1.32e-6** (6.04e-07)	.1947*** (.083)	√
Postal and courier services	1.86e-6** (5.49e-07)	.509*** (.047) (highest)	
Printing and reproduction of recorded media	1.66e-6** (6.01e-07) (10th highest)	.333*** (.087) (10th highest)	
Professional, scientific and technical activities	6.40e-7*** (1.57e-07)	.0498 (.043)	
Programming and broadcasting activities	.000019*** (3.63e-06) (3rd highest)	-.008 (.073)	
Publishing activities	1.4e-6 (1.21e-06)	.187*** (.079)	
Remediation activities and waste management	.000029** (.000015) (highest)	.131* (.066)	√
Scientific Research and development	3.95e-6* (1.08e-06) (6th highest)	.314*** (.044)	√
Sewerage	.000015*** (4.87e-06) (4th highest)	.219*** (.052)	√
Telecommunications	1.96e-7 (3.07e-07)	.109** (.012)	
Transportation and Storage	2.7e-7*** (5.49e-08)	.1695*** (.045)	√
Warehousing and support activities for transportation	6.64e-7*** (1.67e-07)	.128*** (.038)	√
Waste collection, treatment and disposal activities	1.22e-6** (5.05e-07)	.253*** (.043)	√
Water collection, treatment and supply	3.55e-7 (1.7e-06)	.146*** (.019)	
Water transport	3.43e-6** (1.46e-06) (5th highest)	.0383*** (.036)	√
Wholesale trade, except of motor vehicles and motorcycle	4.65e-8** (1.78e-08)	..183*** (.051)	√
No. of Obs	1224		
No of groups	52		
Obs per group	Min = 5		
	Avg = 23.5		
	Max = 38		
R-sq	Within = 0.9874		
	Between 0.9152		
	Overall = 0.9832		
Corr (u_i, Xb)	-0.0589		

Given this caution in comparison, nonetheless the difference in the lists of sectors significant for turnover and productivity on country productivity is quite remarkable. Firstly, there is a substantial decrease in the listing of sectors significant for turnover, with previously significant sectors with high slope responses such as basic pharma, furniture, leather and other mining and quarrying found to be insignificant. Secondly, only five of the sectors within the10 highest slope responses for turnover overlap with the previous list. Thirdly, while sectors significant for productivity are not substantially reduced, again the listing of the sectors with the 10 highest slope responses is different. In this case,six of the sectors with the highest slope response for productivity overlap with the previous list. As the time period of analysis is shorter and certain observations may lose their weight, it is not a straightforward comparison. Notwithstanding this caution, it is to be noted that the list of sectors found significant for both their turnover and productivity on country productivity is diminished.

These results have two pertinent implications. Critically, they suggest that turnover per employee, despite its similar correlation to country productivity, is limited in its role as proxy for sector productivity as measured by GVA per employee. Secondly, the results further substantiate the earlier conclusion that sectors differ in their channels of influence on country productivity. Size of revenue appears to remain a valid and separate channel of influence from sector productivity on country productivity.

Essentially, both these detailed sector regressions deliver two findings. Firstly, these results indicate that not all core innovative sectors contribute equally to country productivity. Certain industries or sectors appear to have a greater influence on country productivity. Specifically, sectors appear to differ in the manner in which they exert an influence, either through productivity or size of revenue. There, however, appears to be a set of sectors that contributes both through aspects of sector turnover and productivity. To discern whether that makes those sectors of greater import for country productivity is beyond the current scope of this study. Further research would be required to ascertain the actual size of turnovers of those sectors in economies and assess net impact through evaluating the slope responses in context with the size of sectors. Nonetheless, the key finding that sectors exert influence through dual channels of size and productivity has critical implications, as it brings firm structures alongside factors of production into the core of the debate surrounding productivity.

3.6.2.2 Sector Share and Sector productivity:

Before concluding this section on sector analysis, we perform one more set of regressions: sector share and sector productivities on country level productivity. Sector share is defined by sector turnover as proportional to total core innovative sector turnover. Sector shares essentially neutralize the size of the sector or its weight in the economy, enable measuring the impact of a unit percentage change of the sector on country productivity, irrespective of size of the sector. This basically enables capturing which unit shifts of sectors, be they smaller or larger dominant sectors, influence country productivity. Identifying those unit shifts with the most significant impact on country productivity could enable policymakers to support those shifts, irrespective of its current size or firm structures. To recap, sector size assesses the original Lewis model proposition that shifting resources across sectors influences country productivity positively by expanding sector sizes of those sectors. In comparison, sector share examines which unit change of a sector, irrespective of its size, influences country productivity most significantly, in effect refining the Lewis model to examine whether changing weightage of sectors in an economy influences country prouctivity. Thus, using sector shares in the regression allows this study to examine whether a unit shift in the relative proportional size of sectors, as opposed to size itself as examined earlier, is of consequence to the labour productivity of an economy.

The FEM results analyzing sector shares and sector productivities on country level productivity using equation (3), with similar controls as in previous regression are listed Table 3.8. Column (1) lists the sector share coefficients and column (2) lists the coefficient for sector productivities, measured by turnover per employee. As these variables again use CIS data, the analysis is conducted over the time period of 2000-2012 for the 32 European economies. Sectors found significant for both aspects are highlighted in column 3.

Table 3.8 FEM of Sector turnover and Sector turnover/Employee on Country Productivity

Sectors	-1 Sector turnover coefficients	-2 Sector Productivity (turnover/Empl) coefficients	Sectors found significant for both aspects
Activities auxiliary to financial services and insurance	535.41** (213.76)	.011 (.009)	
Advertising and market research	336.9 (727.9)	.034** (.017)	
Air transport	-134.95* (84.3) (negative)	.0047 (.0035)	
Architectural, engineering and technical activities	197.69 (148.65)	.05** (.011)	
Collection, purification and distribution of water	-64.20 (262.3)	.051***	
Computer programming, consultancy and related activities	437.1*** (165.8)	-.0019 (.0207)	
Electric power generation, transmission and distribution	-65.3 (55.82)	.001 (.002)	
Electricity, gas, steam and air conditioning supply	-97.41*** (33.03) (negative)	.005** (.003)	√
Extraction of crude petroleum and natural gas	-1.92 (14.09)	.002* (.001)	
Financial service activities, except insurance and pensions	-29.65** (12.12) (negative)	.019*** (.005)	√
Insurance, reinsurance and pension funding	97.27*** (35.9)	.004 (.003)	
Land transport and transport via pipelines	-75.16** (31.7) (negative)	.098*** (.013)	√
Manufacture of basic metals	-91.05*** (35.49) (negative)	.024*** (.0045)	√
Manufacture of basic pharmaceutical products	122.37 (209.6)	.039*** (.01)	
Manufacture of beverages	139.7 (283.07)	.031*** (.009)	
Manufacture of chemicals and chemical products	79.28* (41.95)	.023*** (.005)	√
Manufacture of coke and refined petroleum products	-57.8*** (22.35) (negative)	.0023** (.0009)	√
Manufacture of computer, electronic and optical products	-107.03*** (34.37) (negative)	.044*** (.009)	√
Manufacture of electrical equipment	-189.89** (94.52) (negative)	.035*** (.01)	√
Manufacture of fabricated metal products, except machinery	-126.02** (53.5) (negative)	.08*** (.01)	√
Manufacture of food products	94.4** (40.7)	.035*** (.008)	√
Manufacture of furniture	-41.57 (173.72)	.073*** (.02)	
Manufacture of gas; distribution of gaseous fuels	34.8 (68.76)	-.003 (.001)	
Manufacture of leather and related products	339.18 (239.85)	.07*** (.01)	
Manufacture of machinery and equipment n.e.c.	14.32 (45.27)	.051*** (.008)	
Manufacture of motor vehicles, trailers and semi-trailers	-63.34*** (19.17) (negative)	.047*** (.007)	√
Manufacture of other non-metallic mineral products	-401.76*** (111.5) (negative)	.047*** (.009)	√
Manufacture of other transport equipment	91.61 (96.25)	.044*** (.007)	
Manufacture of paper and paper products	-53.67 (61.75)	.048*** (.007)	
Manufacture of rubber and plastic products	-114.79 (71.27)	.067*** (.01)	

Sectors	-1 Sector turnover coefficients	-2 Sector Productivity (turnover/Empl) coefficients	Sectors found significant for both aspects
Manufacture of textiles	-212.63 (148.3)	.083*** (.011)	
Manufacture of tobacco products	-592.78*** (204.83) (negative)	.005* (.002)	√
Manufacture of transport equipment	-40.62 (73.57)	.039 (.034)	
Manufacture of wearing apparel	-27.11 (89.31)	.053*** (.007)	
Manufacture of wood and products of wood and cork	-102.96*** (36.09) (negative)	.064*** (.01)	√
Mining of coal and lignite	-80.50 (182.39)	.023*** (.007)	
Mining of metal ores	-558.92** (260.34) (negative)	.021 (.015)	
Mining support services	-388.67*** (145.76) (negative)	.02*** (.004)	√
Motion picture, video and television	-672.69 (2329.04)	.022 (.02)	
Other manufacturing	753.48 (566.7)	-.012 (.026)	
Other mining and quarrying	-558.82 (469.05)	.035*** (.005)	
Other professional, scientific and technical activities	959.61 (1421.79)	.015 (.028)	
Postal and courier services	-675.002 (905.88)	.02*** (.005)	
Printing and reproduction of recorded media	-1.42 (120.59)	.096*** (.013)	
Professional, scientific and technical activities	246.17*** (81.57)	-.011 (.013)	
Programming and broadcasting activities	-609.9 (991.88)	.06 (.019)	
Publishing activities	-294.87 (335.63)	.077*** (.0165)	
Remediation activities and waste management	3691.59 (3385.2)	.029*** (.018)	
Scientific Research and development	242.89 (446.82)	.063*** (.015)	
Sewerage	2642 (2389.3)	.054*** (.019)	
Telecommunications	-313.26*** (89.4) (negative)	.006 (.005)	
Transportation and Storage	3-15.25 (25.02)	.077*** (.016)	
Warehousing and support activities for transportation	-44.42 (47.96)	.039*** (.009)	
Waste collection, treatment and disposal activities	192.1 (131.05)	.028*** (.006)	
Water collection, treatment and supply	709.6 (692.7)	.043*** (.0105)	
Water transport	-113.86 (100.1)	.023*** (.006)	
Wholesale and retail trade, repair of motor vehicles	15.3 (11.69)	.029*** (.006)	
Wholesale trade, except of motor vehicles and motorcycle	1.79 (11.99)	.018*** (.0042)	
No. of Obs	2,297		
No of groups	59		
Obs per group	Min = 8 Avg = 38.9 Max = 61		
R-sq	Within = 0.9695 Between 0.6259 Overall = 0.9573		
Corr (u_i, Xb)	-0.1136		

*** indicates significance at 1% p-value, ** indicates significance at 5% p-value and * indicates significance at 10% p-value. Values in parenthesis are standard errors.

The coefficient or slope-response of sector share measures the unit change of each sector's weight in the economy on country productivity. On the other hand, sector productivity coefficient is same as in earlier regressions and measures the slope-response of country productivity to sector productivity. For both coefficients, the higher the coefficient value, the greater is the impact on country productivity for a unit change of sector turnover (or sector productivity).

As stated earlier, in essence the sector share examines which unit change of a sector, irrespective of its size, influences country productivity most significantly, in effect refining the Lewis model to examine whether changing weightage of sectors in an economy influences country productivity. Comparing these results of sector share as listed in table 8 to sector turnover in table 6, certain differences are immediately apparent. Firstly, there are far fewer significant sectors impacting country productivity through the unit change in the size of their relative share, in contrast to a higher number of sectors that impacted country productivity directly through their turnover. Secondly, a large number of the significant sectors for their relative size appear to influence country productivity negatively. A few conclusions can perhaps be drawn from these results. Primarily, it appears that the relative unit change of sectors may be less important than actual size of turnover when examining influence on country productivity. This seems to draw attention to the makeup of sectors and the aspects driving the turnover of size of sectors, rather than an indiscriminate focus on relative size of sector in an economy. Factors such the type of innovation determining turnover in those sectors, firm-structures and consequent productivity may be of greater consequence than its relative size when examining influence of that sector on country productivity. Secondly, and more puzzling, is the negative impact of quite a large number of unit change of relative sector shares on country productivity. The causes for this result would appear to be outside the current realms of this study, but could indicate that either dominance or the opposite, too small a relative size of sectors could detract from country productivity. Both of these results are intriguing and would benefit from more detailed examination, specifically a study to isolate why and how relative size of sectors, be it dominance or smallness, can appear to have a negative impact on country productivity. In essence though the conclusion remains that sectors appear to influence country productivity both through sector productivity and sector turnover, in this case through their relative share in sector turnover.

Overall, these findings provide not only an alternative assessment of the impact of firm-size structures on productivity; they shed a light on the firm-size structures relevant to sectors, depending upon the channel through which they influence country productivity. Sectors with only productivity contributions would appear to benefit from small and large firm structures. On the other hand, sector with turnover contributions would appear to require all three firm-size structures, specifically large-firm structures. Sectors contributions through relative share in turnover appear to be more complex and would require assessment beyond the scope of this study, specifically examination of relative sector dominance or weakness in an economy. As this study is restricted by data availability and unable to regress firm-size structures at detailed sector level, further analysis would be required to assess these potential implications.

These results need to be qualified in their findings on a few aspects. Firstly, although it uses panel data, the time period is essentially short. It is biannual data over a period of 12 years (2000-2012) and thus limited in its depth of study. Secondly, although the study controls for country-specific aspects that influence productivity, it does not provide the depth of an individual country analysis conducted over a longer period of time. Thirdly, by using Eurostat firm data on turnover measured on a bi-annual basis, it captures the entries and exits of firms providing a dynamic picture of the firm presence in sectors. Fourthly, though the study uses some hard data from World Bank Database (WDI), the study draws heavily from processing raw data obtained from innovation and business surveys collected by Eurostat. This has its limitations in the extent and uniformity of coverage of all sectors, specifically internationally across all 32 economies and thus the results may suffer from similar limitations. Shortage of data availability meant that not all variables could be weighted to altogether avoid this disparity.

Lastly, without an endogenity regression to check reverse causality, these results only confirm that firm-structures are a characteristic of economies with high productivity levels, not necessarily a determinant of it.

3.7 Conclusion

This study proposed an adapted Lewis model to relate how particular firm-size classes presence in an economy may influence country labour productivity. In particular, it proposed that size of large firm-size presence in an economy, is critical to country productivity and the consequent reduction (expansion) could lead to a fall(rise) of country productivity.

To assess this relationship, the study examined the influence of firm-size structures on country labour productivities through two channels: firm turnover share and firm productivities. Using FEM panel data was examined for 32 European economies over a time period of 2000-2012, across core innovative structures encompassing both manufacturing and service sectors. Whereas Fixed Effects Methods (FEM) was used to minimize sector or country specific effects, an additional array of country-level variables was also used to control for country-specific aspects that could influence country labour productivity.

The regressions assessed whether firm structures are indeed significant for a country's labour productivity economy as proposed in the Lewis adapted model, and if so, which firm-size structures? It also examined whether large or small firm-size structures are relevant for country level productivity, irrespective of their firm productivities. These firm-size structures were assessed for their influence both through turnover share impact on country labour productivity. The findings reveal that the size of large firm presence in an economy, captured through its turnover share and firm productivity, is the most significant influence on country productivity. In contrast, the turnover share of the smaller and medium sized firms' presence in an economy appears to have a negative influence on country productivity, although small firm productivity is found significant and positive for country productivity. Thus although SMEs are well recognized in previous research for their importance on the economy through channels of growth or employment, in terms of country productivity it appears overall that large firms are of most importance in an economic landscape.

The findings are very suggestive. Substantially they offer these two insights, i.e. that positive impact of size of large firm presence in an economy on country productivity versus negative impact of size of smaller and medium sized firms on country productivity seem to validate the proposed adapted Lewis model. This model centrally proposes that the size of the large firm presence in an economy is critical for its influence on country productivity and that reduction (or expansion) would lead to consequent fall (or rise) of country productivity. The findings from these regressions appear to support the mechanism of influence of firms structures on country labour productivity, as proposed in the adapted Lewis Model.

Although these insights highlight the importance of large firms' influence on country productivity, however, the means through which large firms may exert their influence on productivity is outside the scope of this study. Previous theoretical insights underscore their financial ability to undertake fixed R&D costs over a longer period of time, extensive skill training feeding into sector as a whole, ability to withstand longer product development times and access to funds for capital investment (Pack &Westphal, 1986; Achs & Audretsch, 1988; Brown et al., 1990).

This mechanism of the adapted Lewis model on the role of size of large firm presence in an economy on country productivity, may deliver some insights on the productivity conundrum currently present in the UK. Specifically, it draws the spotlight to the UK's reducing intensity of large firm presence. According to Van Ark and Monnikhof, the UK had a comparable large firm intensity to Germany in the 60's, but this had reached a lower intensity comparable to France in the late 80's (Van Ark & Monnikhof, 1996). Though this study's data does not contain direct intensity data, using firm turnover share to capture firm intensity, the UK in 2012 appears to have roughly a third the level of large to small firm intensity compared to Germany and about 60 percent of that in France. These figures are only approximations and not accurate enough to lead to firm conclusions. Nonetheless, they invite future UK firm-level research to examine carefully how changes in the varied firm size structures in UK over the decades may have impacted country labour productivity. Specifically, detailed research examining the means through which this relationship exerts an influence on country labour productivity.

Furthermore, this study assessed whether sector size and not only sector productivity was of relevance in determining country labour productivity. The analysis revealed size indeed to be important for some sectors, whilst sector productivity appeared significant for other, with a few sectors retaining both channels of influence. This was also an interesting result, from two perspectives. Firstly, if sector size is of import, as indicated, as well as sector productivity, then future policy making on productivity could best be served by looking at both these aspects. Secondly, this finding has possible implications for firm-structures most suited to sectors depending upon their mode of influence. Though needing further corroborations, the implication is that sectors influencing through size would benefit most from presence of turnover contributions of all three firm-size structures. In contrast, sectors contributing through sector productivity may benefit from a higher intensity of large firms in that sector. These implications were outside the scope of the current study, due to limitations of firm-structure classification at detailed sector level data. Should that data become available in the future, these implications could be corroborated allowing future policy support of firm-structures to be shaped in accordance to mode of influence of sectors.

Lastly, this study also examined whether sector share, the proportion of a sectors turnover share to total core innovative sectors turnover, as distinguished from sheer size of sector also exerts an influence on country productivity. In essence, sector share examines which unit change of a sector, irrespective of its size, influences country productivity most significantly, in effect refining the Lewis model to examine whether changing weightage of sectors in an economy influences country productivity. The results indicate that unit change of some sectors is significant for country productivity, although comparatively fewer sectors than those found significant for size of turnover. It would appear that focussing on size of sectors, as proposed in Lewis model is relatively of greater importance than consideration of the change of relative weight of a sector in the economy. Nonetheless, what is puzzling is that of those sectors found significant in terms of share, quite a large number appeared to have a negative influence on country productivity. Although isolating the cause for this result is outside the scope of the study, this could be indicative of a negative impact through either dominance or conversely weakness of sectors proportional to the total innovative sectors. Further in-depth research would be needed to assess whether this is or is not an issue for country productivity.

