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Innovative Firms and
Growth

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Executive Summary

Background

Over the last two decades there has been a growing realisation that the long run economic performance of nations, firms and industries is dependent on their ability to exploit technological innovation (Cohen, 2010). This has created a significant interest among policy makers in how policy can be designed to support innovation and encourage innovative firms to grow.

Such policy making needs to take account of a striking outcome of academic research on innovation: the finding that the distribution of performance is highly skewed, with a small percentage of firms generating a disproportionate amount of innovation and employment growth. The UK Community Innovation Survey, for example, shows that the majority of UK firms are not particularly innovative, while roughly 20% of firms are responsible for most innovative activity. Similarly, in relation to growth, Storey (1994) showed that roughly 4% of firms generate 50% of new jobs, and Cowling, Taylor and Mitchell (2004) showed that only one third of firms create any jobs at all. These skewed distributions are a robust feature of the economy and are repeatedly found across datasets, across different national settings and through time.

Understanding the behaviour of firms in such a highly skewed environment represents significant statistical challenges, as data-sets and statistical methods have been developed to analyse the average impact of the average firm, rather than the highly skewed impacts of a small minority of firms. As a result, research findings are often very context specific and can change according to the time period, methodology, unit of analysis, and national setting that is being explored. A number of ambiguities and inconsistencies exist about the relationship between R&D, innovation and growth, and important policy questions remain unanswered. In this report we exploit a range of novel econometric approaches to explore the UK Community Innovation Survey datasets. Our specific empirical focus is on Highly Innovative Firms (HIFs) and High Growth Firms (HGFs), their relationship to one another, and how their features and behaviour influence their performance. HIFs are defined as the top 20% of firms in terms of R&D spending and the top 20% of firms with sales from new to market products and services, which is operationalized as those firms with more than 11% of sales from new-to-market products and services. HGFs are the top 5% of firms by employment and sales growth performance. In particular, we explore whether:

1. Highly Innovative Firms are also High Growth Firms, in terms of the magnitude of their output, employment and productivity.
2. Highly Innovative Firms collaborate more closely with scientific institutions, such as universities and publicly-supported research

establishments. If they do, are there any sectoral or regional patterns to their collaborations, and how are they influenced by firm characteristics?

3. Highly-Innovative Firms have been influenced by the recent recession.

Methodology

Innovation can be defined as the first successful commercial exploitation of a new invention. As such, the term covers both the process of change and its outcome. Innovation processes are complex, uncertain, distributed and draw on a wide range of inputs to generate a wide range of direct and indirect outputs. They come in very different forms, with some drawing on formal research and R&D, while others relying on informal learning-by-doing and engagement with customers and suppliers. They can be positioned on a continuum from incremental to radical, and can generate either new products, or processes, or services, or organisational structures. This complexity and heterogeneity makes innovation difficult to measure. Since we cannot measure it perfectly, research on innovation draws on a range of imperfect indicators to address the inadequacies of individual metrics (Hopkins and Siepel, 2013).

To address the questions highlighted above the research team used an input and output measure of innovation to capture the subset of highly innovative firms. R&D spending was used as a measure that captured inputs to innovation, while the share of sales derived from new-to-market products was used as an output measure of innovation. As noted previously, the input measure captured the top 20% of firms by spending on R&D, and the output measure captured the top 20% of firms deriving sales from new products. In general the two measures yielded similar results, but there were a few important differences. As might be expected the upstream R&D measure was more closely associated with links to research, while the more downstream sales measure was more closely associated with links to suppliers and customers. Performance was measured using a wide range of traditional metrics such as sales, employment, innovative performance, productivity, sales growth by turnover, and employment growth.

The research used four waves of the Community Innovation Survey for the UK for the years 2004, 2006, 2008 and 2010, which were linked to the ONS Business Structural Dataset (BSD) to create a panel. The survey was analysed as yearly cross sections and as an integrated panel of all four waves. Analysis involved both univariate statistics to capture differences between highly innovative, high growth firms and other firms, and then multivariate regression analysis across the performance measures to unpick and quantify the individual variables' impact on overall performance. Various regression techniques were used as appropriate. The multivariate models allowed us to control for a range of confounding variables in the data that might influence the results. By adopting a big-data approach (i.e. running >500 regressions) we are able to understand qualitative changes in quantitative results as different metrics, measures and methods are used. This provides for extensive robustness checking of the results that reduces the number of statistically spurious findings. We can therefore be more confident about the robustness of the reported results.

Main Findings

At first glance, **we do not find that Highly Innovative Firms (HIFs) are readily distinguishable from Less Innovative Firms (LIFs) using traditional firm demographic measures.** Taking into account other differences, we do find that younger and smaller firms are slightly more likely to be HIFs, but the effect is small. There are also some small regional differences, but in general we do not find a particular class of firms in high-tech, science-intensive sectors concentrated in particular geographic settings consistently driving innovation in the economy. This is an important positive message as it shows that **HIFs are found throughout the country.** Whilst there is a widespread belief that HIFs are entrepreneurial start-ups concentrated around particularly technology hubs, our analysis does not show particular regions or types of firms being disproportionately favoured. London, for example, is a major technological hub, but has slightly fewer than expected HIFs.

However, we find that HIFs differ substantially from LIFs using more specific metrics. In particular we find that **HIFs have a significantly higher share of employment accounted for by science and engineering (STEM) graduates, and moreover we find that this has a large positive influence on a range of performance metrics.** Firms with more science and engineering graduates in their total workforce are associated with more R&D, more new to market products, more external co-operation and greater use of external information (see also Coad, 2012). The beneficial impact of hiring science graduates is a robust finding that is consistently found to be important across a range of measures and models. Conversely, the lack of science graduate employment in LIFs is particularly striking: the median number of STEM graduates employed by LIFs is zero.

HIFs also tend to be much more internationally orientated than LIFs and more focused on exporting to international markets. By contrast LIFs are more focused on selling into local and regional markets. This international focus tends to be driven by older, larger firms employing more STEM graduates. So while HIFs are not concentrated in science-intensive sectors, we do find HIFs in all sectors with scientifically qualified workforces that enable them to network with other institutions, and sell innovative products and services in international markets, more successfully.

The second main finding is that high levels of growth are not strongly persistent. While a small percentage of firms in any particular period are responsible for a large proportion of overall growth (Cowling, Taylor and Mitchell, 2004), **we do not find the same firms across consecutive periods.** It is therefore misleading to conclude that a specific small percentage or subset of high performance firms consistently drive growth in the economy. This finding is consistent with previous research suggesting firm growth is approximately as

persistent as our ability to predict a coin toss (Coad, 2009).¹ For any period of time there will be a small percentage of high performance firms, but this performance is only weakly carried forward into the next period. In fact, we find a small negative autocorrelation between growth in sales and employment, suggesting firms that grow in one period are slightly less likely to grow in the next.

The third main finding is that, by contrast, there is a strong persistence in the innovative status of firms, with most HIFs remaining highly innovative and most LIFs remaining less innovative. While approximately 60% of HIFs maintain HIF status over time, only a small percentage of LIFs (~10%) become Highly Innovative. This is consistent with previous work showing that differences in R&D intensity across firms are highly persistent. While economic theory suggests that investment in innovation offers temporary advantages that competitor firms can readily innovate around, the empirical evidence clearly suggests this is not the case. Instead, it suggests that high performance firms have specific innovative capabilities that take time to accumulate, are difficult to copy, and enable firms to consistently introduce new and improved products and services. Importantly we find that **this persistent innovator status is conserved from 2008 to 2010, suggesting few HIFs have been adversely affected by the recession drastically enough to curtail their HIF status.**

The fourth main finding relates to the processes that drive growth. Using VAR (vector auto-regression) techniques we have been able to unpick and explore the processes of growth. The analysis suggests that **the growth process starts with increased employment, which then leads to future increases in R&D spending and New to Market Products, which in turn lead to future increases in Sales.** We do not find a feedback loop from increased sales to increased employment that would lead to persistent growth at the individual firm level. This causal chain suggests policy should avoid focusing exclusively downstream and consider what upstream capabilities need to be in place for increases in employment and ultimately sales to occur. For example, policies that attempt to increase sales directly may be ineffective if they do not take into account the need for firms to have products and services to sell, which in turn requires prior innovation and innovative capacity (people and technology), which in turn builds on investments in people and skills over an extended period. Without these previous upstream investments, policy may not be effective, while indirect policy interventions to increase sales by increasing employment might complement policy interventions directly focused on growth.

The fifth main finding is that HIFs, on average, tend to perceive more barriers to innovation than other firms, even though they do not seem to

¹ Where exceptional firm growth does deviate from a random walk, this tends to be associated with a tiny subsample of atypical firms, for example, in the US the tiny number of firms backed by large, technological sophisticated, professional VC funds (Shane, 2008:164).

affect their relative performance compared to LIFs who perceive fewer barriers to innovation. Previous research on HIFs has suggested that they can be substantially constrained by problems accessing managerial and technical skills, and accessing financing (Couerduroy et al., 2012; Siepel et al., 2012; D'Este et al., 2012; Hutton and Nightingale, 2009). These findings tend to support this previous research but also suggest managers' perceptions of barriers to innovation may be unrealistic about their impact on relative performance.

The analysis does find significant differences in perceptions about which barriers to innovation are the most problematic. HIFs are particularly concerned about financial constraints and the cost of innovation. This contrasts with relatively limited concerns about the costs and impacts of regulation.

On a more positive note, we find that the recession has not had a negative impact on HIFs in terms of perceptions of barriers to innovation for the 2010 survey compared to previous surveys. Moreover, we also find that the positive impact that innovation has on performance across a range of performance metrics declines in 2010. Care must be taken in interpreting these results, but the findings are consistent with a weaker economy subject to financial constraints and decreased demand. These findings are concerning, but they do not reflect the severe impact of the recession on investment in innovation and firms performance in the Eurozone found by Filippetti and Archibugi (2011). Perhaps more importantly **perceived barriers to innovation appear to have little relation to relative performance.**

Policy Implications

The first key policy message of this analysis is that **HIFs and High Growth Firms do not overlap to a significant degree.** HIFs, on average, grow faster than Less Innovative Firms, but do not overlap with the High-Growth Firms category any more than their prevalence in the population of firms would suggest, even during the recession. It is therefore misleading to assert that they overlap. Innovation and growth have a complex and indirect relationship: many Highly Innovative Firms are low growth, or no growth, while many High Growth Firms are not innovative.

The second key policy message is that **while both innovative activity and growth are highly skewed, they differ fundamentally. Innovative activity is largely persistent through time, while high growth is largely episodic.** The contribution of innovation to economic growth is a long run, gradual background process, while firm growth performance is a short run series of largely unrelated episodes. These episodes typically involve both growth, stability, and contraction. While innovative activity leads to macroeconomic growth, it is far from obvious that individual innovating firms will succeed, if they do succeed it is not clear they will benefit, and if they benefit it is not clear they will grow. The importance of innovation to aggregate macro-economic growth has much stronger empirical support. So while innovation is the main driver of economic growth, this does not mean that there is a one-to-one correspondence between (persistent) innovative performance and (persistent) growth at the firm level.

The persistence of innovative performance reflects the dependence of innovation on long term investments in building innovative capabilities (for example, through the employment of STEM and other graduates throughout the firm). Persistent investment is needed because of the long periods of time needed for learning to take place, for customers to understand technical products and services, for relationships to develop, and for the organisational changes that are often needed to exploit new technology to take place. This is why persistence of R&D investment is a better predictor of outcomes than absolute level of R&D spending at a particular point in time (Cefis and Orsenigo, 2011). Firms that spend consistently on innovation over many years tend to perform better than firms that concentrate resources in a single time period, even if the absolute level of spending is higher (Lööf et al., 2012).

Growth, on the other hand, is also skewed, but is a more intermittent, sporadic activity. It is subject to random, unforeseen setbacks and factors outside managers' control (Coad, 2009). For example, competitors can launch better products, customers can change their requirements and plans to expand into new markets can go awry. It is more erratic from time period to time period, with periods of high growth followed by periods of stability and contraction and vice versa. While it is useful for policy makers to recognise that growth rates are highly skewed, it is very misleading to think that the same subsample of firms is responsible for growth in successive periods of time. These results raise questions about the value of policy focused on High Growth Firms at the level of the individual firm.