Chapter 4 Why does the UK not have its own Google, let alone a new ARM - does firm independence matter?'

An assessment of how firm independence and tax, financing and regulatory policy incentives are impacting firm growth in UK

4.1 Abstract

The UK is considered globally successful at generating innovative start-ups. Yet, despite this abundance of innovative start-ups, why has not even a single one of them scaled up and gone on to become at least one of the new future Googles of UK or a new ARM? That is the key question.

This chapter examines whether firm independence, previously not considered critical for firm growth, may indeed be an important criterion to enable scale up of innovative firms into successful frontier large firms. To shed light on the role of independence, the study examines the drivers of firm growth and the policy tools used to support tax & financing incentives along with M&A activity drive firm growth – with innovative independent firms separately assessed from overall innovative firms. Using firm level dataset for all UK sectors between 2006-2016, policy tax and financing tools supporting start-up, growth and merger activity are examined alongside growth theory drivers, globalization and monetary lending policy. The empirical analysis reveals that independent firms reap much higher growth, with age of independence delivering a bonus growth-dividend. Firm independence appears to be one of the most vital aspects for growth – an aspect neither enhanced nor specifically protected in current policy.

Other findings reveal that lower corporate tax rates promote innovative firms, though general firms can grow despite increased rates. Access to seed and venture capital was found positive both general and innovative firm growth, specially SMEs. The verdict on mergers and acquisitions (M&A) was slightly mixed, with M&As positive for general and innovative firms, though they do no drive innovative SMEs – only large innovative firms and general SMEs.

4.2 Introduction

Why has Europe not given birth to a significant tech company in the past 30 years, except ARM?, to paraphrase Michael Moritz's query (Moritz, 2016). Scrutinizing the 40 most valuable tech companies in Europe formed over the last 25 years, Moritz observed that ARM Holdings, a UK firm, was the sole European entrant. Although Moritz's observations were perhaps directed towards a defence of American tech companies, the question remains valid. Ironically, however, a few months after Moritz's question, the UK high tech firm ARM was taken over by a Japanese firm (BBC News, 2016). Even though ARM may have been the only British tech company in the top 40 by valuation created over the last few decades, it was not the only tech company sold to foreign ownership. In fact, there have been other potentially significant UK frontier technology companies created across that same period that were sold before they appeared to reach full potential - DeepMind, CSR, Swiftkey or Skyscanner, to name but a few.

It was however the sale of ARM holdings that provoked some outcries directed at the incoming prime minister, Theresa May, to reassess this potential takeover (Guardian, 2106), which also led to talks on revival of industrial policy with specific new national interest tests to vet foreign takeovers of UK firms (Financial Times, 2016). National interest tests to vet takeovers would not be unique to UK. Countries such as US have their own foreign takeover vetting system in the form of the Committee on Foreign Investment CFIUS (Jackson, 2016), as does Australia with its Foreign Investment review board (Ghori, 2015), amongst some other advanced nation states. As a point of fact, public interest tests were part of UK law earlier, until they were removed by the Enterprise Act 2002 (Elks, 2014). Indeed, this issue of public interest tests was also raised earlier in the UK during a potential foreign takeover bid by Pfizer for UK's second largest pharmaceutical firm AstraZeneca (Miliband, 2014). This issue was raised yet again by Unilever in its fight to stay independent against a hostile bid from Kraft-Heinz (FT, 2017). Unilever's urgings to reshape the UK takeover code, which in contrast to that of the Netherlands leaves firms far more exposed, were met by the government "with official shrugs" (FT, 2107). It appears that Unilever's recent decision to rebase its headquarters to Netherlands could be partly rooted in the greater protection afforded to firms in Netherlands from hostile takeovers (FT, 2018), bringing the issue of firm independence and mergers and takeovers to the fore. As GKN, another well-established aerospace UK firm, currently strives to defend itself against a hostile takeover (FT, 2018), it appears that the issue of independence cannot be ignored. Is independence then indeed critical to the growth of the firm and could it be one element in a complex puzzle to explain why UK has only managed to create one significant tech firm by market valuation over the last few decades. What has prevented UK from creating the global giants of today – and does independence matter?

It is this very question that this study aims to shed light upon. Answering it requires understanding firm growth at both ends of the spectrum. At one end, understanding the key growth drivers for small and medium sized firms (SMEs) and at the other end, understanding the key drivers for continued growth or rejuvenation of large UK firms. To put the importance of addressing both ends of this spectrum into perspective, it is perhaps best to understand the current position of both SMEs and large firms in the UK economy.

UK has quite an impressive position for generating innovative start-ups in the world. While the UK ranks 9th in the world on Global entrepreneurship index (GEI) for quality innovative start-ups in 2016, it was placed 4th in 2015 (GEDI , 2016). On the other hand, it ranks quite a bit lower, in fact 26th, on the GEI's finer scale of scale-up quality of start-ups. This scale, which measures quality of growth for start-ups/SMEs over 5 years, appears to capture a weakness in UK's scaling up ability of SMEs (ibid). This compares to US position as 1st in this measure, with France and Germany in 12th and 15th position respectively. An OECD analysis assessing start-up survival rates across 18 OECD countries, also found that only 5% of UK's micro firms still grew after 3 years (Criscuolo, Gal, & Menon, 2014). This scaling up weakness of UK start-ups is coupled with large firms diminishing on the UK economy landscape. Appraising large firm share in the UK's economy, OECD analysis revealed a decreasing trend in large firm share starting from the 1970's, which proceeded into the 1990's (Van Ark & Monnikhof, 1996). This trend was observed to continue by UK's business, innovation and skills (BIS) department reporting that large firm share in UK economy was 8 percent lower in 2013 compared to 2000 levels (BIS, 2013). However, the latest BIS figures appear to show a reversal of this trend, with current large firm share in economy in 2016 having risen back to 2000 levels of 0.13% share of large firm in economy (BEIS, 2016). Albeit positive that it has recovered to 2000 levels, it is perhaps important to realize that UK ‘s current large firm share of 0.13% compares to US large firm share of 0.81% in 2011 (SBA , 2016). That comparison reveals UK to have quite a gap, possibly as large as a factor 6-7 lower than the US. Given that current OECD analysis suggests US large firm share has continued to grow in 2016 (OECD, 2016), this gap could conceivably grow larger. To understand why this may matter – either a weakness in scaling up SMEs or a diminishing large firm share, it is perhaps best to understand how the landscape of firm-sizes in an economy relates to the two central pillars of UK’s growth: productivity and innovation.

One of the challenges facing UK economy since the 1970’s has been its lower productivity levels amongst the G-7, which have lagged behind those of France, Germany and US (Harari, Number 06492, 2016). This could be viewed as detrimental in the long run, as economic development models appear to stress that not capital, but rather productivity is the long run driver of growth (Lewis A. , 1954) (Gollin, 2014). Gollin indeed emphasizes the central role of resource allocation in generating productivity (Gollin, 2014). Around a similar period as Lewis, analysing growth models, Solow concluded that innovation was the most important factor by far in explaining long term economic growth (Solow, 1956). As productivity and innovation are viewed as complementary to each other, though often accompanied by a lag (Tunzelmann G. V., 2000), these theories and understanding of growth drivers are not contradictory. Previous research has shown that firm-sizes can play a critical role in shaping both innovation and productivity, the two driving pillars of growth in the long run.

The earliest research on firm size impact on innovation can be traced to an Austrian economist Joseph Schumpeter, who viewed firm size as one of the key elements influencing both these aspects (Schumpeter, 1934; Schumpeter, 1942). Schumpeter questioned which firm size was critical in driving innovation, initially emphasizing small firms (1934) and later advocating the critical role of large firms (1942). Subsequent research has shown that firm sizes play a complex role in innovation (Bhattacharya & Bloch, 2004; Achs & Audretsch, 1988). Although in terms of productivity, large firms were generally found to have higher productivity (Van Ark & Monnikhof, 1996; Van Biesebroeck, 2005; ECB, 2013), small firms have been found to be more productive in certain sectors

(Snodgrass & Biggs, 1996). A recent study examining firm-size share impact on an economy also found that large firm presence was significant in shaping country level labour productivity (Bradley, 2016). Although not conclusive, evidence does appear to support the importance of large firm share in an economy to drive productivity, with the presence of both small and medium sized firms important for employment and growth (Beck et al., 2005; World Bank, 2004; World Bank, 2002). Given this importance of firm-sizes to both innovation and productivity, but specifically large firm size impact on productivity - the query as to why UK has not been able to grow global innovative titans in frontier technology sectors, be it creative, science or digital sectors acquires even greater significance.

Thus, this study seeks to understand why UK has not produced the new innovative giants of tomorrow through analysing whether firm independence matters - and how this fits in alongside tax & financing incentives and M&A activity: policy tools which drive firm growth. The aim here is to determine how independence or policy tools influence firm growth and to distinguish insufficiencies in incentives or regulation currently, which may partially explain UK’s lack of frontier firm giants. Specifically, the idea is to distinguish factors having an impact on innovative firms, although overall firms are analysed as a starting point. The question, put in other words, is whether these various policy initiatives over the last few decades in UK could have inadvertently shaped the current UK economy – perhaps boosting the creation of innovative start-ups like DeepMind (Shead, 2016), but not sufficient to support firms to last the distance to scale up to create the Googles itself? Furthermore, as the sale of potential successful innovative UK firms before reaching their potential, which is a part of M&A activity, appeared to be of relevance to this issue - it became important to identify the impact of this firm characteristic – independence on firm growth. To identify the influence of independence, the growth reaped from basic growth drivers was examined relative to overall firms. As research is currently largely absent on the influence of firm independence on firm growth, this appeared to be an important void for this study to fill. Hence, the main contribution of this study is to understand the influence of independence on firm growth – which allows the value of the various growth policy tools to be put in context and thus to enable re-assessment of insufficiencies or shortcomings in the current policy toolkit, something which is important as independence is currently neither protected nor specifically supported in growth policy.

In order to understand this influence of policies and independence on firm growth, this study measures firm growth through revenue growth, one of the OECD defined measures of firm growth (OECD,2005). Previous studies have scrutinized some of the tax and financing policy tools impact on other firm aspects (Devereux & Maffini, 2006; Gemmel et al., 2010; Achleitner et al., 2012; Wright et al.,2009), but not revenue growth. However, as this study seeks to understand what enables the growth of firms to become the innovative giants of tomorrow, the various policy tools are examined for their impact on firm revenue growth.

To enable putting the value of independence on firm growth in context with other growth policy tools, it is first required to measure the influence of these policy tools on firm growth. The first tax policy tool or incentive considered for its influence on firm growth is corporate tax. Analysing its influence on firm growth seems particularly relevant, as UK has viewed it as one of the key policy measures to promote firm growth. So much so, that UK has been near the forefront in lowering corporate tax in G7 countries over the last decade, although it is not the only OECD country vying to lower this tax (Devereux & Vella, 2014). As a point of fact, UK's corporate tax at 29% in 2009 was the second lowest statutory rate amongst the G7 (Griffeth & Miller, 2010), and the UK rate became the lowest in G7 when it was lowered to 26% by 2012 (Bilicka & Devereux, 2012). As corporate tax has been considered an important policy tool, it has drawn valuable previous research, yet this previous research seems not to have focussed on firm revenue growth. Conducting an extensive review, Devereux & Maffini classify the focus of various corporate tax studies on assessing the impact on location of capital, firm production and firm profits (Devereux & Maffini, 2006). Furthermore, corporate tax has been examined for its influence on investment, productivity and innovation as measured by total factor productivity (TFP) (Vartia, 2008; Grubert & Mutti, 2000; Gemmel et al., 2010; Devereux et al., 2016). This study, in contrast, seeks to understand if this policy measure of lowering corporate tax, actually influences the growth of firms. In particular, it will explore whether lowering of corporate tax will promote growth of the innovative firms, which could become the frontier giants of tomorrow.

Another area of tax, also missing previous examination for its impact on firm growth, are UK's competitive tax relief incentives around venture capital investment and capital gains tax. In fact, UK has maintained the lowest capital gains tax rate amongst G7 economies since 2000, as an incentive to promote venture capital investment (Achleitner et al., 2012). This low capital gains tax exists alongside financing incentives to support innovative start-ups, such as the enterprise investment scheme (EIS) which UK has operated since 1994 (OECD, 2015) or the Venture Capital Trust Scheme (VCT) offering relief to indirect investments into smaller businesses operational since 1995 (ibid), These have been further enhanced through the introduction in 2012 of a Seed Enterprise Investment Scheme (SEIS) (OECD, 2015). Nonetheless, despite all these initiatives UK venture capital ratio relative to GDP is still about a factor 7~8 lower than US (OECD, 2016). Wright et al, reviewing extensive studies on private equity, show that these venture capital studies cover a wide area of impact extending from profitability, productivity, employment and wage growth to investment strategies (Wright et al., 2009). Surprisingly, these previous studies have not assessed venture capital's impact on firm revenue growth, despite the fact that these policy initiatives appear to be aimed at firm growth, involving both the scaling up of start-up firms, as well as rejuvenation or growth of medium and large firms. Yet, the assessment of venture capital on firm revenue growth seems essential, in order to judge the importance of these venture capital-enhancing policies in shaping the innovative firm landscape of the economy. Thus, this study aims to fill this gap by examining how venture capital shapes firm growth, as well as enable placing these policy tools in context with other policy tools and firm characteristics for their importance in creating the innovative giants of tomorrow.

The analysis of mergers and acquisitions (M&A) influenced both by policy regulation and policy incentives, on firm growth appears also essential. The impact of private equity is not only through venture capital for start-ups, but it appears to have a potential impact on medium and large firm growth through mergers and acquisitions as a means of accessing new knowledge (Purunam & Kannan, 2005). In fact, business historians assign an important role to mergers and acquisitions in creating British conglomerates post-Second World War period (Toms & Wright, 2002). In contrast, Chandler, another business historian, views mergers and acquisitions as having only a subsidiary role in large firm growth, emphasizing instead the role of organic growth (Chandler A. , Scale and Scope, 1990). Not denying acquisitions could serve as a possible means for accessing new technologies, Chandler cautions that historically they also appear to have destroyed value across a range of industries (Chandler A. , 1994). As Wright et al. (2009) pointed out in their review, private equity in the form of mergers and acquisitions has been empirically analysed for its impact on employment, wages, profitability and innovation. This debate raging within business history upon the role of mergers and acquisitions impact on medium and large firm growth underscores the importance of assessing the impact of this activity on firm revenue growth in econometric analysis. More importantly, as mergers and acquisition form the channel through which firms not only grow but also lose independence, its impact on firm growth needs to be evaluated. If the impact of mergers and acquisitions activity on firm growth outweighs the gains of growth from firm independence, then firm independence should not be an issue of consideration for policy regulation. If, however, firm independence surpasses impact of other policy tools in influence, then some form of policy regulation to support independence may become advisable.

Analysis of these policy regulations and tools on firm growth appears essential, as successive UK governments have launched a multitude of policy incentives over the last few decades, aimed at increasing firm growth. Peculiarly, analysis of these incentives on firm revenue growth itself has been absent. Notably, despite these globally competitive tax and financing incentives, firms have not grown to become the frontier UK giants of tomorrow. More so, regulation hindering mergers and acquisitions was reduced since the removal of public interest tests in Enterprise act 2002, also aimed at boosting firm growth. Yet despite these myriads of initiatives, its puzzling that UK has not created even one of the frontier global giants of tomorrow. This study seeks to shed light on this puzzle by assessing the impact of these policy initiatives on firm growth. Have these policy tools been perchance been insufficient, or could policy regulation have missed protecting/enhancing firm independence, if that is an important firm characteristic for growth itself? This analysis undertakes to put all these policy tools in perspective, alongside the firm characteristic of independence – to try to determine, whether or which aspect is most critical for firm growth.

The outcome was quite unexpected. Contrary to expectations, the impact of independence on growth seems to outweigh other influences, though policy tools still provided valuable aid to growth. Independence, not only allows innovative firms to reap much greater response from basic growth drivers, there also appears to be a bonus independence growth dividend based solely on the years that a firm can manage to stay independent. This independence growth dividend appears to deliver a quite astonishing 15% growth for each year of independence, albeit at 15% significance. It appears that independence has a large impact on firm growth and the fact that currently there is no policy tool in place either to support or protect it, may be one of the reasons that UK's innovative firms struggle to scale up into the future frontier UK giants of tomorrow.

Notwithstanding the importance of firm independence as a vital influence on growth, policy tools remain a critical component to aid growth. However, even the analysis of policy tools led to some surprising outcomes. It appears, that general (innovative and non-innovative) firms can grow despite increases in corporate tax rates, contrary to expectations. However, the policy of lowering corporate tax rates does appear to benefit innovative firms, where lowered corporate tax rates are positive for firm growth. Albeit, the magnitude of impact on firm growth is relatively small and as such, this context should be kept in mind when weighing the cost of such a policy tool. Thus, it would appear that a blanket policy on corporate tax rate reduction may not be the best choice, rather a tailored policy approach adapted to type, and size of firms seems advisable, weighing the benefits of this policy carefully against the costs. In contrast, access to seed and venture capital does appear to be an important source of finance to support long-term growth for both general and innovative small and medium (SME) sized firms, albeit yet again the magnitude is relatively small. It would seem that policy tools enhancing seed and venture capital promote across the board, both general and innovative SME firm growth. Indeed, it seems these policy tools need further enhancing, as UK has approximately a factor 7~8 lower availability of venture capital ratio to GDP relative to US

(OECD, 2016). The verdict on mergers and acquisitions was slightly mixed. Mergers and acquisitions (M&A) were analysed through both management buy-outs (MBO's) and buy-ins (MBIs) impact on firm growth. The findings suggest that M&As are positive and significant, with a similar impact for both general and innovative firms. Yet again to put the impact in context, it is not large relatively, as MBO's which include external hostile/consensual takeovers as well as management buyouts, have about half the impact of venture capital. In contrast MBIs seems to have a much higher impact than venture capital, though MBI's make up a very small fraction of M&A activity (Wright & Wilson, 2013). More so, detailed analysis revealed that M&As do not drive firm growth for innovative SME's, only large innovative firms and general SME's. It would appear that M&A play a differing role in promoting growth for different firms and thus remain an important tool of choice for creating a diverse economy– it appears not to be the option for delivering growth for innovative SME firms.

These results show the importance of maintaining a diverse policy tool kit for growth, yet at the same time underscore the importance of bringing in some policy tools to either support or protect firm independence, given its reasonably large impact on firm growth. Especially, as policy is currently absent in this area.