The third key policy message is the importance of STEM graduates and skills more generally to the economy. The findings of the report highlight again that the value of investment in the research base comes primarily through the production of trained graduates and post-graduates who have the ability to solve complex technical problems and network more effectively, rather than from the production of technology or university spin-out firms. It is the production of 'talent not technology' to borrow the title of a previous study (Salter et al., 2000).

The importance and value of STEM graduates is a robust finding in this report. It suggests that policy makers would benefit from thinking of the UK science base as an institution that contributes to the *demand* for innovation as well as its *supply*. Our findings show that suppliers, customers and even rivals are generally much more likely to be sources of supply-side inputs for innovation than universities. However, **public investment in research generates talented graduates** who leave the university system and go and work in industry. Their problem-solving skills reduce the costs and increase the economic benefits of innovation, increasing its *demand* and encouraging its exploitation and diffusion.

While the analysis highlights that university research is a vital part of the UK innovation system, and is regularly exploited by a wide range of HIFs, engagement with customers and suppliers along supply chains is a significantly more important innovative activity and is enhanced by the employment of STEM graduates. University research is important, but the less photogenic production of highly skilled, well trained graduates should remain the key priority. Policies

that concentrate research funding in a smaller number of institutions may be economically counter-productive if a reduction in the production of high quality STEM graduates reduces the demand for innovation in the economy.

These results suggest it is misleading to think of the typical Highly Innovative Firm in the UK as a university biotech spinout in Cambridge or London that directly draws on scientific research. Our analysis suggests it might be equally useful to think of the typical Highly Innovative Firm as an engineering company anywhere in the UK that draws on the university system for the STEM graduates that help it innovate in collaboration with its customers and suppliers, within complex and often international supply chains. The recent **increases in the production of science graduates, and their diffusion into the workforce, may well prove a major benefit in the future**, as they will allow LIFs, who are unaware of their lack of skills, to upgrade.

The fourth key policy implication is that the link between innovation and economic growth could be enhanced by **policies that focus on helping firms capture value from innovation, regardless of whether that innovation is their own or was generated elsewhere in the economy.**

The reason innovative firms do not necessarily grow is because there is a difference between value creation and value capture. The ability of firms to create value depends on them having made investments in innovative capabilities that enhance firms' chances of success when they undertake uncertain innovation projects. To capture value, on the other hand, firms need "complementary assets" such as brands, sales forces, links to customers, managerial skill, financial resources, production facilities etc to capture the value (Teece, 1982). Without these complementary assets firms that create value may lose it to other firms. The importance of value capture can be seen in the superior performance of HIFs measured by output (sales – which indicates an ability to capture value) compared to HIFs measured by inputs (R&D – a value creation activity).

Most UK innovation policy focuses on value creation, implicitly assuming value capture is easy. Our results suggest it is not, and many innovative firms lack the business models that enable them to capture value. As a result, they have lower growth and profits and therefore return their investors lower returns, reducing the incentives to invest in the UK innovation system despite its ability to create value. Moreover, the analysis outlined in this report also suggests that many LIFs lack the basic capabilities needed to create and capture value, and are often seemingly unaware of their constraints. A market failure may exist if LIFs can only weakly discern what influences their long term performance. Under such circumstances, policies that encourage them to upgrade their ability to capture value from innovations generated elsewhere might be helpful.

Conclusion

In conclusion, the relationship between Highly Innovative Firms and High Growth Firms is not simple. HIFs grow faster on average than other firms, but are no more likely to be in the top 5% of HGFs than any other type of firm. Younger and smaller firms also grow faster (perhaps because they are below the minimum efficient size for their industry), and younger HIFs are more likely to translate their superior innovation capability into high growth. But in nearly all cases growth is erratic and being a HGF is not a persistent status.

Consequently, innovation contributes to economic growth through an indirect, long run process, and is based on persistent investment in the capabilities firms need to engage in the uncertain experiments that underpin innovation. Firm growth on the other hand is a short run phenomenon in which firms move in and out of growth in a largely erratic way. While it is useful to recognise that both innovation and growth are highly skewed, it is also important to recognise this difference, as the small percentage of firms that generate the majority of growth in any particular period will not be the same firms later on. Recognising this difference helps avoid a composition fallacy that conflates the growth of the economy with an economy with many high growth firms.

Capturing more of the value of innovation will help both firms and the economy grow. It requires firms to invest in long term capability building to create value, and in the complementary assets needed to capture value (Teece, 1982). Both of which are strongly linked to the employment of STEM graduates who help firms link to external institutions and develop new products and services for international markets. The importance of this human-capital based capability building is reflected in the processes that drive growth: investments in new employees precede increased investment in innovation, the generation of sales from new products and services, and finally increases in overall turnover. However, there is no evidence of a feedback loop, and at any given point in time, different sets of firms are at different points in this causal chain. So while the share of the total stock of firms that are high growth is stable, but there is little or no stability in terms of who the high growth firms actually are. These complexities highlight how the relationship between innovation, firm growth and growth in the wider economy are multifaceted and indirect, and mediated by organisations ability to capture value. Policy makers should recognise the importance of innovation, but also recognise that the growth of the overall economy requires attention to more than just innovation.

Summary Findings

Profile of Highly Innovative Firms

The initial analysis of the dataset suggests that HIFs are difficult to distinguish from LIFs using traditional firm demographic measures such as age, size, sector or region. The typical (median) firm for both HIFs and LIFs had between 35 and 60 employees while the average firm size (200-400) is skewed by very large firms in the sample. Different definitions of HIFs (measured by R&D spending or turnover share from new products and services) produce slight variations in size, but these do not tend to be significant. For instance, HIFs defined by our output measure, as might be expected, have higher labour productivity than LIFs, but this relationship is not found when HIFs are measured by inputs.

HIFs are found in all industries and regions. HIFs tend to be more common in SIC codes 2 and 3 (relating to metals and non-metals manufacturing respectively), and less common in SIC 4 (other manufacturing), 5 (construction), and 6 (retail). While SIC 7 (services and knowledge based activities) shows the highest presence of HIFs, there is little difference between propensity towards being HIF or LIF in this sector even though this is the SIC code where many R&D focused firms are located (SIC code 7310 includes R&D based firms). HIFs are widely distributed throughout the UK regions and there is little variation in the relative proportions of HIFs. This finding challenges prevailing orthodoxy.