The rest of this study is organised as follows. The next section reviews the previous studies conducted on the tax and financing incentives taken into consideration for this research, selected for their influence on reducing finance constraints for firm growth. These include impact of seed and venture capital on firm growth, impact of mergers and acquisitions on large firm growth and studies on corporate tax impact. This is followed by the empirical section, describing methodology, analysis and results. The conclusion summarizes the findings and possible policy considerations.

4.3 The selection of tax and financing policy incentives for this study for their impact on firm growth

As mentioned in the introduction, this study aims to understand the drivers of firm growth and place the various tax and financing policy tools currently targeted at firm growth in context of these drivers, lastly distinguishing whether the characteristic of firm independence influences either growth itself or these drivers. The tax and financing policy tools impacting firm growth considered for this study are those that have been a key focus of British government over the last few decades, which include: corporate tax; seed and venture capital financing incentives; and impact of mergers and acquisitions on firm growth.

To enable this objective, the next sub-sections firstly explain why these tax and financing tools have been selected and thereafter explores the previous studies conducted on these tax and financing objectives and examines how they have been researched for their impact on firm growth.

4.3.1 Why tax and financing incentives that shape finance for firms matters for firm-growth

The selection of tax or financing incentives for their impact on firm growth is rooted in the basics of growth theory. Although basic growth theory would hold that both physical and human capital, alongside innovation, are critical to growth (Solow, 1956), this study focuses on policy incentives aimed at enhancing physical capital for firms, in particular those reducing financial constraints on firms. Using the lens of finance as a growth constraint on firms, the tax and financing incentives are identified for those that may have impacted the current firm landscape of UK.

Although Lucas may have disregarded the importance of finance in growth as an “over-stressed” driver of economic growth (Lucas R. , 1988), Schumpeter long advocated the importance of finance in driving economic growth (Schumpeter J. , 1912). Previous studies would appear to endorse Schumpeter’s view, as their findings generally appear to support availability of finance as one of the pertinent enablers of both economic and firm growth. Levine, reviewing a wide array of theoretical and empirical studies on the inter-connectedness of finance and economic growth, concludes that overwhelming evidence suggests that availability of finance, through financial intermediaries or markets, appears to matter for economic growth (Levine, 2005). Focusing specifically on impact of finance and firm growth using cross-country research, Beck and Demirguc-Kent found that constrained access to finance can have significant diminishing impact on small and medium sized (SME) firm growth (Beck & Demirguc-Kent, 2006).

Their research suggests that small firms particularly face larger constraints on access to formal sources of external finance, thus hampering growth. Aghion et al. (2007), evaluating both entry and expansion of small firms in industrialized and emerging economies, observe that access to finance has again a significant impact on the entry of firms, but also particularly in influencing their expansion growth. Assessing different sources of finance impact on firm growth, Segarra and Teruel (2009) associate the availability of long-term debt with high growth firms, with short-term debt being correlated to lower growth firms.

Furthermore, assessing finance’s impact on innovation, Savignac (2008), using a specifically designed innovation survey for French firms, observes that financial constraints are also seen to hamper innovative activity. Even when Fernando and Ruggieri (2015) examine the impact of restrained financial access on firm labour productivity, they observe that financial constraints impact it negatively. Thus, financial constraints appear to have a significant impact on firm growth, be it through direct influence on growth or through hampering innovation and productivity in firms.

Over the last few decades UK has competitively engaged in certain tax and financing incentives, which could have influenced finance constraints of firms. In particular, these would include venture capital, mergers and acquisitions and corporate tax, which are investigated in this study.

4.3.2 What have previous studies on Venture capital deduced for firm growth

Venture capital is a critical source of finance for firms, alongside traditional bank lending, especially for high-risk but also high-growth innovative firms. An OECD project on SMEs and Entrepreneurship (WPSMEE) undertook an extensive review of financing options for SMEs, as part of its objective to understand the challenges facing both start-ups and small and medium sized firms (OECD, 2015). While acknowledging that bank lending remains an integral part of finance for many SMEs, they recognize the challenges in accessing traditional finance for both innovative higher risk start-ups, as well as SMEs seeking to change ownership structures or to de-leverage and improve their capital structures (ibid). Reviewing options of external financing alternative to straight debt, they observe that equity financing targets the start-ups or innovative high-risk SME's with the potential of high growth. According to their classifications of alternative financing, equity finance incorporating venture and seed capital, as well as private equity, can provide significant access to finance to overcome the capital gap often faced by such firms.

Specifically, analysing the impact of venture capital on young and high growth firms in Germany, Engel finds that surviving venture capital backed firms appear to have higher employment growth compared to non-venture capital funded comparable firms (Engel, Discussion paper 02-02, 2002). Moreover, his findings appear to indicate that venture capitalists are able to push firms towards higher growth compared to other investors. However, when using German firm data to distinguish the impact of venture capital on growth as well as innovation, Engel and Keilbach found that while venture capital has indeed a positive impact on firm employment growth, it appears not to have a significant impact on innovation (Engel & Keilbach, 2007). This finding was further corroborated by Peneder, using Austrian firm-level data to examine impact of venture capital on firm growth, observes that while venture capital impact is positive on firm growth, it appears to have no impact on innovation output of firms (Peneder, 2010). It would appear that these findings suggest that while venture capital has a positive impact on growth, it is less so on innovation. In fact, Engel and Keilbach imply that venture capitalists pre-select innovative firms and focus on enhancing commercialization of the innovative product, rather than adding to innovation itself (2007).

Using Swedish survey data, Smlarski and Kut use their study to qualify the impact of incremental versus lump-sum venture capital finance, combined with number of external investor involvement on firm growth (Smolarski & Kut, 2011). According to their analysis, firm growth is positive with either incremental financing or a syndicate of two or more investors. However, when these two aspects are combined, this appears to have a negative impact on firm growth. Thus, the type of investor involvement combined with method of financing appears to alter the impact of venture capital on firm growth.

Lastly, the research by Bottazi and Da Rin using European data, caution that financing policy incentives to encourage venture capital may not be sufficient in themselves to deliver firm growth, unless the policies and regulations to support maturing of capital markets are in place to support it (Bottazi & Da Rin, 2002). While they do find venture capital provides critical access to finance for otherwise constrained highly innovative firms, they do not find venture capital-backed firms grow any quicker than non-venture capital backed firms. Intriguingly, they imply that this could to some extent be attributed possibly to immature European capital markets. Their supposition is based on the lengthy time period taken to develop venture capital industry in the US. Describing the historical path taken by US venture capital, they trace the establishment of the first venture capital fund American Research and Development (ARD) in 1946. However, the maturation of the venture capital was not straightforward, with the 1980's still finding venture capital heavily reliant on publicly funded Small Business Investment Companies (SBIC). According to Botaazi and da Rin, the industry only really managed to take off in the late 1980's, after the 1979 Employment Retirement Income Stabilization Act had enabled pension funds to invest in venture capital. The resulting overwhelming increase in funds allowed SBIC's to be gradually replaced by limited partnerships as the dominant form of venture capital firms, resulting in the successful venture capital industry of today. These studies caution that venture capital financing incentives in themselves may not be sufficient to increase the impact of venture capital on growth – that polices and regulations to support maturing of venture capital markets may be as necessary a part of this process. Aspects which cannot be evaluated with the current data unfortunately and thus a possible limitation to this studies analysis.

These various studies provide us with valuable insights into the impact of venture capital and how that process was built up over time. Nonetheless, there are opportunities to build upon this research and take the analysis somewhat deeper, specifically through using firm level data. These studies, limited often by shortage of data, were often confined to evaluating venture capital's impact on firm growth through comparing growth between similar subset of venture capital backed or non-venture capital backed firms. Notwithstanding their pertinent conclusions, they were unable to distinguish between seed and venture capital effect on firm growth mainly due to data limitations, nor could they capture a direct correlation measure between venture capital investment and firm growth. These are some of the gaps that this study hopes to provide further insights on.

4.3.3 What is known about the impact of mergers and acquisition impact on firm growth

Following up further with policy tools that influence firm growth alongside access to finance, mergers and acquisitions (M&A) is another route for firm growth. Indeed, it is a tool of firm growth, which was employed by British firms in the 20th century, the benefits of which have been debated by business historians and management literature. In particular, this tool is of interest, as there has been a debate across the field of business history and management literature, whether M&A still remain a pertinent route of firm growth, with the debate on the merits of organic growth versus growth through acquisitions.

According to business historians, mergers and acquisitions (M&A) have played an important role in large firm growth in the first half of the twentieth century, allowing British firms to create their own conglomerates to catch up with US firms (Hannah, 1983; Lamoreaux, 1988). Yet, this appears to have changed in the second half of the twentieth century, with Chandler viewing mergers as subsidiary to large firm growth and instead emphasizing the role of organic growth (Chandler, 1990; Chandler, 2005). However, Miskell & Jones following resource-based management literature (Harrison et al, 1991), find that complementary rather than related acquisitions can provide valuable source of growth for large firms (Miskell & Jones, 2007). These historical studies, though not conclusive, appear to assign at least a subsidiary if not slightly more significant role to acquisitions and mergers in large firm growth. In fact, it would appear that acquisitions could be important in rejuvenating large firm growth, depending on the type of acquisitions.

The significance of type of acquisition in determining the impact on large firm growth appears to be borne out also in management studies. Recent management studies examining acquisitions have found technology sourcing to be one of the motivations driving mergers and acquisitions (Desyllas & Hughes, 2008; Ruckman, 2004). These technology-driven acquisitions have led to some financial studies evaluating the consequent market valuations of acquired firms

(Feys & Manigart, 2010) , as well some management studies examining the impact of acquisitions on consequent innovation of the combined firms (Cefis, 2010).

Despite this varied historical and management analyses on mergers and acquisitions, econometric analyses examining the impact of mergers and acquisitions (M&A) on the growth of the consequent combined firm seems to be largely absent. Previous empirical studies appear to have mainly focussed examining impact of M&A activity on employment or wage growth, not firm growth. Burghardt and Helm use Swiss firm data for newly acquired firms to assess employment growth (Burghardt & Helm, 2015). They find that the size of the acquiring firm is correlated positively to the labour growth of the newly acquired firm. Contrastingly, the combined size of the net establishment is negatively related to its net workforce growth. Conyon et al. (2002), examining the impact of mergers on employment in UK firms, suggest that the combined merged firms tend to reduce labour after mergers, while Gugler and Yutoglu (2004) find similar negative effects for mergers amongst European firm, though not amongst US firms. Another management study, using Swedish data, assesses firm growth in order to distinguish whether firm growth drives acquisition or the reverse (Xiao, 2013). These studies mainly yield insights into the impact of mergers and acquisitions on employment growth and its impact on labour growth within the merged units of the firm.

On the whole, it would appear that mergers and acquisitions seem to exert a significant impact on large firms, though this could be a positive or negative impact based on a complex set of criteria. This is perhaps a positive impact when it leads to rejuvenation of technology or absorption of new capabilities, with a possibly more negative influence if merger focus detracts from organic growth.

Given the importance of this influence of mergers and acquisitions on firm growth, it is perhaps also pertinent to understand the limitations of the influence of tax policy on this process. Although private equity buyouts have been critiqued as a possible tax shield (Treasury Select Committee, 2007), Auerbach & Reishaus previously researching US firms found no strong evidence to support taxation as a driving factor in merger activity (Auerbach & Reishus, The

Effects of Taxation on the Merger Decision, 1988). Indeed, Auerbach and Reihaus, evaluating American firms, did not find tax benefits to play an important role in shaping the activity of mergers and acquisitions (ibid). However, Klodt and Kleinert reviewing merger waves over the last century, attribute increased merger activity to sectoral shocks, with deregulation and globalization possibly influencing the last wave of mergers (Kleinert & Klodt, 2002). Thus, though tax policy itself may not have a direct influence on mergers and acquisition, it appears the regulations governing the wider financial sector have had a significant impact on the process.

These historical and empirical studies yield insights, which may help explain the complex interaction shaping the outcomes of mergers. Nonetheless, it is noteworthy that there is an absence of empirical analysis examining the impact of acquisitions on firm growth. Yet, it is precisely this insight on the impact of mergers and acquisitions on firm growth, which could perhaps some shed some light on explaining the decline of larger firm share. Did UK large firms not have the option of technology acquisition, or was there some other obstacle hampering their innovation? An empirical study may not be able to answer conclusively, but it may provide some clues to deepen our understanding of this process.

4.3.4 **Impact of Corporate tax on firm growth**

Essentially, this research to assess finance constraints, along with mergers and acquisition impact on firm growth, is motivated by the expectation of clarifying or at least placing some order of significance on policy incentives, specifically the policy incentives that could influence this firm growth. Within that framework, there is the multitude of tax relief schemes associated with EIS, SEIS and VCT. Furthermore, there is capital gains tax and lastly, corporate tax. Corporate tax perhaps deserves a particular mention, as it has been long considered a means to attract inward investment by foreign MNC Britain, as well as make British medium and large firms competitive (Devereux & Vella, 2014; Devereux et al., 2002).

To understand its impact on inward investment and firm competitiveness, Devereux and Maffini (2006), conducting an extensive review of studies, conclude that tax does appear to play a role in location and capital allocation choices of multinational firms (MNC). Using American MNC firm data, Grubert and Mutti (2000) find that average effective tax rate appears significantly to influence the location of capital invested in a host country. Using industry level data for 16 OECD economies, corporate tax is found by Vartia (2008) to reduce investment as well as productivity. Using Firm level data in OECD countries, corporate tax is also found to have a negative impact on innovation, along with investment (Gemmell et al., 2010). Devereux et al. (2016) examining the influence of capital allowances, a sub component of effective marginal corporate tax rate, conclude that it has a significant impact on investment.

These numerous studies provide substantial evidence that corporate tax can have significant impact on MNC choices of investment and location and profit diversion. Yet, an empirical analysis directly between firm growth and corporate tax appears absent. This study aims to fill this gap, which could provide a direct insight into the supportive impact of corporate tax on making domestic firms competitive.

4.4 Methodology and Data

As stated earlier, this study's main contribution is to fill the void of research on impact of independence on firm growth. Furthermore, using this understanding of the impact of independence to place the value of the current policy tools in context, clarifying which policy tools are supportive or perhaps even detrimental to growth. To this end, it was imperative to keep firm growth as a point of focus – assessing initially general (innovative and non-innovative) firms, thereafter both overall (independent and non-independent) innovative firms and independent innovative firms, measuring firm growth by revenue growth, one of the OECD defined measures of firm growth (OECD, 2005) and specifically, distinguishing the impact of independence on innovative firm growth, identifying in the process the type of firms which can potentially grow into frontier giants.

4.4.1 Data Sources

This research uses firm level data sourced from Amadeus database from Bureau Van Dijk, extracted from Wharton Research Data Services (WRDS) database.

Relevant variables are downloaded both from profit/loss account and balance sheets of firms.

UK Firm-level Panel data is analysed for time period 2006-2016 for all sectors - 89 in total. The firms are analysed initially incorporating all firm sizes. This is followed by separate analysis per firm-size class: large, medium and small firm size-classes, as defined by OECD.

Data separating investments on early stage seed funding, later stage venture capital funding (2nd and 3rd round), as well as differentiating management buy-out & management buy-in funding from replacement capital is only available at country level on an annual basis from industry reports by the British Venture Capital Association (BVCA).

Interest rate data for UK is collected from World data bank from IMF database.

4.4.2 **Methodology**

Using Fixed effects estimation, this analysis seeks to shed light on corporate tax and financing incentives and its influence on firm growth. Firm growth, as measured by annual turnover growth as a share of operating revenue, is regressed upon by a set of varied variables. The variables of interest are sourced from either firm-accounts data or BVCA sector level data, in order to throw light of the tax and financing incentives on actual firm growth, which has been empirically absent in current literature. It also aims to shed light on the differential impact of mergers and impact on firm growth, where differences exist either in the qualitative business history literature or there is absence of actual firm growth measurement, as in management literature.

A) Dependent variable:

As Firm growth, the dependent variable, is measured as annual firm growth. This is deduced from the profit/loss account sheet of firms as annual growth in Operating revenue/turnover as % age of operating revenue.

Firm growth (F_{irm} G_{rth}) = [Operating Revenue – Lagged Operating revenue]/Lagged Operating Revenue

B) Variables of interest: tax and financing incentives and firm independence

As referred to earlier, although corporate tax has drawn substantial valuable research, yet it is lacking specific analysis on how it may have shaped firm growth. Using firm level data drawn from Amadeus database, based on similar measures used in studies reviewed by Devereux et al. (2006), this study considers measuring corporate tax either through using EBIT (earnings before income tax) or Profits (P/L) before and after tax, from the profit/loss account of firms:

Corporate tax measure ($C_{orp}T_{ax}$) = [P/L before tax – P/L after tax]/Gross profits

To examine impact of tax relief incentives such as capital gains tax reduction through schemes such as enterprise investment schemes (EIS), Seed Enterprise Investment Scheme (SEIS) and a mixture of corporation tax and capital gains reduction through Venture Capital Trust Scheme (VCT) on firm growth, this study assesses them through their impact on venture and seed capital investment. As detailed firm data for these aspects is not available, this study uses venture capital investment and seed/angel investment data aggregated at country-level compiled by British Private Equity & Venture Capital association (BVCA).

Capital gains and venture capital tax schemes are differentiated for their impact on early stage funding (seed and early stage venture capital aimed at initial stage of start-up), from that of later stage funding (2^{nd} and 3^{rd} round of funding, usually for expansion of firm) and any other form of later stage funding. These are thus measured as:

- To capture Seed and Enterprise investment schemes:

  ($S_{eed}I_{nv}$) = Investment Amount (measured in unit of million pounds) in early stages Seed funding and early (1^{st} round) Venture capital (sector specific)

- To capture venture capital investment schemes and impact of capital gains tax:

$(V_{en}\,C_{ap})$ = Investment Amount (measured in unit of million pounds) in later stage (2nd and 3rd round of funding) Venture capital (sector specific)

- To capture other forms of later funding rounds:

$(L_{at}\,V_{en}\,C_{ap})$ = Investment Amount (venture capital) (measured in unit of million pounds) in further later stages of firms(sector specific)

Given the debate around different impacts of mergers and acquisitions based on type of merger, an attempt is made to differentiate these activities. As private equity tax relief measures not only influence seed/venture capital investment, but also mergers and acquisitions, this differentiation will be quite crude. Yet it may give an indication. While some management theories suggest acquisitions can be positive for firm growth if used to acquire new technologies, some business historians suggest that these could be negative when distracting from organic growth. Furthermore, the debate on reinstatement of national interest tests, based on the earlier removal of public interest tests in Enterprise act 2002, makes this issue a separate concern.

This study thus tries to separate private equity activity from venture capital and aims to measure merger and acquisition activity, using BVCA sector level data.