We do find that **HIFs have a significantly greater share of employees who are science based graduates.** This is an important distinction because employment of STEM graduates is repeatedly associated with higher performance in our analysis.

HIFs also have a higher propensity to export than LIFs, and are more likely to target international and national markets. HIFs seem to be slightly different from other firms, in that they operate in different markets, are less locally focused and have more science intensive human capital endowments. HIFs are also much more likely to use intellectual property mechanisms to protect their investments.

As might be expected, R&D spending (our input measure) has a greater positive effect on intermediate outcomes (e.g greater use of wider range of information to support innovation) and engenders more co-operation with HEIs and Government Agencies. While the later stage output measure becomes more significant the closer to the market the firms get, and is associated with increased levels of co-operation with clients and competitors.

Performance: Growth Dynamics and Persistency

We find strong evidence of persistent in HIF and LIF status. Roughly 55% of the HIFs captured in 2004 retained their status as HIF by 2010. We find that roughly 40% of HIFs move into LIF status two years later, but that the 60% that remain

are fairly constant through time. By contrast, only approximately 10% of LIFs move status over the period of the surveys.

In relation to their growth dynamics of the full sample, the models measuring the persistence of growth are non-significant (i.e growth last period is not associated with growth this period). However, in our robustness tests, using random effects models we find a marginally significant negative autocorrelation (i.e firms that grew last period are slightly less likely to grow this period). Hence we do not find that success-breeds-success and that high growth firms in one period grow more than their peers in the next period. Comparison between HIFs and non-HIFs suggests HIFs have steadier and smoother employment growth, while their sales growth is more erratic. In line with previous research we find smaller and younger firms grow more in terms of both sales and employment, and that (lagged) employment of science graduates has a positive impact on both.

Information Use

In relation to information use we find that while all firms make extensive use of external sources of information, the use by HIFs is more intensive. We do not find remarkable difference between Input and Output measures of innovation in the use of information sources. The largest difference we find is that HIFs are more likely to source information from universities, government research organisations agencies such as Business Link and private research organisations. HIFs are also more likely to use internal sources of information and trade sources of information, which covers professional organisations, trade bodies and conferences. Nearly all HIFs use markets as sources of information,

From our regression analysis we find that age was significantly associated with using external information. Manufacturing firms tended to have a much wider use of external information than construction and service sector firms. Larger firms tended to use more information, although this diminished for very large firms. **Firms with a higher share of science graduates were associated with more use of all sources of external information.** This suggests that having talented people increases a firm's absorptive capacity and also their willingness and ability to network and bring in outside knowledge.

Co-operation

Our univariate analysis found that on average HIFs tended to establish more frequent cooperation with all partners, and there was little difference between Input and Output measures of innovation in the propensity to cooperate. HIFs were much more likely than LIFs to cooperate with HEI and public research organisation, and with their suppliers. This illustrates two different patterns of cooperation: on the one hand the "institutional model", on the other one a "vertical chain model", more related to upstream than downstream cooperation.

The regression analysis has highlighted that age is not significantly associated with the propensity to cooperate for innovation. By contrast there is a strong sector-specific element to co-operation with service-firms less likely to cooperate with clients and manufacturing firms more likely to cooperate with HEI. Firms size is generally positively, significantly and persistently associated

to the likelihood to cooperate, regardless the type of partners. Firms with higher share of science graduates tend to cooperate more, *ceteris paribus*, and with any kind of partner. Lastly, innovation is positively associated with the tendency to cooperate with any partner.

Barriers to Innovation

Univariate analysis of barriers to innovation suggests that, overall, HIFs and LIFs tend to perceive obstacles to innovation in a similar way, with a slightly higher perception of obstacles for HIF. There is little difference between Input and Output measures of innovation in the perception of barriers. Across the different types of barriers we find that financial obstacles appear to be perceived as the most constraining obstacle, for all firms.

The regression analysis has highlighted that firms' age does not affect their perception of (any type of) barriers. This evidence holds over time. We also find that with the exception of regulation barriers, the more science graduates the firms employ, the more they tend to perceive barriers to innovation as relevant. The strongest result is related to the HIFs, where being highly innovative – both in terms of input and output – is associated with a significantly higher probability of perceiving barriers as relevant. This is particularly strong for financial obstacles and is relatively persistent over time.

1 Introduction

Over the last two decades there has been a growing realisation that the long run economic performance of nations, firms and industries is dependent on their ability to generate and exploit technological innovation (Cohen, 2010). Research has shown that high levels of R&D, high levels of innovation and high levels of productivity are all positively related (Cohen and Klepper, 1992; Andersson et al., 2012:5). Research showing that the public returns to innovation are higher than the private returns has increased interest in how government policy can support innovative firms generate and exploit new products and processes (Martin, 2012).

The potential of innovation policy to generate economic benefits would appear to be substantial. Levels of actual investment in innovation appear to be significantly below socially optimal levels (NBER, 2000). Jones and Williams (1998) for example suggest that the socially optimal level of R&D investment is between two and four times the actual level.

In addressing this underinvestment, policy makers need to take account of the highly skewed distribution of innovative performance (Scherer, 2000). A small percentage of innovative firms generate a disproportionately large amount of innovation, with a large proportion of firms reporting no innovative activity or investment.

These fat-tailed skewed distributions seem to be a robust feature of the economy and are repeatedly found across a range of performance metrics, in different national settings (Range, 2010). The UK Community Innovation Survey, for example, suggests that the majority of UK firms are not particularly innovative with approximately 20% of firms being responsible for the majority of innovation. Similarly, in relation to growth, Storey (1994, 17) showed that roughly 4% of firms generate 50% of new jobs (see Henreksson and Johansson 2010 for a review of current findings) and Cowling, Taylor and Mitchell (2004) show that only one third of all firms create any jobs.

Shane (2008:164) has highlighted how disproportionately large the impact of a tiny proportion of innovative firms has been on the US economy. He notes that the 2,180 public companies funded by Venture Capital between 1972 and 2000 were less than 0.05% of all the firms that were founded. However, they ended up generating 11% of sales, 13% of profits, 6% of employees, and created approximately one third of the market value of all public companies in the USA, a sum that exceeds \$2.7 trillion (ibid).