Although the measures are only approximate due to lack of detailed data, private equity buyouts termed as secondary buyouts are captured in the replacement capital term, which is a combined term of secondary buyouts, replacement capital (capital repair and depreciation) and bank refinancing.

- Hence secondary buyouts reflective of private equity are measured by:

Replacement Capital $(R_{ep}\,C_{ap})$ = Capital invested for Secondary buyout + Replacement capital + bank refinancing.

Furthermore, data allows differentiation between types of management buyouts:

- Firstly, Management Buyouts, while these normally refer to management team of the firm buy their own firm, in this data this term has a wider classification in the industry reports by BVCA. This is understood as follows:

  Management Buyout (MBO) = It includes capital invested by management teams to buy own firms (MBOs), but also Institutional Buyouts (IBOs): capital used by private equity, venture capital or commercial financial institution to acquire a firm, could be in cooperation of target firm or hostile takeover, which may include leveraged buyouts (LBOs), which incorporates use of highly leveraged or borrowed funds to acquire target firm.

- Secondly, if an external management team buys a controlling stake in the firm, replacing the existing management team – usually if a firm is undervalued, poorly managed or needing succession:

  Management Buy-in (MBI) = Capital invested (unit millions of pounds) by external management team to replace existing team.

A related measure to mergers and acquisition available in Amadeus database, is the independence indicator[13] based on ownership data:

- Indep (F_{irm} I_{nd}) = Independence of a firm is indicated by A or A- or A+ status. Else it has another ultimate owner

This defines whether the firm is independent or owned by another ultimate ownership, indicative of a buy-out or acquisition of firm by an external firm. It is to be noted that firm independence in this aspect primarily checks that the firm has no controlling shareholder. This independence indicator mainly assesses whether any shareholder (excluding public shareholders for quoted firms), be it

[13] Definition in appendix

an owner, financial firm or industrial firm has controlling shares, with equity over 25%. This indicator would capture loss of independence of firms which have been acquired by another firm, but would mistakenly also classify some of the big Silicon Valley independent firms as dependent. These are exceptions and only few, which follow the trend set in Silicon Valley after Steve Jobs experience of being ousted from Apple, where founders have sought to retain controlling shares, if possible. This is evident in Facebook (Financial Times , 2017) or Tesla (Los Angeles Times, 2018) to name a few, but not so in Amazon or Alphabet. Thus, although this measure may mistakenly miss some successful UK independent firms, which similar to these Silicon Valley icons may have retained controlling shares by founders, this indicator in the main may be understood to represent independent firms, not acquired by another firm or private investor.

Another possibly relevant measure, to assess maturity of firm:

- Firm Age ($Firm_{age}$) = The time span between year of analysis and firm's year of incorporation

C) Control Variables

To examine impact of these tax and relief incentives on firm growth, it is necessary to ensure other control variables are in place to capture elements from growth theory, globalization and monetary policy.

The control variables rooted in growth theories, firm-level measures such as capital expenditure and human capital can be extracted from the profit/loss account and measured for their growth:

- Gross capital Growth measure ($G_{ross}\ C_{ap}\ G_{rth}$) = [Fixed assets (Tangible) – Lagged Fixed assets (Tangible)] / Lagged Fixed assets (Tangible).

- Human Resource (employees) ($C_{ost}\ E_{mply}\ G_{rth}$) = [Cost of staff Employees – Lagged Cost of staff Employees] / Lagged Cost of staff Employees

A possible variable to capture both the innovativeness of the firm, as well as an aspect of technology considered critical for national innovation systems, is R&D

expenses. R&D expenses, as defined in firm data, captures both internal R&D or firm costs for R&D alliances, which implies the firm could itself be developing that innovation or buying in that research. Yet, in the absence of other measures, it is a reasonable measure to serve as a proxy for the innovative level of the firm. This is also available through profit/loss accounts:

- Hence, technology (R&D G_{rth}) = [Research and Development expenses – Lagged Research and Development expenses] / Lagged Research and Development expenses

To capture aspects of globalization of firms, firm level data on export revenues are also extracted from profit loss account:

- Export (E_{xp} R_{ev} G_{rth}) = [Export Revenue – Lagged Export Revenue] / Lagged Export Revenue

- To capture impact of monetary policy:

  Interest rates (I_{nt} R_{ates}) = Bank of England interest rates set nationally

D) Summary statistics and correlation matrix of Variables

Summary statistics of the variables used in this regression are listed in Table 4.1 below. It is to be noted that not all firms provide data on the variables used in our regressions. In particular R&D expenditure is available for a much smaller subset of firms, which is used by this study to indicate innovativeness of firm as mentioned above. Similarly export data and skilled human resource costs data is also less prevalently available in firms, though more so than R&D expenditure.

Table 4.1:Summary statistics of variables used in regressions

	Observations	Mean	Standard Deviation	Min	Max
Firm growth	1,479,257	2587.4	689377.6	-8.7e+07	5.58e+08E+08
Year	2,073,538	2010.72	2.85	2006	2017
Gross capital growth	1,127,045	1570.12	380611.9	-1754000	3.17e+08
Skilled Human Resource growth	583,164	100.04	27969.2	-548.5	2.11e+07
R&D expenditure growth	14,077	337.5	16016.7	-906.73	1291225
Export Growth	120,665	537.6	52750.2	-11766.1	1.06e+07
Corporate tax growth	572,789	67.34	50249.6	-1.78E+07	3.05e+07
Firm age	2,072,102	14.5	16.32	0	159
Later stage funding	1,463,763	1346.33	345.03	841	1772
Replacement Capital (includes secondary buyouts)	2,020,054	1160.57	651.7	254	2669
Management Buy-out (MBO) capital	2,020,054	3365.73	1864.665	1051	7373
Management Buy-in (MBI) capital	2,020,054	120.25	92.95	16	348
Other late funding	1,666,580	538.85	533.67	143	1886
Lending interest rate	1,843,457	1.86	2.05	0.5	5.5
Dummy independence	2,073,538	0.08	0.26	0	1

In addition to the summary statistics listed above, the correlation of variables is listed below in Table 4.2 and Table 4.3. As the variable Early stage funding with Later stage funding shows a high correlation, the variable Early stage funding is dropped from the final equation used in the regressions in order to reduce potential errors arising from multicollinearity.

Table 4.2:Correlation Matrix values (observations 56,191 – if R&D excluded)

	Firm growth	Gross Capital growth	Skilled Human Resource	Export Growth	Corporate tax growth	Firm age	Early stage funding	Later stage funding	Replace ment capital
Firm growth	1								
Gross capital growth	0.007	1							
Skilled Human Resource	0.22	0.007	1						
Export Growth	0.001	0.0002	0.03	1					
Corporate tax growth	0.17	-0.0001	0.003	.0003	1				
Firm age	-0.04	-0.0023	-0.03	-0.003	0.0007	1			
Early stage funding	0.01	-0.0004	0.006	-0.0004	0.0021	-0.004	1		
Later stage funding	0.0013	0.0005	0.007	-0.003	0.0039	-0.002	0.913	1	
Replacement Capital (includes secondary buyouts)	0.013	0.001	0.0036	0.003	-0.004	-0.007	0.763	0.48	1
Management Buy-out (MBO)	0.017	-0.0004	-0.0018	-0.003	-0.002	0	0.443	0.606	0.23
Management Buy-in (MBI)	0.008	0.0034	-0.0007	0.006	-0.01	-0.005	-0.32	-0.51	0.32
Other late funding	0.006	-0.001	0.0008	-0.003	-0.003	0.009	0.005	-0.17	0.37
Lending interest rate	-0.02	-0.003	0	-0.003	0.009	0.005	-0.17	-0.12	-0.54
Dummy independence	0.013	-0.0003	0.0007	-0.002	-0.001	0.059	0.0002	-0.0003	-0.002

	Managment Buy-out (MBO)	Manage ment Buy-in (MBI)	Other late funding	Lending interest rate	Dummy independence
Management Buy-out (MBO)	1				
Management Buy-in (MBI)	-0.27	1			
Other late funding	0.74	-0.56	1		
Lending interest rate	-0.545	-0.654	-0.045	1	
Dummy independence	-0.001	0.004	-0.005	-0.003	1

Table 4.3 Correlation Matrix – for R&D growth (observations 5,736 – if R&D included)

	Firm growth	*Gross Capital growth*	*Skilled Human Resource*	*Export Growth*	*Corporate tax growth*	*Firm age*	*Early stage funding*	*Later stage funding*	*Replace ment capital*
R&D growth	0.027	-0.0006	0.017	-0.0007	0.0005	0.028	-0.004	-0.006	0.003
	Managment Buy-out (MBO)	*Management Buy-in (MBI)*	*Other late funding*	*Lending interest rate*	*Dummy independe nce*	*R&D growth*			
R&D growth	-0.006	0.009	0.003	-0.003	-0.007	1			

4.5 Empirical Analysis

Going back to the aims, this study seeks to understand why UK has not produced the new innovative giants of tomorrow through analysing whether firm independence matters and how this may fit in alongside current policy tools which drive firm growth: tax & financing incentives and M&A activity.

As such the first regression assesses what drives frim growth - examining growth drivers alongside the tax and financing incentive policy tools as well as M&A activity, as these are considered to be policy tools targeting support of firm growth. These drivers and policy tools are overall examined for their impact on firm growth for overall general (on-innovative and innovative) firms and then compared for their impact on innovative firms. Upon shortlisting the drivers that matter most for driving innovative firms (the object of this study), then a regression is performed examining how these short-listed drivers may differ for independent firms, trying to answer whether independence matters for firm growth.

Before listing regressions, the model is explained briefly in next sub-section.

4.5.1 **Model**

For all the regressions, an initial set of drivers based on the rudiments of growth theory and globalization as defined in above section are used as control variables, alongside the policy variables of interest to evaluate impact of tax and financing incentives on firm growth. The variables used in model are listed in Table 4.4.

Table 4.4: Variables used in Model, source (author)

Dependent variable	Firm growth measured annually
Control variables	• Gross capital growth; • Skilled Human resource, either capturing expansion of employees or increasing skills level of firms; • R&D expenditure growth, capturing changing technology level or innovativeness of firm – possibly more relevant for growing small and medium firms, whereas for large firms R&D budgets may not increase significantly for new innovations and instead may be conducted through a shift of resources; • Export growth – capturing changing global market exposure of firm.

Policy variables of interest to evaluate tax and financing incentives:	• Corporate tax growth (annual firm level);
	• Venture capital (annual country level) - - the funding available for firms is differentiated by seed funding/early stage venture capital to later stage funding.
	  o Seed funding/early stage funding (annual country level) - – this to an extent captures initiatives impact of capital gains tax entrepreneur relief and financing schemes EIS and SEIS.
	  o Later stage venture capital funding (2nd and 3rd round) (annual country level) - – this would to an extent capture impact again of capital gains tax relief, as well as financing schemes such as VCT
	  o Other late stage funding – for further capital investment in further rounds
	• Acquisitions are differentiated for Management Buyouts (MBO) activity from management Buy-ins (MBI), although the data only allows for a limited differentiation:
	  o MBI - External management takeover replacing existing management
	  o MB) - all types of either external hostile/cooperative or internal management takeovers.

A point to clarify in above Table 4.4, is a limitation in the data while examining acquisitions, attempt is made to differentiate Management Buyouts (MBO) activity from management Buy-ins (MBI). The motivation behind this differentiation is rooted in the debate in business history, which differs from management studies – where complementary acquisitions are considered positive for firm growth, whilst others could be seen as harming growth. However, as available data MBO – merges the cooperative takeovers alongside the hostile takeovers in the same figure, this differentiation was not fully possible with this data. This data only allows for a limited differentiation - distinguishing between an external management takeover replacing existing management (MBI), versus all types of either external hostile/cooperative or internal management takeovers (MBO). This limitation is important to point out, as the interpretation of results is done accordingly.

Further to above listed variables, in model, a variable to assess whether a firm grows at varying rate based on age of age of firm, the analysis also includes:

- Firm age (annual firm level) – age of firm based on year of incorporation

Furthermore:

- Time dummies are removed, as venture capital variables appear to have constant time effect and could not otherwise be analysed.

- Also, early stage funding appears to be closely correlated with later stage funding. Hence, two separate regressions are used to assess them.

This model with variables listed in Table 4.4 is depicted in Diagram 4.1 to enable easier oversight of the different drivers and policy tools influencing firm growth.

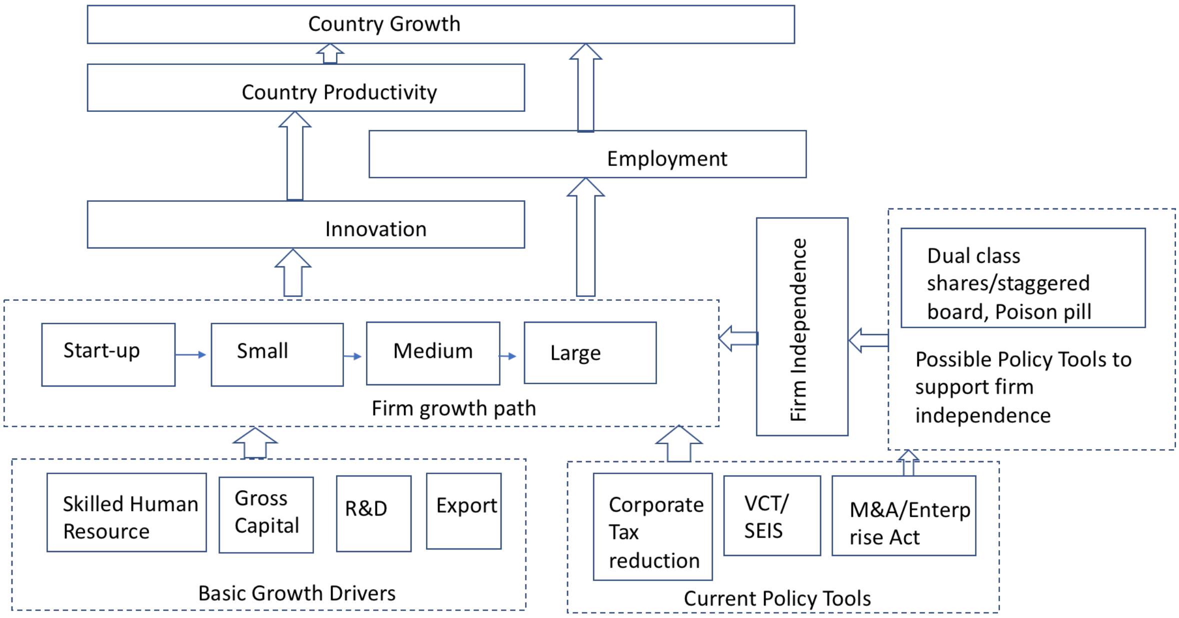

Figure 4.1 Model depicting Basic growth drivers and policy tools influencing firm growth leading to country productivity and Growth, source (author)

Using Fixed effects method to remove sector specific effects, the equation for the model used for this analysis, is thus defined as:

$$\text{Firm growth } (F_{irm}\,G_{rth}) = \alpha + + \beta_1(G_{ross}\,C_{ap}\,G_{rth}) + \beta_2(C_{ost}\,E_{mply}\,G_{rth}) + \beta_3(R\&D\,G_{rth}) + \beta_4(E_{xp}\,R_{ev}\,G_{rth}) + \beta_5(I_{nt}\,R_{ates}) + \beta_6(Firm_{age}) + \beta_7(C_{orp}T_{ax}G_{rth}) + \beta_8(S_{eed}I_{nv}) + \beta_9(V_{en}\,C_{ap}) + \beta_{10}(L_{at}\,V_{en}\,C_{ap}) + \beta_{11}(R_{ep}\,C_{ap}) + \beta_{12}(MBO) + \beta_{13}(MBI) + \beta_{14}(F_{irm}\,I_{nd})$$

Equation (1)

As mentioned earlier, analysing the correlation matrix for firms in Table 4.2 indicates that early stage and later stage (2^{nd} & 3^{rd} round) funding are highly correlated, indicating they could cause near perfect multicollinearity in regressions. Hence, the regressions use only late stage funding, dropping early stage ($S_{eed}I_{nv}$), as shown in Equations 2:

$$\text{Firm growth } (F_{irm}\,G_{rth}) = \alpha + \beta_1(G_{ross}\,C_{ap}\,G_{rth}) + \beta_2(C_{ost}\,E_{mply}\,G_{rth}) + \beta_3(R\&D\,G_{rth}) + \beta_4(E_{xp}\,R_{ev}\,G_{rth}) + \beta_5(I_{nt}\,R_{ates}) + \beta_6(Firm_{age}) + \beta_7(C_{orp}T_{ax}G_{rth}) + \beta_9(V_{en}\,C_{ap}) + \beta_{10}(L_{at}\,V_{en}\,C_{ap}) + \beta_{11}(R_{ep}\,C_{ap}) + \beta_{12}(MBO) + \beta_{13}(MBI) + \beta_{14}(F_{irm}\,I_{nd})$$

Equation (2)

The following regressions are performed using the equation above.

4.5.2 **Regression results**

Using Fixed effects method (FEM) to remove sector and firm specific effects, the regressions are conducted on panel data over time period 2006-2016, for UK 89 sectors at firm-level, to examine firm growth.

Initially the regressions analyse overall general firm growth and then the same analysis is conducted only for innovating firms – based on firms which report R&D expenses. As mentioned above, early and late stage funding appear to be highly correlated, thus only late stage (2^{nd} and 3^{rd} round venture capital) funding is used in regressions, using equation (2) for all regressions. Given the UK's bigger challenge lies in upscaling firms, rather than the birth of innovative firms, a focus on venture capital funding of 2^{nd} and 3^{rd} round is more pertinent to this study than the initial seed funding.

Furthermore, as lending interest rates as well as late stage funding are omitted because of collinearity, these two variables are not listed in the results. Lastly, throughout these regressions time dummies are removed, as they caused the annual country level data of venture capital and financing incentives to be omitted – which are our variables of interest. These results are listed in Table 4.5 below for aggregate level analysis of overall general (innovative and non-innovative) in column 1 and innovative firms in column 2.