These sorts of figures have captured the attention of policy makers and suggest that policy might be more effective if it focuses on a small number of high performance firms, rather than on the large number of average performance firms. If we assume that the main driver of employment growth is firm growth, and the main driver of firm growth is superior firm-level capabilities, with better

firms growing faster, the obvious implication is that high-growth firms will be highly innovative, or high-tech, or in some way superior to their slow growth counterparts (Reid and Coad, 2011:10).²

This focus on high performance firms is supported by research which has shown that in many, but not all, instances, high performance firms tend to retain their positions in skewed distributions over time (Andersson et al 2012). Differences in R&D intensity for example tend to be highly persistent.

This persistence is surprising as traditional theory suggested that investments in innovation would only offer temporary advantages, as competitor firms would rapidly imitate and copy innovative goods and services. Hence it was previously thought that market competition would diffuse the advantages of high performance, while driving poor performance firms out of the market (Friedman, 1953). Traditional neo-classical (so-called Solow) growth theory, for example, assumes the level of output in the economy is determined by the amount of labour and fixed capital that interact within a framework of technology, that is available to all firms and generated 'outside the economic system'. Hence all firms (and nations by extension) can access technology and should quickly converge (or catch up) with one another.

However, the evidence contradicts this and suggests that innovative capabilities are extremely difficult to imitate. Innovative capabilities allow firms to maintain their positions in the upper segments of the skewed performance distribution through constant innovation. This includes innovations that improve the processes firms use to innovate. As a result, we find economies characterised by a small percentage of high performance firms, and a long tail of weaker firms, with the typical firm in the economy being relatively marginal, often undersized, and generally having poorer performance and lower productivity (Nightingale and Coad, 2013).

The extent to which a small number of firms drive overall outcomes has shifted economists' attention from absolute numbers of firms to how high performing firms identify opportunities and allocate resources. It seems the processes by which resources are allocated to enhance productivity can be more important to economic growth than the absolute amounts that are allocated (i.e. the accumulation of inputs such as physical capital) (Jorgenson, 1995; Levine, 2005:7). 'How' rather than 'how much' seems to be the key issue. This raises the possibility that differences in economic performance can be explained by the extent to which different economies generate the high performance that enables firms to grow. As a result, support for high impact firms has attracted significant policy interest.

² An alternative view is that high growth firms do not need support and making lots of investments in raising the capability of the 'average' and less efficient firm would be a cheaper and, in aggregate, more beneficial mode of intervention.

In Europe, for example, there is widespread concern that the lack of high performance firms, compared to the USA, has constrained economic development. This is often explained in terms of a more entrepreneurial American culture, but there do not seem to be major differences between nations in entrepreneurial activity. More fundamentally, the perception of superior US economic performance is not always supported by the evidence. For example, UK and US Multi Factor Productivity growth between 1985 and 2011 are virtually identical, and growth in average real GDP per hour worked (labour productivity) was higher in the UK for 12 out of the last 22 years with an average growth of 2.05% per annum compared to 1.84% in the US. Indeed, one reason the US is richer is because American workers work longer hours and take fewer holidays than their European counterparts.

Similarly, there does not seem to be much support for the notion that the typical US firm is more innovative than its European counterpart. Data from the 2008 Community Innovation Survey and from the equivalent American survey (US National Science Foundation InfoBrief 11-300) suggest the share of US firms reporting a new to the firm product or process innovation is lower than many European nations (i.e. Germany, Finland, Italy, France, Austria, Spain, Czech Republic, Sweden, etc) (Hall, 2011). This is supported by data on productivity per hour worked, where a similar list of European nations outperform the US. Indeed, large European firms often outperform their US counterparts operating in the same sectors (Veugelers and Cincera, 2010, p5)

US performance tends to be superior in two main areas. First US firms tend to move into new high-tech, high-growth sectors more effectively, which is why they have higher R&D intensities (Veugelers and Cincera, 2010, 3-5). This is important as high numbers of high growth firms can signal subsequent industry growth (Bos and Stam, 2011), suggesting they are associated with Schumpeterian 'creative destruction', the rejuvenation of declining industries and the rise of new ones.

Secondly, in an important study Bartelsman et al (2005) find that American firms have higher post-entry growth in employment (60%) than European firms (5-35%). This can partly be explained by size differences: US start ups tend to be smaller, and US incumbent firms tend to be larger, than their European counterparts, even controlling for the sectoral composition of the economy. It may also reflect differences in demand and market structures in Europe dominated by incumbent firms.

Where are the Googles?

Together, this suggests a more experimental US approach, where smaller firms are able to grow faster if their initial experiments are successful. By contrast, European firms are less likely to experience the rapid, prolonged growth that

leads to young large firms (Bartelsman et al, 2005)³ or “Yollies” – Young Leading Innovators (Veugelers and Cincera, 2010). This is consistent with the observation that the UK (and EU more generally) have not generated as many young large firms, such as Google, Amgen, Cisco, Microsoft or Sun, as the US. There may be constraints on the development of high performance firms in the UK, or their initial starting positions may be weaker, or both. This is concerning as rapidly growing firms in emerging sectors are particularly vulnerable to problems with financing, access to skills and weak connections to customers, suppliers, regulators and publicly funded research organisations. As a result, there is increased policy interest in the barriers HIFs and High Growth Firms face and how they can be addressed.

Before exploring these issues, it is worth highlighting a few concerns about the underpinning assumptions in this debate. First, within the existing policy literature there is often an implicit assumption that innovation and growth are closely linked because innovating firms continuously capture the benefits of their innovations. Secondly, start-ups or young firms are seen as the best vehicles for this process. These implicit assumptions are consistent with, and possibly reflect, the widespread adoption of a Schumpeterian model of entrepreneurial innovation. However, a number of key “stylised facts” about innovation suggest these assumptions are questionable.

Innovation

Innovation is an inherently uncertain matching process that links a technological development with a market demand (Freeman, 1982). This inherent uncertainty means innovation processes rely on extensive empirical experimentation (Pavitt, 2001), that is guided by technology-specific knowledge, and firm specific organisational routines (Nelson and Winter, 1982). As organisations build up cumulative technological capabilities they can innovate in particular areas of the technological frontier better than other firms (Dosi, 1982). These capabilities are difficult to acquire (except through a costly, uncertain and time consuming process of experimental learning), which is why firms can maintain their positions in the skewed distributions of firm performance.