Table 4.5:FEM of tax and financing incentives regressed on Firm growth (measured by growth in operating revenue from year before, as a percentage of current operating revenue) separately for aggregated general firms and separately for aggregated innovative firms

LHS variable: Firm-growth	*(1)* *All General firms (Innov and non-innov firms)* *(Venture capital 2nd & 3rd round)*	*(2)* *Only Innovative firms* *(Venture Capital 2nd & 3rd round)*
Control variables:		
Growth theories		
• *Gross capital growth*	.00009 (.0001)	.00008 (.0002)
• *Human Resource growth*	.012*** (.003)	.492*** (.01)
• *Technology (R&D) growth*	(Not used)	.0003 (.0002)
Globalization		
• *Export growth*	-5.99e-06(9.23e-06)	.00009 (.0002)
Tax and Financing policy tools:		
• *Corporate Tax Growth*	0.03***(.0008)	-.03*** (.002)
• *Later stage funding (2nd & 3rd round)*	.016*** (.004)	.01**(.004)
• *Replacement capital (incl secondary buy-outs)*	-.024*** (.009)	-.022**(.009)
• *Management buyouts*	.005*** (.001)	.004***(.001)
• *Management Buy-ins*	.439***(.13)	.347***(.119)
Firm Age	-10.37*** (2.8)	-9.03***(2.5)
Constant	217.2***(59.1)	231.4***(63.7)

Observations	56, 191	5,736
No. of groups	16,184	2,127
Obs per group	min = 1 avg= 3.5 max= 6	min = 1 avg= 2.7 max= 6
R-sq	within= 0.08 between = .0069 overall = 0.0057	within= 0.4182 between = .0212 overall = 0.0174
Corr (u_i,Xb)	-0.8897	-0.9862

Note: The regression equation uses Eq (2) for Firm growth ($F_{irm}\ G_{rth}$) = α + + $\beta_1(G_{ross}\ C_{ap}\ G_{rth})$ + $\beta_2(C_{ost}\ E_{mply}\ G_{rth})$ + $\beta_3(R\&D\ G_{rth})$ + $\beta_4(E_{xp}\ R_{ev}\ G_{rth})$ + $\beta_5(I_{nt}\ R_{ates})$ + $\beta_6(Firm_{age})$ + $\beta_7(C_{orp}T_{ax}G_{rth})$)+ $\beta_8(S_{eed}I_{nv})$ + $\beta_9(V_{en}\ C_{ap})$ + $\beta_{10}(L_{at}\ V_{en}\ C_{ap})$ + β_{11} $(R_{ep}\ C_{ap})$ + β_{12} (MBO) + β_{13} (MBI) + β_{14} $(F_{irm}\ I_{nd})$ – R&D variable excluded in column (1) to allow observation of general overall firm types, as only innovative firms seem to list R&D.

*** indicates significance at 1% p-value, ** indicates significance at 5% p-value and * indicates significance at 10% p-value. Standard errors are listed in parenthesis.

These main results for these regressions can be summarised as:

- Surprisingly, Gross Capital is not a significant driver. At first sight, this is surprising, however it could be indicative of the fact that capital investments are not reflected in immediate growth but may rather have a delayed effect on firm growth. This should be explored in future research to understand if indeed this is the case.

- Human Resource – is significant, and this coefficient x2 for innovative firms. Yet there is no significant policy in place to boost increasing skilled human resource available to firms.

- The impact of Corporate tax growth is very small and surprisingly positive for overall (innovative and non-innovative firms) ie. Overall firms grow despite increased corporate tax. However, this figure is negative for innovative firms, albeit smaller in impact relative to Human resource – despite it being considered as one of the key attractions for driving growth in UK policy making. As such although the current policy focus to reduce corporate tax would appear to help innovative firms, its impact is relatively much smaller and brings into question as to whether this policy tool should be centre stage for attracting or supporting innovative firm growth. More so, the question arises whether this policy should be a blanket policy for all types of firms, as these findings indicate that overall firms (includes non-innovative firms) can grow despite increased corporate tax.

- Later stage funding (2nd & 3rd venture capital round) although significant, it appears a relatively smaller impact. Bearing in mind that these are not percentage growth figures, rather it measures the change in percentage growth for firms for every million pounds invested, its interpretation differs from above variables.

  This is a level – not a growth figure of venture capital - and cannot be directly compared with earlier growth coefficients. It can only be used to relatively compare other level of invested capital. As such, it appears that every million pounds invested in venture capital would have 2.5x higher impact on firm growth than MBOs, which include capital of either cooperative or hostile takeovers of IBOs and LBOs.

- Replacement capital including secondary buyouts, appears negative - which could be just the cost of replacement capital, but could also indicate that secondary buyouts may not be positive for firm growth. As these two figures are inter-bound, it is not possible to isolate the two impacts.

- Both Management buyouts (MBO) and Management buy-ins (MBI) are positive for firm growth, with Management buy-ins showing higher figures. As mentioned earlier, each million invested in MBOs (capturing both management buyouts, but also hostile/cooperative IBO takeovers) seem to have 2.5x lower impact than each million invested in venture capital. On the other hand, MBI, which captures external management using capital to replace existing teams usually for undervalued firms, seems to deliver 100x higher firm growth than MBOs. However, MBI's are much less prevalent as much riskier to fund and appear to be less than 1% relative to MBO's in UK (BVCA, 2016).

Thus, perhaps the main takeaway of these figures is a comparison of venture capital with MBO figures - that direct venture capital invested into the organic growth of a firm delivers more growth than an acquisition/takeover. Thus, while M&A's seem to be positive on firm growth, venture capital investing in organic firm growth seems relatively a larger impact, supporting economic historians evaluation of importance of organic firm growth over growth through acquisitions. As such, greater focus in policy making to support access to finance to encourage organic firm growth above M&A's, seems important for firm growth.

- Firm age is surprisingly negative – i.e. the older or more established a firm, then that age works negatively on growth. This would appear to indicate that the longer the firms last the distance, then each year of incorporation has a negative impact on firm growth. This appears contrary to Business historians and is investigated in further detail in follow-up regressions to enable understanding of this result.

- Three variables: lending interest rates; other further later stage of lending and independence dummies are omitted due to collinearity

These results are also further checked for how these drivers may impact firm size classes differently, again using equation 2 to assess firm growth.

The firm growth is differentiated for firm-size classes: micro (employees < 10), small (employees < 50), medium (employees < 250) and large (employees 250+). In all, a set of further eight regressions are performed. These regressions are listed in Table 4.6 for innovative firms and Table 4.7 for general overall firms.

Table 4.6 FEM of tax and financing incentives regressed on (Innovative firms) Firm growth, differentiated for firm class sizes

LHS variable: Firm-growth	*(1) Innovative firms (micro)*	*(2) Innovative firms (small)*	*(3) Innovative firms (medium)*	*(4) Innovative firms (large)*
Control variables: Growth theories				
• *Gross capital growth*	-.067 (.203)	.005(.005)	.0002(.002)	.004(.003)
• *Human Resource growth*	-2.45 (2.01)	.537***(.08)	.48*** (.009)	.747*** (.026)
• *Technology (R&D) growth*	.101 (.105)	.0004 (.004)	.0003(.0008)	.0004** (.0001)
Globalization				
• *Export growth*	.076 (.062)	.049***(.012)	.00003(.0001)	.0001 (.0003)
Tax and Financing policy tools:				
• *Corporate Tax Growth*	-1.87 (1.32)	-.028*** (.004)	.03**(.01)	.003 (.004)
• *Later stage funding (2^{nd} & 3^{rd} round)*	.598(.39)	.013(.023)	.009*(.005)	.004 (.005)
• *Replacement capital (incl secondary buy-outs)*	.502 (.441)	-.023 (.043)	-.022**(.009)	-.019** (.009)
• *Management buyouts*	Omitted	.006(.007)	.003(.002)	.005** (.001)

• *Management Buy-ins*	Omitted	.47(.63)	.266** (.133)	.33* (.127)
• *Firm Age*	353.6 (270.97)	-9.3(13.7)	-7.8*** (2.8)	-8.9*** (2.7)
• *Constant*	-6905. (5223.6)	163.6(262,6))	189.9*** (63.7)	294.07*** (86.9)
Observations	51	805	2,873	1,984
No. of groups	36	368	1,167	691
Obs per group	min=1 avg=1.4 max=4	min =1 avg =2.2 max =6	min =1 avg =2.5 max =6	min =1 avg =2.9 max =6
R-sq	within= 0.5175 between = .04888 overall = 0.0245	within= 0.2192 between = .0162 overall = 0.0125	within= 0.6483 between = .0288 overall = 0.0376	within= 0.4102 between = .0346 overall = 0.0132
Corr (u_i,Xb)	-0.9999	-0.9688	-0.9685	-0.9964

Note: The regression equation uses Eq (2) for $(F_{irm}\ G_{rth}) = \alpha + \beta_1(G_{ross}\ C_{ap}\ G_{rth}) + \beta_2(C_{ost}\ E_{mply}\ G_{rth}) + \beta_3(R\&D\ G_{rth}) + \beta_4(E_{xp}\ R_{ev}\ G_{rth}) + \beta_5(I_{nt}\ R_{ates}) + \beta_6(Firm_{age}) + \beta_7(C_{orp}T_{ax}G_{rth})\ ) + \beta_9(V_{en}\ C_{ap}) + \beta_{10}(L_{at}\ V_{en}\ C_{ap}) + \beta_{11}(R_{ep}\ C_{ap}) + \beta_{12}(MBO) + \beta_{13}(MBI) + \beta_{14}(F_{irm}\ I_{nd})$ – with lending interest rates, early stage lending, other late stage lending and independence dummy not listed as they are omitted due to collinearity

*** indicates significance at 1% p-value, ** indicates significance at 5% p-value and * indicates significance at 10% p-value. Standard errors are listed in parenthesis.

Main findings of these regressions on innovative firm sizes:

- Micro firm-class: no significant drivers below 10% p-values, although late stage (2nd and 3rd round) venture capital is significant at 17% p-value, which is valid enough and indicates access to finance is key for these small firms

- Small firm-class: Skilled human resource is the most influential driver on firm growth, with export also significant driver and reduction in corporate tax reductions also significant for small firm growth, though half the magnitude of impact of export growth and factor 20x less than skilled human resource.

- Medium firm-class: Skilled human resource yet again the most significant, with increase in corporate tax positive on growth and later stage venture capital (2nd and 3rd round) also significant for firm growth. Though the impact of venture capital on medium firms is relatively far smaller on firm growth than for micro firms. MBOs (includes external hostile/consensual takeovers as well as internal management buyouts) have 11% p-value significance, which indicates that M&A are a positive impact for medium firms – though we cannot distinguish whether that is driven by management buyouts by internal management team or external takeovers. MBI's are separate and they show a significant and positive impact.

- Large firm class: Yet again, skilled human resource is key – in fact this driver is the largest in magnitude when compared across all firm-sizes. Export and corporate tax are surprisingly not significant, instead replacement capital (including secondary buyouts) is a drag on growth, with MBOs (external takeovers, as well as internal management buyouts) a positive on frim growth, as well as MBIs. Yet again , indicating that M&A's play a significant role in firm growth of large firms, however data not distinguishing whether this is due to external acquisitions or internal management buyouts.

Table 4.7 FEM of tax and financing incentives regressed on (General firms) Firm growth, differentiated for firm class sizes

LHS variable: Firm-growth	*(1)* *General firms (micro)*	*(2)* *General firms (small)*	*(3)* *General firms (medium)*	*(4)* *General firms (large)*
Control variables: Growth theories				
• *Gross capital growth*	.002(.002)	.001(.002)	.00009 (.00006)	.0001 (.0004)
• *Human Resource growth*	.05*** (.02)	1.01*** (.018)	.085*** (.002)	.16*** (.004)
• *Technology (R&D) growth*	Not used	Not used	Not used	Not used
Globalization				
• *Export growth*	.002*** (.0007)	-.0002*** (.00002)	6.5e-7(7.3e-6)	.00002 (.00005)
Tax and Financing policy tools:				
• *Corporate Tax Growth*	.06***(.0009)	-.0008(.02)	-.07*** (.006)	.062*** (.007)
• *Later stage funding (2nd & 3rd round)*	.019(.019)	.017 (.012)	.014*** (.003)	.012** (.006)
• *Replacement capital (incl secondary buy-outs)*	-.03 (.038)	-0.036(.025)	-.02*** (.007)	-0.014(.013)

• *Management buyouts*	.008(.006)	.007* (.004)	.005*** (.001)	.003(.002)
• *Management Buy-ins*	.588(.563)	.568* (.367)	.382*** (.101)	.304(.19)
• *Firm Age*	-11.8 (12.2)	-13.01*(7.96)	-8.6***(2.2)	-8.3** (4.1
Constant	157.6(173.9)	226.2(142.7)	180.5(46.5)	218.512** (104.4)
Observations	2,925	13,731	27,386	11,831
No. of groups	1,327	5,007	8,507	3,452
Obs per group	min=1 avg=2.2 max=6	min =1 avg =2.7 max =6	min =1 avg =3.2 max =6	min =1 avg =3.4 max =6
R-sq	within= 0.6757 between = .1195 overall = 0.2058	within= 0.2848 between = .0129 overall = 0.0229	within= 0.0919 between = .0066 overall = 0.0058	within= 0.1657 between = .0085 overall = 0.0059
Corr (u_i,Xb)	-0.7302	-0.9546	-0.9450	-0.7130

Note: The regression equation uses Eq (2) for $(F_{irm}\ G_{rth}) = \alpha + \beta_1(G_{ross}\ C_{ap}\ G_{rth}) + \beta_2(C_{ost}\ E_{mply}\ G_{rth}) + \beta_3(R\&D\ G_{rth}) + \beta_4(E_{xp}\ R_{ev}\ G_{rth}) + \beta_5(I_{nt}\ R_{ates}) + \beta_6(Firm_{age}) + \beta_7(C_{orp}T_{ax}G_{rth}) + \beta_9(V_{en}\ C_{ap}) + \beta_{10}(L_{at}\ V_{en}\ C_{ap}) + \beta_{11}(R_{ep}\ C_{ap}) + \beta_{12}(MBO) + \beta_{13}(MBI) + \beta_{14}(F_{irm}\ I_{nd})$ – with lending interest rates, early stage lending, other late stage lending and independence dummy not listed as they are omitted due to collinearity

*** indicates significance at 1% p-value, ** indicates significance at 5% p-value and * indicates significance at 10% p-value. Standard errors are listed in parenthesis.

Main findings from these regressions for general firm sizes:

- Micro firm class: Skilled human resource, export, as well as increased corporate tax are significant drivers for micro firms. Interestingly venture capital does not seem to play a part in driving micro firm growth of general firms, which underscores literature that venture capital is involved mostly in innovative firms.

- Small firm class: Skilled human resource with a significantly larger coefficient relative to micro firms is a key driver, as well as MBIs and MBOs, indicating M&A play a part in driving even small firm growth of general firms. Yet again, unfortunately the data does not enable distinguishing between internal management buyout or external takeovers as to which is the key component of MBOs. Exports are surprisingly a negative driver. Venture capital is significant , although only at 17%. Furthermore, firm age is also a negative driver with a quite large coefficient value, indicating the age of a firm seems to impose a significant drag on the growth of a general small firm.

- Medium firm class: Skilled human resource is once again evident as a strong driver, with capital growth a very small influence though p-value of 15%. Surprisingly late venture capital (2nd and 3rd round) is positive driver for firm growth, alongside MBOs and MBI indicating M&A (be it internal management buyout or external takeover) play a positive role in driving firm growth. Increased corporate tax growth has a negative impact on medium firm growth, while firm age has yet again a large value and imposes a negative drag on frim growth.

- Large firm class: Yet again, Skilled human resource is highly significant, with increased corporate tax as a positive indicating large general firms can grow despite increased corporate taxes. Late venture capital (2nd and 3rd round) is surprisingly positive, indicating venture capital does seem to impact large firm growth. Future research should identify how this is -whether this is spin-offs of large firms or financing of specific M&As perhaps. MBOs and MBIs are both found positive, though at 14 % p-value and 11% p-value respectively. Firm age is yet again a negative significant impact.

Overall conclusions (both innovative firm-classes and general firm-classes) on variables of interest:

Firstly, corporate tax increase – this is found broadly to be positive for general (innovative and non-innovative) firms indicating they can grow despite tax increase, while its negative for innovative firms implying that corporate tax increase is a drag on innovative firm growth. Exploring this in detail at the differing firm-size levels, it appears only micro and large general firms can grow despite increased corporate tax, while increased corporate tax would impose a drag on small innovative firm growth, yet medium innovative firms appear to be able to grow despite increased corporate tax. These are quite important variations which sheds doubt on the suitability of the current blanket policy of corporate tax reductions, indicating policy could be tailored differently for innovative firms, more so also differently for firm size-classes.

Secondly, Venture capital 2nd and 3rd round funding – this was broadly found positive and significant for both general (innovative and non-innovative), as well as innovative firms. Upon detailed analysis at firm size levels, venture capital (2nd and 3rd rounds) was found significant and positive for growth of only micro and medium innovative firms, not small – possibly investment at that stage feeding into expansion of firm resources and not growth. In contrast, venture capital 2nd and 3rd round funding is significant at 17% p-value for small general firms, while fully significant for medium general firms as well as significant for large general firms, unlike large innovative firms. While the coefficient values cannot be directly compared to growth coefficients given data limitations, these findings indicate roughly .01% firm growth for every million pound invested for general and innovative firms. While this growth is not large, it is still growth and seems to support growth of SMEs (small and medium sized) for both innovative and general firms. As UK appears to have a scale-up problem of its smaller firms, as mentioned in the introduction where UK scores 26th in GEI index in scaling up despite scoring 4th in the creation of innovative start-ups, and this is further combined with reduced venture capital availability relative to US - this seems to be an insightful result shedding some light on this problem. It would appear that policy support to further enhance access to venture capital would help boost scaling up of firms, though yet again it is not the largest driver of firm growth and should be kept in that context.

Furthermore, venture capitals lack of significance for large innovative firms seems to indicate they may be able to utilize other sources for investment, also in line with previous literature (OECD, 2015). On the other hand, detailed analysis of general (innovative and non-innovative) firm size classes, reveals that venture capital is significant for large size-class of general firms. In this case, indicating venture capital supports growth of large size-class of general firms. This would appear to be in line with previous literature on use of private equity in complementary business acquisitions to fund large firm growth (Miskell & Jones, 2007). In essence, it appears that venture capital is a relevant and positive source of finance which supports growth, particularly for growth of micro, small and medium innovative firms – albeit it is not that large an impact and as such should be kept in that context

Thirdly, M&A activity captured by MBOs and MBIs – broadly, both of these were found positive and with a similar impact on both general (innovative and non-innovative) or innovative firms. Interestingly, MBO impact was roughly half the impact of venture capital on firm growth, whereas MBI had 20x the impact of venture capital on firm growth. Yet, MBI makeup a very small part of M&A activity as they are seen as a riskier venture (Wright & Wilson, 2013). Further analysis at detailed firm size level indicates that both MBO and MBI are significant drivers for small and medium general firms, with MBI nearly 100x higher impact on firm growth. While for innovative firms, they are both significant for medium and large firms. This would appear to support the literature that mergers which are related to either technology acquisition or complementary growth could be beneficial. However, this data does appear to show that while M&As promote growth, their impact is much lower relative to venture capital which promotes organic growth. This to an extent seems to support business historians' claims that organic growth is a greater driver of firm growth relative to acquisitions. If these conclusions are correct, then policies to support organic growth should be given a higher precedence over M&A activity – which would involve retaining firm independence.