The complexity of modern products and services mean that large numbers of people are typically involved in innovation, with increased cognitive complexity leading to increased organisational complexity (Pavitt, 1999). As this cognitive and organisational complexity has increased, innovation processes have become increasingly distributed and have expanded from entrepreneur-inventors, to R&D laboratories, to entire firms, to supply chains and links to customers, universities, and producers of capital-goods. This changing division of innovative labour has led to more complex organisational relationships between large and small firms and means that the firms that generate innovations are not necessarily the firms that exploit them. Hence, innovation

³ High growth firms are defined by the OECD as firms that experience average annual growth in employment of 20 per cent or more over three consecutive years.

can drive growth in the economy, even if innovative firms do not necessarily grow themselves.

The interactive, distributed nature of innovation, and the way in which it draws on knowledge and resources from a wide range of institutions has increased interest in ‘systems of innovation’ and how they influence patterns of innovation. Individual firms’ ability to innovate depends on both their own capabilities (such as management skills, know-how, ability to find and absorb external knowledge, and internal learning processes), and also on the capabilities and behaviour of other institutions they connect to. Hence, how they innovate and grow depends on the extent and quality of the links that do (or do not) exist to those institutions, and the framework conditions of regulations, rules and cultural norms, that enable the overall system to develop and adapt.

These systemic effects make the connection between innovation and growth indirect and complex. This point is nicely captured in the discussion about high-tech manufacturing firms in the background report to the 2011 UK *Innovation and Research Strategy for Growth*:

“High-tech manufacturing sectors are, in themselves, small. A policy focus on these sectors therefore excludes a large part of the economy. High-tech activities mainly produce inputs that are used elsewhere – so the success of high-tech industries, and their impact on productivity, depends on the extent to which they are adopted by other, lower-tech industries” (BIS, 2011)

These features of innovation suggest that it is (a) a diffused process spread across a range of organisations that (b) requires persistent investments (to maintain the researchers and technologists that have the firm specific knowledge needed to innovate), is (c) inherently uncertain and experimental, which means it is characterised by (d) inevitable failures and setbacks, rather than persistent success. Moreover, (e) where successes do occur, it is not necessarily the case that the benefits accrue, in their entirety, to the firms responsible for the original innovation. As a result, it is not surprising that neither the level nor rate of growth of R&D at the firm level has a very strong statistical association with the introduction of new products and processes, or productivity, or employment growth.

Given the relationship between innovation and performance is likely to be complex, it is not clear there should be a consistent link between HIFs, high-tech firms or High Growth Firms. Indeed if we look at growth, we do not find that either HIFs or R&D intensive firms grow abnormally fast. Most firm growth follows an erratic path and is extremely difficult to predict from simple indicators such as levels of innovation or spending or growth of investment in innovation. It is rare for a firm to come up with an innovation, on its’ own, and then capture all the benefits of it through a continuous, un-interrupted process of growth. There are firms in the economy that continuously grow, but their prevalence is not much higher than the prevalence we would find if growth were entirely random. This study analyses these relationships in detail.

Aims and objectives of this study

The overall aim of the study is to assess the effects of being a highly innovative firm (HIF) on firms' performance across a range of outcome measures, compared to less innovative firms (LIF). We also consider how HIFs differ in terms of (a) their core characteristics (age, size, sector), (b) their use of information, (c) the formation of linkages and co-operative ties with other external agents, and, (d) barriers to innovation. In particular, the study answers the following questions:

- Do HIFs perform better than LIFs? Are they also High Growth Firms, in terms of the magnitude of their output, employment and productivity?
- Do HIFs differ from LIFs in terms of their core characteristics?
- Do HIFs use external sources of information to a greater (lesser) extent than LIFs?
- Are HIFs more (less) likely to develop co-operative ties with external agents, such as scientific institutions, universities and publicly-supported research establishments? If they do, are there any sectoral or regional patterns to their collaborations, and how are they influenced by firm characteristics?
- Do HIFs experience more barriers to innovation than LIFs, and if so, how important is this to performance?
- Have HIFs been adversely influenced by the recent recession?

Methodology

In addressing these questions we build on previous research findings on firm growth, innovation and economic development. This research has highlighted significant methodological problems with the measurement and analysis of innovation. Innovation can be defined as the first successful commercial exploitation of a new invention. It is the results of a complex, uncertain, distributed, often intangible, temporal process that draws on a wide range of inputs and generates a wide range of direct and indirect outputs. Innovation processes come in very different forms, with some drawing on formal research and R&D, while others relying on informal learning-by-doing and engagement with customers and suppliers. Innovations can also be positioned on a continuum from incremental to radical, and can either generate new products, or new processes, or new services or new organisational structures. This complexity and heterogeneity makes innovation difficult to measure (Nesta, 2006) and means care must be taken not to generate spurious and fragmented findings. Since we cannot measure innovation perfectly, research ideally adopts a 'plural and conditional' approach that draws on a range of imperfect indicators (Hopkins and Siepel, 2013) to help address the inadequacies of individual metrics.

To address the questions highlighted above the research team used two measures of innovation to capture the subset of HIFs. First, an input measure that captured the top 20% of firms by spending on R&D. Otherwise firms are classified as Less Innovative Firms (LIF). Secondly, an output measure that captured the top 20% of firms with sales from new to market products and services, which was operationalized as those firms with more than 11% of sales from new-to-market products and services. Firms that do not are classified as Less Innovative Firms (LIF). For High Growth Firms we focused on the top 5% of firms, as this is similar to definitions used in previous policy research, and because the distributions are so skewed that moving to the top 10% is likely to begin to capture firms that have only added one employee.

In adopting these two metrics we note two potential problems. First, R&D is an input measure, and as such does not actually measure innovation. Moreover, R&D is only an input to a subset of innovations and much innovation in the economy takes place outside formal R&D settings, for example, in design shops, in production or systems engineering departments etc. Secondly, the size of the subsample that we have explored is larger than in other studies. The choice of 20% and 5% rather than 4% or 6% or 0.05% reflects official UK definitions. Subsamples that are much smaller cannot be robustly analysed with the CIS dataset because the number of firms in the subsample would quickly be too small for robust statistical analysis.