Unfortunately, firm independence cannot be evaluated from these regressions, listed as a collinearity problem in the regression. As this indicator shows low variation of status over the period of analysis, it is also possible that firm independence could also be removed as a consequence of using fixed effects method (FEM). Given the importance of this debate and the possible conclusions on policies to support firm growth, the next sub-section tries to explore an alternative regression to evaluate impact of firm independence on firm growth.

4.5.3 **Independence of firms**

As mentioned above, business historians' claims that acquisitions can be a distraction and negatively impact longer term organic growth is an important concern and if true, has considerable policy implications – specifically as it would appear to require policies if not to protect, at least to support firm independence. More so, the data analysis above indicated that venture capital which supports organic firm growth has at least 2x the impact on form growth relative to MBO's, which includes both external acquisitions and internal management buyouts, appearing to support importance of organic growth. However, firm independence itself could not be evaluated in above regressions. Given the importance of this characteristic, as it encapsulates organic firm growth, an alternative set of regressions are performed in this section to try to examine this effect on firm growth.

To find a way to analyse independence and whether this matters for firm growth, a regression is undertaken which compares the growth response of overall innovative firms (independent and dependent firms) relative to independent innovative firm growth. Equation (2) is used for FEM analysis for both these regressions, with independent firm growth being examined by restricting database to independent firms only, using the firm independence indicator as provided by Amadeus data and described in data section.

These results of impact of drivers on firm growth for overall (independent and dependent) innovative firms is listed in column 1, versus growth for independent innovative firms in column 2, Table 4.7.

Table 4.7 FEM of Innovative independent firm's growth, compared with FEM for Innovative overall firms (dependent and independent) growth

LHS variable: Firm-growth	*(1)* *Dep & Indep firms* *All sizes Innovative firms (Venture Capital 2nd & 3rd round)*	*(2)* *Independent firms only* *All sizes Innovative firms (Venture Capital 2nd & 3rd round)*
Control variables: Growth theories		
• *Gross capital growth*	.00008(.0002)	-.022(.021)
• *Human Resource growth*	.493*** (.01)	.913***(.1)
• *Technology (R&D) growth*	.0003(.0002)	-.0007(.003)
Globalization		
• *Export growth*	.00009(.0002)	.239***(.024)
Tax and Financing policy tools:		
• *Corporate Tax Growth*	-.026 ***(.002)	-.119*** (.02)
• *Later stage funding (2nd & 3rd round)*	.01**(.004)	-0.019(.016)
• *Replacement capital (incl secondary buy-outs)*	-.022*** (.008)	.047(.033)
• *Management buyouts*	.004*** (.001)	-.005(.005)
• *Management Buy-ins*	.347***(.12)	-.722(.49)

• *Firm Age*	-9.03***(2.5)	15.05(10.45)
Constant	231.43***(63.7)	-463.89***(322.22)
Observations	5,736	703
No. of groups	2,127	210
Obs per group	min = 1 avg= 2.7 max= 6	min = 1 avg= 3.3 max= 6
R-sq	within= 0.4182 between = .0212 overall = 0.0174	within= 0.4625 between = .0004 overall = 0.0004
Corr (u_i,Xb)	-0.9862	-0.9897

Note: The regression equation uses Eq (2) for $(F_{irm}\ G_{rth}) = \alpha + \beta_1(G_{ross}\ C_{ap}\ G_{rth}) + \beta_2(C_{ost}\ E_{mply}\ G_{rth}) + \beta_3(R\&D\ G_{rth}) + \beta_4(E_{xp}\ R_{ev}\ G_{rth}) + \beta_5(I_{nt}\ R_{ates}) + \beta_6(Firm_{age}) + \beta_7(C_{orp}T_{ax}G_{rth}) + \beta_9(V_{en}\ C_{ap}) + \beta_{10}(L_{at}\ V_{en}\ C_{ap}) + \beta_{11}(R_{ep}\ C_{ap}) + \beta_{12}(MBO) + \beta_{13}(MBI) + \beta_{14}(F_{irm}\ I_{nd})$ – with lending interest rates and other late stage lending not listed as they are omitted due to collinearity

*** indicates significance at 1% p-value, ** indicates significance at 5% p-value and * indicates significance at 10% p-value. Standard errors are listed in parenthesis.

The findings can be summarised as follows:

- Skilled human resource is significant, but approximately 2x higher impact for independent firms

- The fact that capital and R&D growth coefficient are negative and not significant, could be consequent of these drivers exerting a delayed impact on firm growth. This appears to be in line with previous studies, which have found that there is a lagged impact of R&D investment on firm profits (Coad & Rao, 2010; Chan et al., 2001)

- Export growth is significant for independent innovative firms, which is insignificant and very small influence for overall innovative firms.

- Corporate tax growth remains a negative for both types of innovative firms – overall and independent

- Surprisingly, venture capital (2nd and 3rd round) is negative and is less significant, as that driver has a p-value of 25%. This finding opposes the premise from earlier regressions that as venture capital supports organic growth, it should also thus support firm independence. These findings appear to show that while venture capital supports organic growth for overall innovative firm, it does not essentially support growth of independent firms. Whether this is due to independent firms seeking debt-finance rather than equity for growth, this regression cannot answer that. It only indicates that equity financing through venture capital is a negative impact on growth. Alternatively, this negative impact of venture capital on independent firm growth could also reflect the de facto lack of access to internal corporate capital for independent firms. Given that these further rounds of venture capital financing could be accompanied by debt or interest paybacks, which could dilute short-term growth as independent firms lack the larger corporate financial structure to buffer against debt repayments. Nonetheless, for independent firms venture capital is not a growth driver – at least in the short term.

- Similarly, as opposed to overall firms, M&A are not significant as driver for independent innovative firms, as both MBOs and MBIs are negative and not significant.

  This is an interesting result as it seems to signify that M&A is not the path of growth for independent firms - supportive of business historians' suggestions that those firms which rely on organic growth, rather than M&A which can be a distraction, have higher long term growth. This long-term growth for independent firms at least seems indeed not to come from M&As – but surprisingly another characteristic which captures the years of independence itself – firm age.

- The biggest surprise is firm age – for independent innovative firms, firm age has a large positive impact at 15% significance, which is valid enough to be considered, opposed to negative impact of firm age for overall innovative firms. Firm age appears to be the largest effect on growth for firms, with each year since incorporation yielding a 15% impact on firm growth.

<u>Key findings and policy consequences from regressions on innovative independent firms are listed below:</u>

- Corporate Tax growth is a negative and thus appears to be a drag on growth for independent innovative firms – supporting earlier conclusion that corporate tax should not be a blanket policy, rather tailored differently for innovative firms and differing firm-sizes.

- Neither venture capital, nor M&A activity appear to drive growth of independent firms – instead seeming to rely on organic growth, as suggested by business historians. Providing a much-needed perspective for the role of venture capital and M&A activity in the policy tool-kit. These two drivers, venture capital and M&A, while helping overall and innovative firm growth are not key for innovative independent firms. Exactly the type of firms - the independent innovative firms that could become the next UK Googles or ARM, whose absence in UK is the motivation for this study. So what policy is needed for them? That appears to get answered in the next observation.

- In terms of firm growth, the largest influence on growth appears to be interconnected – the age of a firm, when the firm stays independent. Firm age, which is the years the firm has survived since incorporation, appears to have a high impact on firm growth – but only for independent firms. More so, firm independence seems to have a significant multiplier effect on key growth drivers: skilled human resource and export. It would appear given the significantly large effect of these three combined aspects, that independent innovative firms would be expected to grow at a much higher rate relative to overall innovative firms.

As such, policies to either protect or at least support firm independence, currently absent in policies – appears to be of critical importance for boosting firm growth in the UK.

In essence, it would appear that ensuring firms stay independent and age while retaining independence – could be the single most important contributor to firm growth, given the multiplier effect of independence. If this is indeed correct, then the sale of UK's successful innovative firms before they reach full potential appears to explain why the UK cannot produce the new frontier giants of the future – the loss of independence seems to lead to significantly reduced growth and moreover, these innovative firms do not grow into giants in their own right as they have become part of another firm.

4.5.4 Overall key findings from Regressions

A) Variables of interest:

Corporate tax:

A surprising finding of this study was the revelation of how corporate tax can have differing impacts on growth. Corporate tax growth was positive for general (innovative and non-innovative) firms, indicating firms could seemingly grow despite increase in corporate taxes – opposite to current emphasis in UK policy with lowered corporate tax rates as one of the headline policies for firm growth. However, upon isolating innovative firms, corporate tax was found to be negative, indicating that a blanket policy for all types of firms may not be advisable. Indeed, when isolating impact of corporate tax for differing firm size classes, it appears that micro and large general firms as well as medium innovative can grow despite increased corporate tax, while medium general and small innovative firms need reduced corporate taxes to grow.

Furthermore, corporate tax growth has an even larger negative influence on independent innovative firms, indicating that corporate tax growth is not an advisable route if UK is wanting its innovative small firms to stay independent and grow into the next UK ARM or Google. However, it seems that general large firms could grow despite increased corporate tax, indicting a tailored approach on this policy may be more advisable relative to current blanket policy approach.

Perhaps the main takeaway on this is that the magnitude of the impact of this driver is low relative to other drivers and as such may explain why despite reduction in UK corporate tax rates over the last decade -UK has not succeeded in getting UK innovative small firms to upscale. It appears not to deserve the headline policy status it has been given over the last decade.

Later stage -Venture capital 2nd and 3rd round:

The findings appear to corroborate the importance of venture capital on firm growth – albeit, its impact on growth is not huge. It appears to be positive and significant driver for both overall and innovative firms, delivering roughly .01% firm growth for every million pound invested for overall (innovative and non-innovative) and innovative firms. Detailed analysis at firm size levels for overall firms reveals that it’s a significant and positive driver for medium and large overall firms. In contrast innovative firm size class analysis reveals that this driver is only significant for micro and medium innovative firms.

In contrast, it appears that venture capital is not significant (indeed negative) for independent innovative firm growth. If the policy objective would be to create the future UK Google/ARM, then policy support for venture capital appears not to be the appropriate choice.

Nonetheless, overall these results would affirm venture capitals position as a positive driver for SME growth and given that UK’s venture capital is approximately factor 7~8 lower availability of venture capital ratio to GDP relative to US (OECD, 2016) – policy effort to enhance venture capital access seems the correct policy stance. However, the relatively low impact on firm growth and non-significance for independent innovative firms explains why it could not in itself be the central policy to scale up innovative firms to become the future UK googles/ARM of UK. For that yet again, it appears we have to look if possible for a driver with greater impact.

Mergers and acquisitions (M&A):

The findings suggest that M&As, based on MBO and MBI, seem to be positive and significant, with a similar impact for both general (innovative and non-innovative) and innovative firms. Although MBO's, which include external hostile/consensual takeovers as well as management buyouts, have a lower impact than venture capital, approximately half. In contrast MBIs seems to have a much higher impact than venture capital, yet MBI's make up a very small fraction of M&A activity (Wright & Wilson, 2013). Given the lower composition of MBI in M&A activity, it would appear that overall M&A impact on firm growth is lower than venture capital and its role as a central tool of firm growth does not seem to be justified.

Based on MBOs, which appear to be the predominant component of M&A activity, detailed firm size analysis suggests that M&As drive growth of small and medium size class for general firms and only large size class for innovative firms. So, it appears not to be the key driver for scaling up innovative small firms to become the UK Google/ARM.

In term of independent innovative firms, M&As have absolutely no significance. Yet again, if the policy objective is to create the next UK Google/ARM, this would not appear to be a driver at all.

Thus, it would appear that although mergers and acquisitions are much lauded as a tool of growth, the data in contrast supports the claim by business historians that M&A activity appears to distract firms from organic growth, which is the longer-term growth. Specifically, it is not the driver for scaling up innovative small firms nor specially for independent innovative small firms to scale up to become the next UK Google/ARM.

B) Control variables, which are basic growth drivers:

Gross capital growth

This was a surprising result when assessing general (innovative and non-innovative) firms and innovative firms – both regressions found gross capital growth to be an insignificant driver for firm growth, contrary to expectation. This also held true for all firm size classes in the detailed analysis. More so, it continued to be insignificant, although negative, also for independent innovative firms. It is possible that this is consequent of the fact that capital investment growth has a lagged effect on growth, which should be explored in future research. Notwithstanding, at least for the short term capital growth appears to be insignificant on firm growth.

Human resource growth

This is the most consistently significant and positive driver for all types of firms – significant for general (innovative and non-innovative) firms and innovative firms. However, interestingly this driver is 40x higher for innovative firms. Detailed analysis shows it is a significant and positive driver for all firm size classes, except intriguingly for micro innovative firm sizes. It appears that skilled human resource impact on firm growth is positive and immediate, also comparatively the largest influence for all growth variables.

Reviewing independent innovative firms, independence seems to deliver a further higher response – in this case, human resource growth delivers x2 higher than overall innovative firms. It appears that independence has a marked increase in the impact of human resource on growth, a consistently key significant basic growth driver.

Technology (R&D) growth

The effect of this driver is only analysed for innovative firms, as non-innovative firms do not list R&D expenditures. Reviewing overall (independent and dependent) innovative firms, technology growth is found to be insignificant although positive driver. Detailed size-class analysis showing it to be a significant and positive albeit small influence only for large firms, staying insignificant for rest of size-classes.

For independent firms, technology growth continues to be insignificant although negative. This requires further review, as it could perhaps be related to independent firms needing to source external funds for R&D, which are associated with higher interest rates (Giebel & Kraft, 2015). Further research in this would appear to be important, as it could indicate that the costs of R&D could be one of the bottlenecks that may persuade independent firms to sell out. However, this is only speculation and needs further research for forming a correct understanding.

Export growth

This was yet again a surprising result – export growth was not significant for general (innovative and non-innovative) firms nor was it significant for innovative firms. Exploring firm size classes, it was found to be a positive and significant driver for micro general firms as well as for small innovative firms, albeit negative and significant for small general firms. Suggesting it has a positive growth impact for some types of SME's, but overall it is not significant for either innovative or general firms. This is a puzzling result, as it implies that these firms source their growth mainly from domestic markets, or if they export then it does not benefit their growth immediately, which should definitely be examined in future research.

This however totally reverses for independent innovative firms, with export growth highly significant and a relatively large impact – 5000x that of the insignificant though positive figure for overall innovative firms. This seems to suggest that independent innovative firms design their product, be it manufacturing or services within the UK and exporting that overseas seems one of the key growth drivers. Once again, it appears that independence has a marked influence on the ability to generate growth from a basic growth driver.

C) Firm characteristics:

Firm age:

The findings on this firm characteristic were yet again surprising and unexpected. Firm age is significant and a large negative impact for general (innovative and non-innovative firms) firms, as well significant and similarly large negative impact for innovative firms - implying the older the firm, there is roughly a drag of 10% on growth for each year of existence. This remains true (with variation of magnitude) for small, medium and large general firms, as well as true for medium and large innovative firms. Its yet again puzzling, as one would expect firms at least expanding from their early stages of micro to SME to show a positive impact of age on firm growth.

Interestingly, this figure yet again totally reverses for independent innovative firms. The variable albeit significant at 15% p-value, shows an even larger positive impact on firm growth, suggesting a 15% growth boost for every year of existence – if firm stays independent. This figure appears to dwarf impacts of other variables. Given the extent of this impact, it would appear that the longer firms remain independent, the greater would be the cumulative impact of age on firm growth. On the other hand, the reverse is also true, non-independent firms face a cumulative drag of age on growth. This finding would appear to be in line with the new US behemoths of today. Initially Google (Entrepreneur, 2008) and Facebook (Tech Crunch, 2012) were only small successful disruptors, but with the passage of time their growth has seemed to accelerate, in accordance with their age of independence (BBC News, 2016; Bellis, 2017).

This result is quite significant, as it underscores the importance of firm independence in firm growth – offering a partial explanation why UK's innovative firms may not scale up to become the next UK ARM/Google, if they lose independence underway on their growth path.

Firm independence:

This was perhaps the most critical finding of the study – firm independence itself appears to be the most vital contributor to firm growth. Independent innovative firms reap more from basic growth drivers and more so, there is a growth boost for each year of independent firm existence – impact of firm age on firm growth.

Indeed, the difference in impact for basic growth drivers is quite striking, with human resource growth x2 higher for independent innovative firms relative to overall innovative firms and export revenue growth x5000 higher. More so, firm age would deliver a boost of 15% a year. Such a significant difference in firm growth for independent firms causes pause for thought.

Out of the policy tools, only reduced corporate tax is beneficial for independent firm growth. Venture capital is not significant and negative, similarly M&A activity is not significant and negative. There is currently no policy specifically to support firm independence nor protect firms from takeovers in the UK, unlike US or European economies which have varied mechanisms such as Dual shares, staggered boards, poison pills (Mayer, 2018).

If these findings are indeed correct and it is difficult to assess the counterfactual given data limitations, then the sale of successful UK innovative firms before they reach potential, could significantly reduce their growth path – possibly offering a partial answer to why UK does not have its own new frontier behemoths.

Thus, in the main, it would appear that perhaps the most vital contributor to firm growth is independence - more so than the other variables of interest. However, there is currently no policy in place to either support or protect firm independence.

4.6 Conclusion

The aim of this study was to seek to understand why UK has not produced the new innovative giants of tomorrow and whether firm independence matters – through examining the sufficiency and effectiveness of current policy tools promoting firm growth put in context of the growth drivers.

The question, put in other words, is whether these various policy initiatives over the last few decades in UK could have inadvertently shaped the current UK economy – perhaps boosting the creation of innovative start-ups like DeepMind (Shead, 2016), but not sufficient to support firms to last the distance to scale up to create the Googles itself? Furthermore, as the sale of potential successful innovative UK firms before reaching their potential, which is a part of M&A activity, appeared to be of relevance to this issue - it became important to identify the impact of independence on firm growth. As firm independence is currently absent in policy, its influence on firm growth is examined to gauge either its relevance or importance towards this problem.

To enable this examination, initially the basic drivers of firm growth are examined alongside the current policy tools which drive firm growth: tax & financing incentives and M&A activity. These are examined first for general (innovative and non-innovative) firms and then innovative firms separately, thereafter being compared to innovative independent firms. To identify the influence of independence, the growth reaped from basic growth drivers was examined and compared to the influence of current policy tools promoting firm growth.

The main contribution of this study was to understand the influence of independence on firm growth in context of the current policy tools - as research seems currently virtually absent on the influence of firm independence on firm growth. Moreover, this appears to be important, as independence is currently neither protected nor specifically supported in growth policy. Furthermore, this study aimed to place the value of the various growth policy tools into the context of actual firm growth and thus to reassess either insufficiencies or shortcomings in the current policy toolkit.

The extent of impact of firm independence on growth was striking and unexpected, with evidence in fact indicating it to be a vital factor for firm growth. Contrary to expectation, the difference reaped in basic growth drivers by independent firms was striking. The difference in impact for basic growth drivers for independent innovative firms relative to overall innovative firms can be summarised as follows: human resource growth x2 higher; and export revenue growth x5000 higher. Moreover, each year of firm independence delivers a bonus independence dividend - a remarkable 15% increase in firm growth per year, though this had 15% significance. Given these quite striking differences in growth that independent firms reap from skilled human resource, a key growth driver, and from globalisation, coupled with the bonus dividend for each year of independence - raises firm independence as an important consideration for firm growth.