Adopting two measures allows us to explore both the differences between HIFs and LIFs and also the relative differences between firms (a) investing in R&D, which indicates a strong commitment to developing innovative products and services in the future, and (b) firms that have already developed and marketed innovative products and services. In general the two measures yielded similar results, but there were a few minor but important differences. As might be expected the upstream R&D measure was more closely associated with links to research, while the more downstream sales measure was more closely associated with links to customers and suppliers. Performance was measured using a wide range of traditional accounting metrics such as sales, employment, productivity, sales growth, employment growth, and innovative performance.

Addressing the research questions in highly skewed environment represents significant statistical challenges, as data-sets and statistical methods have typically been developed to analyse the average impact of the average firm, rather than the highly skewed impacts of a small minority of firms. The research used four waves of the Community Innovation Survey for the UK for the years 2004, 2006, 2008 and 2010. This survey data was linked to the longitudinal Business Structure Database (BSD) to create a panel dataset. The survey was analysed as yearly cross sections linked to panel performance data, as well as an integrated panel of all four waves. There are two core elements to this assessment: first cross-sectional analysis of the Community Innovation Survey waves, and then panel analysis of the combined Community Innovation Survey-BSD longitudinal data.

Analytically, a mixed approach was adopted, involving both univariate statistics to capture differences between highly innovative and other firms, and then

multivariate regression analysis across the performance measures to unpick and quantify the individual variables' impact on overall performance. Core responses are presented at a univariate level with cross-breaks where interesting differences were apparent across core business demographics. This univariate analysis was supplemented by econometric modelling to identify key relationships in the data.

Various regression techniques were used as appropriate, including a range of robustness checks. The main 'workhorse' regression was a binary probit, which was complemented with other methods, such as VAR methods, as appropriate. Robustness checks are mainly done by exploring the sensitivity of the results across years, for different regions and industries, checking for nonlinear effects in some cases by using quadratic terms for graduate share, R&D, etc. Analysis was redone using both more comprehensive and lighter-touch sets of control variables, and using different econometric estimators (e.g. OLS vs median regression for the growth rate regressions etc). These multivariate econometric models allowed us to control for a range of confounding variables in the data that might influence the results.

The analytical analysis involved a "big-data" approach, defined as methods where more than 500 regressions are run. This allows the analysis to explore how different definitions, methods and measures generate different outcomes, allowing a qualitative appreciation of quantitative outcomes. Such an approach has the advantage of allowing researchers to understand spurious and non-robust findings, and see patterns in the outputs that would be invisible to traditional methods. However, the large amount of data that the method generates makes presentation difficult. To reduce the size of the report, key regression results are presented in an appendix.

Structure of the report

In Chapter 2 we profile HIFs and identify what, if anything, is distinct about them compared to LIFs. Chapter 3 focuses explicitly upon business performance using a variety of metrics including employment and sales growth, geographical market reach, exporting and labour productivity. We also seek to identify the causal chain which might ultimately lead to higher sales growth, and discuss, in detail, the journey through the innovation process. Chapter 4 considers the use of external information. Chapter 5 considers external linkages and co-operation with third parties to support the innovation process. Chapter 6 identifies barriers to innovation. We conclude in Chapter 7.

2 Profile of Highly Innovative Firms (HIFs)

Introduction

In this chapter we present descriptive statistics for the dataset to characterise HIFs, drawing upon the waves of the CIS collected in 2004, 2006, 2008 and 2010. These measures, including sales, employment, labour productivity, age, sector and region, show that there is little to clearly differentiate HIFs from LIFs using these metrics. Descriptive statistics are presented using both the input and output definitions of HIFs, to highlight the differences between the two measures.

Size of Firm

We begin by considering mean and median turnover for HIFs and LIFs in the sample. Fig 2.1, Fig 2.2, Fig. 2.3 and Fig 2.4 show the comparative differences in average sales and employment between HIFs and LIFs. The mean figures broadly show higher levels of turnover for LIFs than for HIFs, with a particularly high disparity between LIF and HIF for Input. However on closer examination of medians, we see that the mean figures reflect highly skewed distribution, with few differences between the HIF and LIF using median measures. If anything HIFs by Output generally have a higher median turnover than LIFs.

Sales

Fig 2.1 Mean Turnover by HIF and LIF (£'000s)