Notwithstanding the importance of independence for firm growth, tax and financing incentives, as well as merger and acquisition (M&A) activity are also critical drivers influenced by policy impacting firm growth. While firm independence results are persuasive in suggesting there should be some policy space to protect or support it, nonetheless the other policy incentives are important as they work to support different types of growth, offering firms' choices to create a diversified firm landscape for a successful economy. So, how did the tax and financing incentives and M&A activity stand up to evaluation?

Firstly, the much-publicized claim that corporate tax cuts are needed for firm growth, appears not to be the case for all types of firms. It appears that general (innovative and non-innovative) firms can seemingly grow despite increase in corporate taxes. However, it is true that for innovative firms specifically, corporate tax growth was found to be negative impact on firm growth, indicating that a blanket policy for all types of firms may not be advisable. Furthermore, corporate tax growth has an even larger negative influence on independent innovative firms, indicating that corporate tax reduction for innovative firms does appear to be the correct policy stance. Nonetheless, given the variation of impact for general firms, a tailored approach on corporate tax reduction policy may be more advisable rather than the current blanket policy approach.

Perhaps the main takeaway on corporate tax reduction is that the magnitude of the impact of this driver on firm growth is low relative to other drivers, appearing not to deserve the headline policy status it has been given over the last decade.

Secondly, are the tax and financing incentives aimed at increasing seed and venture capital, helping firm growth? The findings appear to corroborate the importance of venture capital on firm growth – albeit its impact on growth is not large, it is a positive and significant driver for both general and innovative firms. In contrast, it appears that venture capital is not significant (indeed negative) for independent innovative firm growth. Nonetheless, incorporating detailed analysis, the results affirm venture capitals position as a positive driver for SME growth. Given that UK's venture capital is approximately factor 7~8 lower availability of venture capital ratio to GDP relative to US (OECD, 2016) and is considered to be one of the alternatives for longer term funding for firms, then increasing availability of this type of capital should partially address the scaling-up difficulties of current UK innovative start-ups.

However, the relatively low impact on firm growth and non-significance for independent innovative firms suggests it could not in itself be the central policy to scale up innovative firms to become the future UK googles/ARM of UK. For that yet again, it appears we have to look if possible for a driver with greater impact.

Thirdly, how does merger and acquisition activity influence firm growth? The findings suggest that M&As, based on MBO and MBI, seem to be positive and significant, with a similar impact for both general (innovative and non-innovative) and innovative firms. To be noted though that MBO's, which include external hostile/consensual takeovers as well as management buyouts, have a lower impact than venture capital, approximately half. In contrast MBIs seems to have a much higher impact than venture capital, though MBI's make up a very small fraction of M&A activity (Wright & Wilson, 2013). More so, detailed analysis revealed that M&As do not drive firm growth for innovative SME's, only large innovative firms and general SME's.

Furthermore, in term of independent innovative firms, M&As have absolutely no significance. As firm independence seems to have a considerable impact in driving firm growth, these findings place this driver in context for its impact on firm growth. Thus, while merger & acquisition are an important option for firms, whether as a choice of exit of firm owners or as a means of improving a failing business or means of growth through technology acquisition – it appears not to be the option for delivering growth for either innovative SME's or independent successful innovative firm.

Thus, it would appear that although mergers and acquisitions are much lauded as a tool of growth, the data in contrast suggests it is not a driver for scaling up innovative SME's nor specially for independent innovative small firms to scale up to become the next UK Google/ARM.

In summation, it appears that the impact of these policy tools pales relative to firm independence – for which there is currently no policy support or protection in place. Thus, although corporate tax reduction and venture capital enhancement are policies that do support innovative firm growth, in contrast to M&A's which have no impact on scaling up innovative SMEs – the most important policy for firm growth could be support of firm independence. Currently absent in policy.

This brings the study back to its earlier concerns – that the sale of successful innovative firms before reaching their potential be one of the underlying reasons that UK does not have the successful new innovative behemoths of the future. This concern appears to be validated by data, given the quite large impact of firm independence. What then can explain the sale of these firms before potential?

Given the relatively large impact of firm independence on firm growth, the lack of policies to support or protect firm independence could be crucial. Perhaps reconsideration of the Enterprise Act (2002) would enable some protection for firm independence through assessing whether and how firms may be protected from hostile takeovers. This study's findings underline that merger and acquisitions can be an option for some firms, be it as an exit route or to bring in best practices to improve growth – but that option, as it involves losing independence, comes at the potential sacrifice of growth for successful firms. Hence a firm should retain choice for this path, an option a hostile takeover seems to remove from the firm. A possible option is the 'poison pill'option available to firms in the Netherlands (Harvard Law School Forum, 2015) or dual class shares, staggered boards as in US (Mayer, 2018). The recent decision by Unilever to relocate its HQ to the Netherlands (FT, 2018), as well as GKN's loss to Melrose in a hostile takeover that went to the wire (FT, 2018) , both seem to underscore the need for re-evaluation.

More so, lack of significant long-term financing could be another critical problems, as venture capital provides one channel through which firms secure longer term financing, enabling SME firm growth. Though it is not significant in this study for innovative independent firms. Given that venture capital as a ratio of GDP is a factor of 7~8 times lower in UK relative to US (OECD, 2016), it is perhaps not coincidental that UK has a factor of 6-7 times lower large firm share presence in the economy compared to US (SBA , 2016). This dearth in availability of venture capital, could conceivably encourage firms to sell in UK, rather than face the battles of uphill struggle to secure finance (Economist, 2017).

Increasing the size of available venture capital for firms in the UK would thus seem a policy priority, providing one option of long-term finance for innovative firms wishing to scale-up and last the distance. Perhaps, UK could pursue an initiative similar to Israel's successful venture capital investment programme as YOZMA (OECD, 2015). Started in 1993, with 0.1 percent of its GDP in public funds to leverage foreign financing, it was so effective at encouraging privately financed venture capital growth that the government could begin to phase out within 7 years. Alternatively, UK could consider introducing measures to enhance pension fund expansion in venture capital. Maybe, in the vein of the US 1979 Employment Retirement Income Stabilization Act, which appeared to propel venture capital expansion in Silicon Valley (Bottazi & Da Rin, 2002). It would appear that this latter direction is supported by UK government in current white paper on Industrial strategy (Financial Times, 2017).

In summary, it would appear that the key growth policies for UK to support its innovative start-ups to have the chance to become a future Tesla or Google are two-fold. Firstly, the government might bring in some policy measures to protect or enhance firm independence – currently absent in policy. Secondly, as the availability of venture capital in the UK is far lower than in the US, policies to further enhance availability of venture capital are much needed, as longer-term finance enables firms the choice of staying independent. Specially, as firm independence appears to have such a paramount impact on firm growth and UK's potential giants appear to get sold before reaching potential - these two policy shortcomings could perhaps partially explain UK's current lack of new tech giants. Yet, it would appear that potential UK behemoths, not short of funding, nor targets of hostile takeovers – did indeed decide to sell (Sawyers, 2016; BBC

News, 2016). The above policy suggestions would not have had any influence in such a situation.

Moreover, it is puzzling that not a single UK innovative firm created in the last 30 years, except ARM, lasted the distance to become a valuable tech firm. Given the successful start-up intensity in UK, the fact that except for ARM holdings not a single tech frontier firm appears to have lasted the distance to become a UK giant is truly perplexing. It is not as if there is a total absence of venture capital, nor do all firms face hostile takeovers. Perchance, there is something else, something deeper – embedded in the mind-set perhaps?

To find answers that delve deeper is beyond the scope of this study, but perhaps some clues to the answer may be found in historical analysis of innovative societies (Mokyr, 1990). While the historical discussion cannot be addressed in this study, Mokyr offers some insights to explain how innovative societies such as the Arab or Ottoman Empire or China were left behind by European industrial revolutions despite their innovative lead. According to Moykr (1990), the role of an innovator is central to grow innovative societies in the long run and the lack of flow of financial rewards to innovators in Arab or Ottoman empire and the lack of status of Entrepreneurs relative to Mandarins in China hindered the innovator from acquiring that central role in those economies. Whether that historical parallel would offer any clues to the situation in the UK is unclear, however further combined economic and historical research into this area could yield insights into deeper underlying issues not answered in this study. Such as whether rewards currently flow to innovators in the UK and/or is there a need to raise the status of innovators presently in the UK? Or do innovators prefer low-risk and liquidate gains earlier, rather than lasting the distance to reap higher gains, but with higher risk? Future research to assess the role of innovator in UK society today, could perhaps yield some clues to this puzzle. As UK needs the visionary entrepreneurs, seeking to change the world as we know it today - looking beyond initial financial gains - to successfully create the Googles of tomorrow.

Chapter 5 Conclusion

5.1 Summary and key insights drawn from research

This research aspired to widen current concepts of innovation and growth through uniting neoclassical stream of thought with evolutionary economics, while further sourcing understandings relevant to innovation from development economics, economic history, industrial organization and entrepreneurial management & finance literature. Through merging of not only these two paradigms of thought but also these other inter-related fields, this research seems to contribute by widening the field of economics of innovation. Not only does this research widen some of the concepts, it goes a step further by connecting innovation to the field of productivity and growth. Analysing productivity through incorporating innovation structures into economic growth development economics models. It concludes by introducing a new concept, the characteristic of firm independence, into the study of growth.

The central theme of this research is that neoclassical factors of production do not perhaps operate in a vacuum in an economy. Rather they are interconnected through linkages and structures, the exposure of which emphasises the importance of supporting these underlying connections as much as the factors of production, when devising policies. Notably in the field of growth and productivity, given the interaction of innovation with both these aspects of an economy.

In particular, this research sought to broaden the current understanding of innovation and its interlinkages with productivity and growth. To widen the analysis of innovation combining formal innovation drivers alongside informal drivers, whilst at the same time exploring the structural aspects governing innovations relationship with productivity and growth. Essentially trying to discern how both the wider set of drivers and the deeper structural determinants of innovation, shape productivity and growth.

In line with these goals, this research assessed three problems in particular: identifying a wider spectrum of innovation drivers explaining firm growth and how these differ across firm structures; revealing the deeper firm and sectoral structures that define productivity adapting development economics models; and, exposing the role of firm independence in shaping firm growth and how this effect compares with current policy tools aimed at shaping firm growth.

To build the wider concepts at the outset, this research used aggregated firm level data to form understandings across EU economies at country and sector level. Building upon these insights, the last chapter focussed on UK, using firm-level data to shed light upon key aspects which support firm growth .

The main empirical findings of this research support the central theme that neoclassical factors do not operate in isolation and that linkages and structures emphasize the intricate relationship of innovation with productivity and growth. Using panel innovation, skills statistics and IMF data of 27 EU economies from 1996-2010, the second chapter of this research broadened the analysis of innovation in firms by adopting a wider concept, one encompassing drivers sourced across growth theory, evolutionary economics, industrial organization theory and globalization. In fact, combining innovation drivers sourced from formal R&D processes promoted by growth theories alongside informal R&D linkages emphasized by national innovation systems (NSI). Although both R&D aspects are well researched for their importance towards innovation, this study researched whether there is an order to this contribution. In effect, distinguishing influences shaping revenue levels as primary drivers and those shaping revenue growth as secondary. The study revealed that industry linkages with academia, public funding of industry, linkages with suppliers and skilled human capital are found significant as primary drivers of innovative firms across all firm sizes. Although R&D investment is not found significant as a primary driver, it is significant as a secondary driver delivering growth of innovative firms. Thus, informal R&D processes such as linkages and tacit knowledge were found to constitute the primary driver, while formal R&D processes such as R&D investment acts as a secondary driver. The key insight that a broader set of policy tools could be used to encourage innovation, which is an important finding for shaping future innovation policies. Significantly, there is an order to this broader set of tools: the initial foundation of innovation driven through primary drivers of informal R&D linkages and tacit know-how, followed by formal R&D investment as secondary driver spurring growth.

Building upon this groundwork of importance of firm structures in the arena of innovation, the third chapter of research draws structures into an understanding of productivity– based on economic development theoretical frameworks. In particular, this chapter explores the structural compositions of the economy that may influence productivity. Not discarding the importance of factors of production, the chapter instead seeks to understand the structures beneath, channelling those factors of production. Using an adaptation of the economic development framework, the Lewis model, this study proposes that country level labour productivity may be driven structurally by the movement of resources across from smaller firm sizes to larger firm-size structures. To enable this analysis, a new database is built up at sector level for the 32 European economies between 2000-2012. The contribution of firm-sizes to country productivity is measured through isolating classifications of small, medium and large firms, alongside control variables capturing growth theory drivers, globalization, credit conditions and monetary lending policies. Large firms are indeed found to be the significant most structure for country labour productivity. These findings underscore that focus on factors of production alone, be it firm investment or skills shortage, may not be sufficient to improve productivity – understanding the firm-landscape composition may be as essential.

Additionally, this chapter examines whether sectoral composition of an economy can shape country labour productivity levels. The chapter investigates both aspects, sector size and sector productivity, and how they influence in shaping country labour productivity. The findings from this sector composition analysis seem less clear. Some sector productivities were found significant for country productivity, while sector revenue-size was found significant for some sectors. These results suggest that firm structures may not be an equally sensitive issue over all sectors.

Nonetheless, these results offer two insights. Firstly, those sectors which influence country productivity through both sector size as well as sector productivity, require policy makers to tailor policy accordingly to both aspects. Secondly, this finding has possible implications for firm-structures most suited to sectors depending upon their mode of influence. Though needing further corroborations, the implication is that sectors influencing through size would benefit most from presence of turnover contributions of all three firm-size structures. In contrast, sectors contributing through sector productivity may benefit from a higher intensity of large firms in that sector. These implications were outside the scope of the current study due to limitations of firm-structure classification at detailed sector level data. Should that data become available in the future, these implications could be corroborated allowing future policy support of firm-structures to be shaped in accordance to mode of influence of sectors.

Lastly, chapter three also examined whether sector share, the proportion of sector turnover to total core innovative sectors turnover, as distinguished from sheer size of sector also exerts an influence on country productivity. The results indicate that for some sectors, sector share of turnover is significant as a mode of influence, although comparatively less sectors than those found significant for size of turnover. More so, of those sectors found significant in terms of share, quite a large number appeared to have a negative influence on country productivity. Although isolating the cause for this result is outside the scope of the study, this could be indicative of a negative impact through either dominance or conversely weakness of sectors proportional to the total innovative sectors. Further in-depth research would be needed to assess whether this is or is not an issue for country productivity.

The fourth chapter of research, building upon the knowledge and insights gained from foundational chapter, tackles one of the very concrete current problems in the UK economy – the weakness of UK firms to scale up. This chapter examines whether firm independence, not known to be driver for firm growth itself, is an important criterion to enable scale up of innovative firms into successful frontier large firms. To shed light on the role of independence brought to the fore in business history and financial enterprise literature, the study examines neoclassical drivers of firm growth alongside key policy tools used to support firm growth – with innovative independent firms separately assessed from overall innovative firms. Using firm level dataset for all UK sectors between 2006-2016, policy tax and financing tools supporting start-up, growth and merger activity are examined alongside growth theory drivers, globalization and monetary lending policy. The empirical analysis reveals that independent firms reap much higher growth, with age of independence delivering a bonus growth-dividend based solely on the years that a firm can manage to stay independent. Contrary to expectation, the growth from the traditional policy tools, though valuable, seems outweighed by the impact of firm independence on growth. It appears that firm independence itself is a vital aspect for growth – an aspect neither enhanced nor specifically protected in current UK policy. Policy tools, currently used in US or Europe such as staggered boards, poison pills or Dual class shares or reshaping of UK Enterprise act 2002 could perhaps be considered to form policy support for firm independence in UK.

Notwithstanding this, current policy tools remain a critical component to aid growth. In particular, two findings stand out. Firstly, although relatively smaller in impact, both corporate tax reduction and access to seed and venture capital appears important to support long-term growth for innovative firms. Though general firms can grow despite increases in corporate tax, suggesting a tailored policy approach is advisable. Secondly, M&A activity appears to enhance growth of general SME's, not innovative SME's only large innovative firms, suggesting M&A's have a role for growth overall – but not for helping scale up the innovative small firms of today to become the frontier giants of tomorrow. These findings invite a rethink of current UK M&A regulation, balancing encouraging M&A activity for overall firms and for large innovative firms, with some protection for innovative SMEs desiring to scale up into possible frontier firms like ARM/UK Googles of tomorrow.

5.2 Future Areas of Research

This research has built on a legacy of research and literature, drawing understandings and insights not only from neoclassical and evolutionary economics, but also from disparate fields of business history, industrial organization and financial and management enterprise literature. The insights were used to guide this research, but despite enormous efforts to draw the maximum insight into this research, one of the challenges lay in the limitations of data. While the increased availability of panel data shed light on many insights, some of the puzzles could not be clarified within the current databases and leave avenues open for future research. I would like to point a few, which I think would continue to develop our understanding of innovation and its intricate relationship with growth.

One of the puzzles only alluded but not resolved in the second chapter on innovation drivers lies in assessing the consequences of short-term versus long-term ownership and governance structures on firm growth. Given current data limitations, this could not be assessed directly, yet it is an important issue. The focus in EU since 2008 to build demographic firm data, which would over time gain sufficient increase in longitudinal time, could in future be linked to financial databases with ownership data. Such an option, might not only enable consequences of ownership structure to be explored, it may also provide further insights on how diffusion or maturing of technology (Tunzelmann G. V., 2000) may change innovation drivers shaping policy makers insights accordingly.

Similarly, the third chapters' research on assessment of firm structures influence on productivity within sectors was limited by data availability to 10 aggregated sector levels. Should detailed firm structure of each sector be made available, that would develop deeper understanding on the interaction of structures and productivity at sector level. Furthermore, it could expose sectoral variations, allowing identification of sectors differing from the norm, and even revealing perhaps sectors where SME's could have higher productivity relative to larger firms, thus allowing in turn fine-tuning of policies to the needs of sectors. Lastly, if data was made available not only on firm structures at sector level, but also of firm-type, innovative versus non-innovative firm – that could shed light on the intriguing puzzle how and why sector shares could negatively impact an economy. These queries, should data be made available, could help further develop our understanding on how structures influence productivity of economies.

Another critical aspect for advancing insights of innovation in the future, hinted but essentially left unanswered in chapter 4, is perhaps as much a challenge in capturing values, as perhaps regulations or policy to support independence to boost firm growth. This pertains to the puzzle of the role of an innovator in lasting the distance and enabling a small firm to become a behemoth of tomorrow. Indeed, queries seeking answers as to why potential UK behemoths like Skyscanner or ARM, not short of funding, nor targets of hostile takeovers – did indeed decide to sell (Sawyers, 2016; BBC, 2016), are not easily addressed. Yet, they need to be understood. Historical analysis seems to offer some possible clues. According to Mokyr (1990), historically innovative societies that failed to develop in the long run, missed allocating innovators a central role in the innovation process: captured either by lack of status of innovators in some societies; or a lack of flow of financial rewards to innovators in others. Should future research perhaps combining historical business studies with demographic data offer possible insights into the aspirations of innovators, these would be very revealing. In fact, not only revealing, they could help shape policies dealing with the unit at the very crux of innovation – the innovator.

Appendix

Chapter 1 appendix

Apendix A: Statistics of data variables representing drivers

Table A1 provides the descriptive statistics for the drivers listed in table 2.

Table A1: Descriptive Statistics for variables used in regression analysis

	Mean	Standard deviation	Minimum	Maximum
Innovative Turnover	3.76e+08	6.92e+08	2573667	4.20e+09
Number of Scientists and Engineers (Skilled human capital)	332.1915	478.5706	4	2281
Total innovation expenditure (R&D investment)	9533784	1.99e+07	20934	1.07e+08
Enterprises using external R&D	2167.616	3060.054	4	16242
Enterprises using internal R&D	5110.252	8195. 296	61	40753
Enterprises with access to public funding _	2420.488	3926.076	14	18573.14
Enterprises with any type of cooperation	2638.093	3529.394	36	20949
Enterprises collaborating with universities	980.0557	1503.702	6	11305
Enterprises collaborating with govt. institutions	647.2313	869.0159	3	4805
Enterprises collaborating with suppliers	1599.733	1951.613	26	13886
Enterprises focusing on National markets	5642.08	8543.078	65.248	45821
Enterprises focusing on International markets	4195.015	6092.886	28	33153
Small firm Innovative turnover (less than 50 emplyees)	4.43e+07	7.26e+07	243162	4.43e+08
Medium firms Innovative turnover (less than 250 employees)	7.34e+07	1.22e+08	179474.8	8.09e+08

CIS and HRST database, Eurostat

Appendix B: Correlation table of drivers

Table A2 provides the correlation values the drivers listed in table 2.

Table A2: Correlation values for drivers used in regression analysis

	Innovative turnover	Number of Scientists and Engineers (Skilled human capital)	Total innovation expenditure (R &D investment)	Ent. using external R& D	Ent. using internal R& D	Ent. with access to public funding _	Ent. with any type of cooperation	Ent. collaborating with universities	Ent. collaborating with govt. institutions	Ent. collaborating with suppliers	Ent. focusing on National markets	En fo usi g o Int rna io l ma ke
Innovative Turnover	1											
Number of Scientists and Engineers (Skilled human capital)	.927	1										
Total innovation expenditure (R&D investment)	.937	.91	1									
Enterprises using external R&D	.917	.906	.921	1								
Enterprises using internal R&D	.916	.892	.937	.986	1							
Enterprises with access to public funding _	.79	.758	.727	.88	.893	1						
Enterprises with any type of cooperation	.93	.937	.905	.922	.92	.783	1					
Enterprises collaborating with universities	.933	.877	.919	.888	.903	.734	.945	1				
Enterprises collaborating with govt. institutions	.932	.941	.88	.87	.85	.701	.954	.931	1			
Enterprises collaborating with suppliers	.843	.869	.91	.833	.822	.70	.953	.845	.889	1		
Enterprises focusing on National markets	.862	.856	.857	.951	.955	.892	.824	.849	.823	.795	1	
Enterprises focusing on International markets	.876	.859	.873	.959	.964	.863	.834	.881	.833	.823	.984	1
Small firm Innovative turnover (less than 50 emplyees)	.844	.769	.734	.810	.822	.81	.826	.814	.80	,771	.821	.82
Medium firms Innovative turnover (less than 250 employees)	.952	.903	.906	.923	.934	.836	.836	.96	.928	.862	.908	.92

CIS and HRST database, Eurostat

C: Overview of proportional ratios for R&D, for top 10 Economies according to R&D investments

Table A3: Top 10 EU economies ranked in order for proportional ratio of R&D driver (innovation output per R&D input, measured in billion Euros output per million Euro R&D investment), covering the period 1996-2010

Countries	Proportional Ratio R&D (innovation output per R&D input, measured in billion euros output per million euro R&D investment)	R&D investment (comprises total R&D costs, including capital and knowledge acquisition, measured in millions of Euros)	Mean Innovative turnover (all firms) – main innovation measure (measured in billions of Euros)
Spain	0.06	10.5	0.63
Poland	0.043	5.57	0.24
Netherlands	0.042	8.9	0.38
Italy	0.04	21.6	0.92
France	0.036	35.7	1.33
UK	0.036	27.8	1.00
Belgium	0.034	8.5	0.29
Germany	0.032	94.9	2.99
Finland	0.028	5.6	0.16
Sweden	0.02	13	0.26

CIS database, Eurostat

D: Overview of R&D figures for advanced economies

A brief overview of mean R&D figures[14],over the period 2000-2010 of advanced economies, as listed in table A4, contrasts with the performance mean innovation measure over period 1996-2010 of EU economies under review in this study in Table A5. Table A4 appears to highlight the variation in delivery of innovation in economies based on R&D investment alone, Table A4 also including figures on US as a benchmark for comparison. It is noteworthy to see how much of GERD is financed by governments and how much by businesses. It seems that quite a few of the higher performing innovative economies amongst top 20 have a government financed GERD around 0.7%. More remarkable to note perhaps is that the difference for the relative much higher GERD appears to be driven by business's financing, as evident for Sweden, Finland, Germany, Denmark and US.

Comparing figures within Table A4, it is noticeable that despite a considerable global innovative lead by US along with Japan over EU economies (PRO INNO Europe, 2007) (Pro Inno Europe, 2011), Sweden appears to have a higher expenditure on R&D, both in GERD and BERD. Though Sweden in its own right is

[14] As R&D expenditure is often listed both in terms of gross domestic R&D expenditure (GERD) and business expenditure on R&D(BERD), the mean values for both are provided in table 1, covering the period of 1996-2010.

ranked as one of the leading European innovative powers, it still trails behind US (European Commission, 2013), yet its R&D expenditure is substantially higher than US. In contrast, Germany and Denmark seem to have relatively similar levels of GERD to US, with Finland though again higher comparatively. Thus, underscoring the variation in R&D investment in order to deliver similar levels of innovation performance, as measured by EIS. These R&D investments of Table A4 contrast with innovation measure performances in Table A5, illustrating the complexities of an innovation system indicating importance of drivers beyond R&D as a means to explain the resulting level of innovation in an economy. To enable a comparative comparison of GERD as share of GDP with the innovative measure, the innovative measure as a share of GDP is listed in Table A6. Although this realigns the top 20 EU economies, Germany still outperforms the other European G7 economies, with UK surprisingly at the bottom of the table.

It seems that the delivery of a high innovation measure may be possible with a wide variation of R&D investment values, with Germany appearing to score the highest innovation measure in Table A5 despite listing a lower R&D investment than some other economies in Table A4. The next section lists the top 20 economies in the innovation measure in Table A5 and then lists the top 10 economies according to performance of the various drivers in Tables A7 and A8.

Table A4: Mean R&D and BERD expenditure between 1996-2010, as %age of GDP

Countries	(Gross Domestic expenditure on R&D) [15]GERD as %age of GDP	GERD financed by govt. as a %age of GDP	GERD financed by Business as %age of GDP	(Business Enterprise expenditure on R&D) [16]BERD as %age of GDP	%age of BERD financed by govt.
Austria	2.14	0.78	0.97	1.60	8.07
Belgium	1.87	0.44	1.18	1.31	5.92
Czech Republic	1.15	0.49	0.58	0.68	12.85
Canada	1.87	0.59	0.91	1.07	3.07

[15] Definition of Gross domestic spending on R&D (GERD) as defined by OECD: The total expenditure (current and capital) on R&D carried out by all resident companies, research institutes, university and government laboratories, etc., in a country. It includes R&D funded from abroad, but excludes domestic funds for R&D performed outside the domestic economy

[16] Definition of Business enterprise expenditure on R&D (BERD) as defined by OECD: Represents the component of GERD incurred by units belonging to the Business enterprise sector. It is the measure of intramural (ie within the sector) R&D expenditures within the Business enterprise sector during a specific reference period.

Denmark	2.40	0.70	1.42	1.62	3.40
Finland	3.22	0.85	2.22	2.26	3.45
France	2.12	0.81	1.10	1.33	10.25
Germany	2.42	0.75	1.59	1.67	6.26
Hungary	0.88	0.43	0.35	0.40	8.89
Ireland	1.24	0.35	0.73	0.85	4.33
Italy	1.07	0.51	0.48	0.54	10.65
Luxembourg	1.60	0.30	1.17	1.33	3.31
Netherlands	1.77	0.70	0.85	0.94	4.47
Poland	0.61	0.37	0.20	0.20	20.13
Portugal	0.90	0.49	0.33	0.35	5.20
Romania	0.48	0.24	0.18	0.26	35.37
Spain	1.04	0.44	0.48	0.55	11.84
Sweden	3.45	0.87	2.28	2.54	6.00
Turkey	0.54	0.25	0.23	0.19	5.76
UK	1.61	0.50	0.73	1.02	8.60
US	2.59	0.78	1.65	1.83	11.05

Mean Gross domestic expenditure on R&D (GERD) and Businesss enterprise expenditure on R&D (BERD) for period 2000-2010 (OECD Main science and technology indicators -MSTI- database)

E: European economies performance in the Innovation measure and drivers

EU economies based on performance in Innovation measure As the innovation measure is the key criterion for establishing level of innovation in economies for this research, bearing in mind the definitions as outlined in the data section, the top 20 economies are listed in table A3, based on a mean value of innovation measure from CIS data over the period 1996-2010. It is a different ranking of economies[17],then that indicated by the level of R&D expenditure as listed in table 3. The ranking based on the main innovation measure in the second column, shows Germany, France and UK as the top 3 innovative economies out of the 27 EU economies included in this research, based on innovative firm performance. The spread between UK, France and Germany is quite large, with Germany nearly a factor 3 higher than UK in the main innovation measure. Germany maintains this lead for small firms and medium firm innovation measure, though Italy and UK jump upwards to second place for these two variables respectively. Again, though worth noting is the remarkably large difference between Germany and any economy coming up in second place.

[17] US is not included in this ranking, as its economy is not covered by CIS data

However, the economies realign when reviewing innovative measure as share of GDP as listed in Table A6. Despite realignment Germany still outperforms the European G7 economies substantially, with UK surprisingly at the bottom of the table. This seems to reaffirm the complexity of innovation systems. Not only confirming the importance of the wider set of innovation drivers but also as summarized in conclusion, the importance of structural aspects – such as firm structures in an economy.

Table A5: Top 20 EU economies ranked in order for mean innovative turnover in absolute value (in billion euros) for all firm-sizes, covering the period 1996-2010

Countries	Mean Innovative turnover (all firms) – main innovation measure (measured in billion euros)	Mean innovative turnover (as share of avg GDP for same time period) x 1000	Mean innovative turnover (for only small firms)	Mean innovative turnover (for only medium firms)
Germany	2.99	1.33	0.23	0.48
France	1.33	0.81	0.11	0.19
UK	1.00	0.56	0.13	0.23
Italy	0.92	0.67	0.16	0.21
Spain	0.63	0.77	0.08	0.12
Turkey	0.62	1.7	0.27	0.14
Netherlands	0.38	0.74	0.05	0.092
Belgium	0.29	1.0	0.048	0.067
Sweden	0.26	0.88	0.04	0.048

Poland	0.24	1.04	0.019	0.046
Austria	0.23	0.96	0.029	0.057
Ireland	0.18	1.32	0.02	0.055
Finland	0.16	1.05	0.015	0.025
Czech Republic	0.15	1.52	0.015	0.032
Norway	0.14	0.62	0.019	0.03
Denmark	0.13	0.66	0.023	0.031
Portugal	0.12	0.83	0.023	0.032
Hungary	0.08	1.09	0.006	0.013
Romania	0.062	0.86	0.006	0.011
Luxembourg	0.057	2.06	0.008	0.013

CIS database, Eurostat

Table A6: Top 20 EU economies realigned in performance for mean innovative turnover (in billion euros) as share of GDP (in trillion euros) for all firm-sizes, covering the period 1996-2010

Countries	Mean innovative turnover (as share of avg GDP for same time period)	Mean Innovative turnover (all firms) – main innovation measure
Luxembourg	2.06	0.057

Turkey	1.7	0.62
Czech Republic	1.52	0.15
Germany	1.33	2.99
Ireland	1.32	0.18
Hungary	1.09	0.08
Finland	1.05	0.16
Poland	1.04	0.24
Belgium	1.0	0.29
Austria	0.96	0.23
Sweden	0.88	0.26
Romania	0.86	0.062
Portugal	0.83	0.12
France	0.81	1.33
Spain	0.77	0.63
Netherlands	0.74	0.38
Italy	0.67	0.92
Denmark	0.66	0.13
Norway	0.62	0.14

UK	0.56	1.00

National accounts, Eurostat

Innovation drivers Keeping in mind the quite large deviation between Germany and the other G7 economies in the innovation measure, we now move to assessing other drivers listed in table 2. They cover respectively drivers of skilled human capital, R&D investment, external sourcing of R&D, public funding for enterprises, firm linkages with academia, firm linkages with governmental organizations, firm linkages with suppliers, national market focus for enterprises and Enterprises focused on International markets. The top 10 ranked economies for each of these drivers is displayed in table A4 and A5[18]. Despite the considerable variation of aspects measured by each driver, Germany's strength of performance across the spectrum is quite remarkable.

Table A7: Top 10 ranking of economies of five of the nine (mean value of) drivers, over the period 1996-2010

Rating of economies per Drivers:	(1) skilled human capital	(2) R&D investment	(3) External R&D	(4) Publicly funded firms	(5) Firms linked with academia
	2066 - Germany	94.9 - Germany	14.6 - Germany	14.1 - Italy	7.3 - Germany
	1455 - UK	35.7 - France	7.9 - Italy	12.6 - Germany	2.8 - UK
	1265 - France	27.8 - UK	6.1 - France	5.7 - Spain	2.3 - France
	841 - Spain	21.6 - Italy	4.6 - Spain	5.5 - France	1.7 - Italy
	721- Italy	13 - Sweden	3.01 - Netherlands	4.96 - Turkey	1.4 - Turkey

[18] The statistics of these drivers is provided earlier in the appendix

	614 - Poland	10.5 - Spain	2.45 - Portugal	3.4 - Netherlands	1.3 - Spain
	463 - Netherlands	8.9 - Netherlands	2.21 – Czech republic	2.89 - UK	1.08 - Finland
	392 - Romania	8.5 - Belgium	2.18 - Turkey	2.4 - Austria	1.07- Sweden
	345- Turkey	5.6 - Finland	2.14 - Sweden	1.58 - Portugal	1.01- Czech Republic
	331- Romania	5.57 - Poland	2.12 - Belgium	1.5 - Poland	0.97 - Austria

HRST database, Eurostat

Mean skilled human capita, scientists and engineers (expressed in 1000's) driver
Mean total innovation expenditure: Covers Internal and external R&D cost, including knowledge and capital acquisitions (expressed in millions of Euro's)
Enterprises sourcing R&D externally (expressed in 1000's)
Public funding of enterprises (expressed in 1000's)
Firm linkages with academia (expressed in 1000's)

Table A8: Top 10 ranking of economies of the remaining four (mean value of) drivers, over the period 1996-2010

Rating of economies per Drivers:	(6) Firms linkages with govt. Institutions	(7) Firm linkages with Suppliers	(8) Firms with home market focus	(9) Firms with Intl. market focus
	3.6 - Germany	6.7 - UK	35.6 - Germany	27.5 - Germany
	2.5 - UK	5.7 - Germany	23.2 - Italy	17.3 - Italy
	1.8 - France	4.7 - France	14 - Spain	11.3 - UK

	1.3 - Spain	3.06 - Poland	12.9 - France	10.3 - France
	1.2- Turkey	2.9 - Italy	10.7 - UK	8.08 - Spain
	0.86 - Poland	2.6 - Turkey	10.5 - Turkey	5.06 - Turkey
	0.856 - Finland	2.3 - Netherlands	6 – Netherlands	4.65 - Netherlands
	0.79 - Netherlands	2.2 – Czech Republic	5.5 - Portugal	3.86 - Austria
	0.68 - Italy	1.98 - Sweden	4.6 - Poland	3.8 - Portugal
	0.55- Belgium	1.79 - Spain	4.5– Czech Republic	3.77 - Belgium

HRST database, Eurostat

Firm linkages with governmental Institutions (expressed in 1000's)
Firm linkages with suppliers (expressed in 1000's)
Enterprises with Home market focus, firms focused in this market does not preclude them from focusing in International markets (expressed in 1000's)
Enterprises with Intl market focus (expressed in 1000's)

Chapter 4 Appendix

Corporate tax measurement at national level:

UK corporate tax, in 2009 at 28% stood was the second lowest statutory rate amongst the G7 (Griffeth & Miller, 2010), which at 26% in 2012 reached lowest in G7 by 2012, though it was ranked 18th when viewed amongst OECD countries (Bilicka & Devereux, 2012). Reviewing UK's ranking again in 2015, Devereux et al. (2016) found UK at 20% reached the lowest statutory corporate tax rate amongst the G20 countries. However, Devereux et al. caution at the use of statutory corporate tax and advocate the use of either effective average tax rate EATR or effective marginal tax rate EMTR, as it captures capital allowances. Thus, instead using EATR and EMTR to assess corporate tax ranking, even by those measures UK was ranked 5th and 10th respectively amongst the G20 countries by 2015 (ibid). Thus, as of late at least, UK has a policy initiative that seems to be supportive of medium and large firms.

OECD firm-structure classification:

•Micro firms: Less than 10 employees and/or less than 2 million euro turnover

•Small firms: Between 0-49 employees and/or less than 10 million euro turnover

•Medium firms: 50-249 employees and/or less than 50 million euro turnover

•Large firms: 250+ employees and/or turnover greater than 50 million euros.

Independence Indicator as defined in Amadeus database (BvDEP, 2006):

The independence indicator, developed by Bureau Van Dijk (BvDEP) accessible in Amadeus database, assigns firms an independence value, based on shareholder ownership share, in line with prescriptions from International Financial Reporting Standards (IFRS). This excludes public share-holders of quoted firms and any unnamed or private unnamed shareholders. Accordingly, the firm is acknowledged independent, if none of the known shareholders have more than 25% of direct or total ownership. This variable may be assigned value of A+/A/A-, based on whether the firm has 6 or more identified shareholders/4 or 5 identified shareholders/or 1to 3 identified shareholders. In all three cases, it is considered independent. These variations do not measure higher or lower degree of independence, only a degree of reliability of the indicator (BvDEP, 2006, page 13)

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