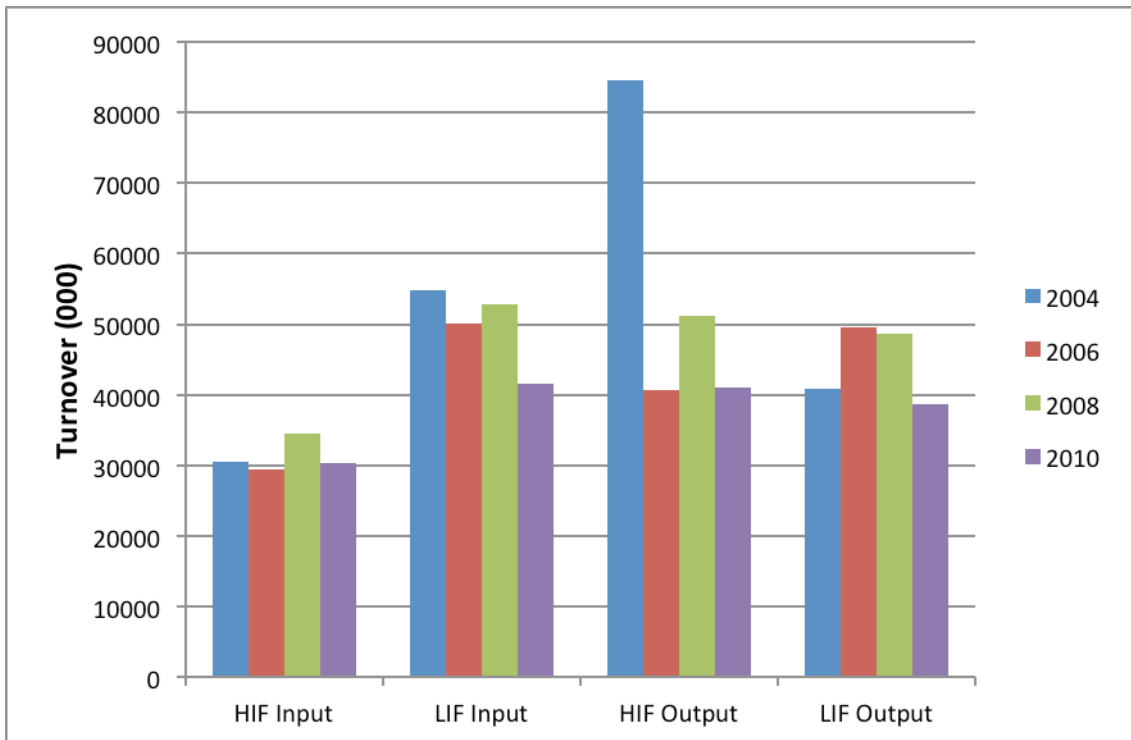
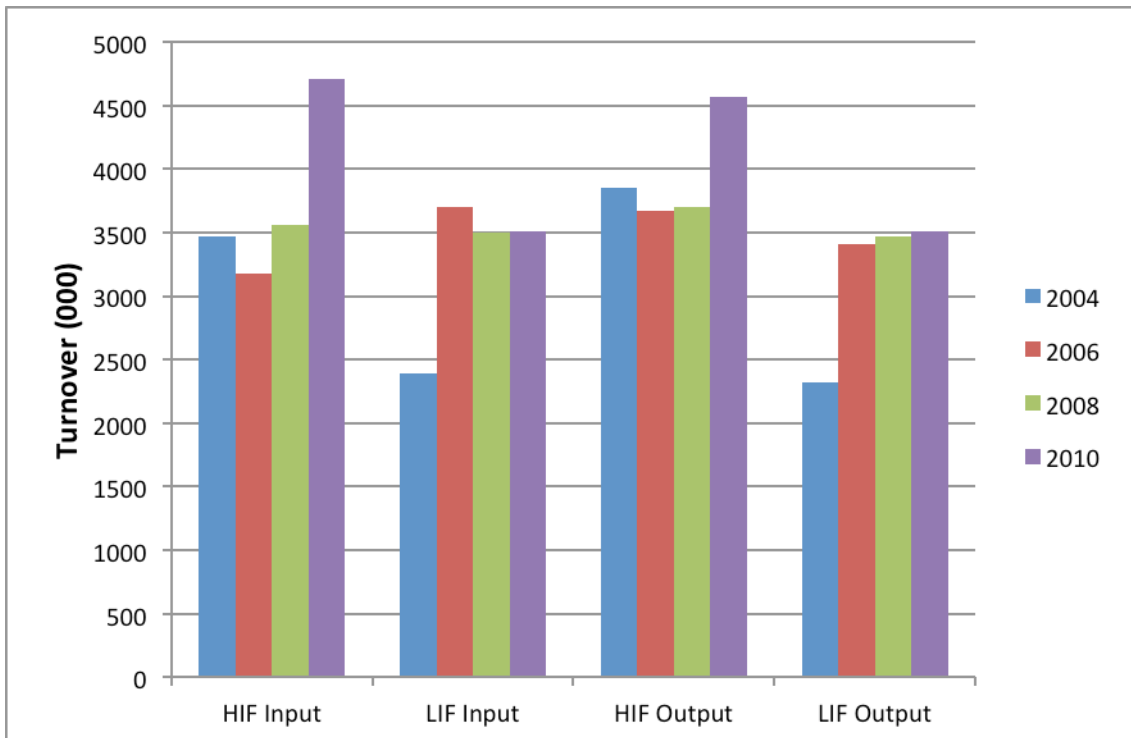


Fig 2.2 Median Turnover by HIF and LIF (£'000s)



Employment

Fig. 2.3 Mean Employment by HIF and LIF

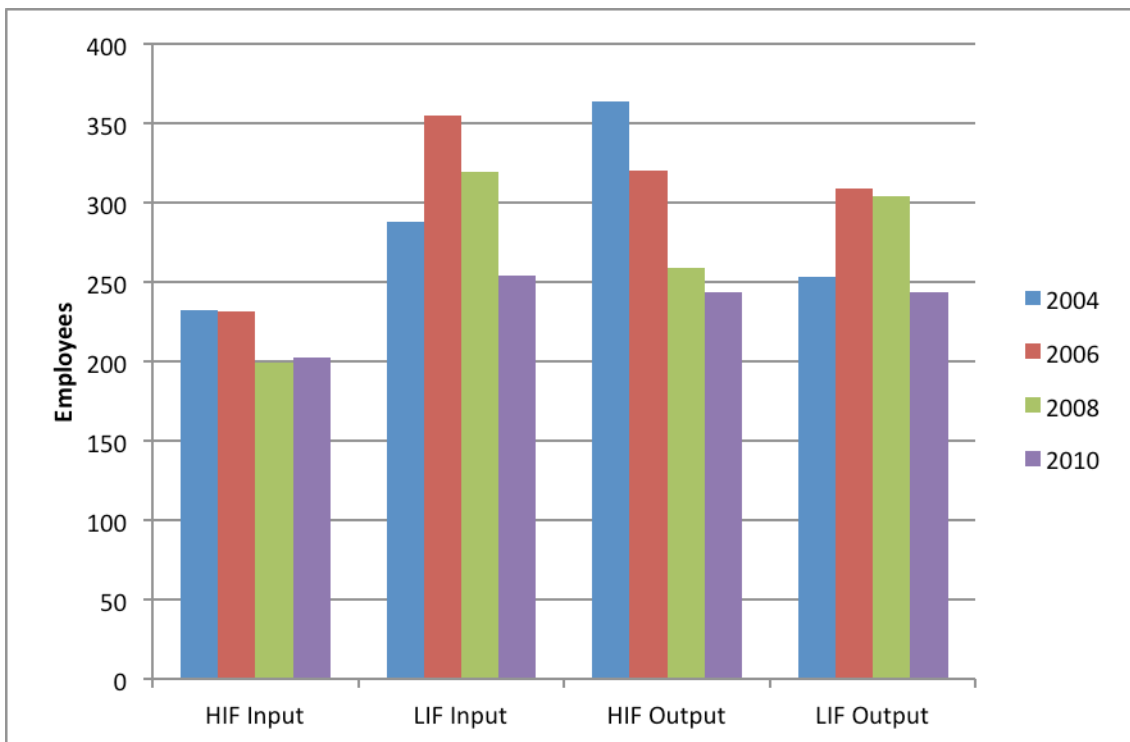
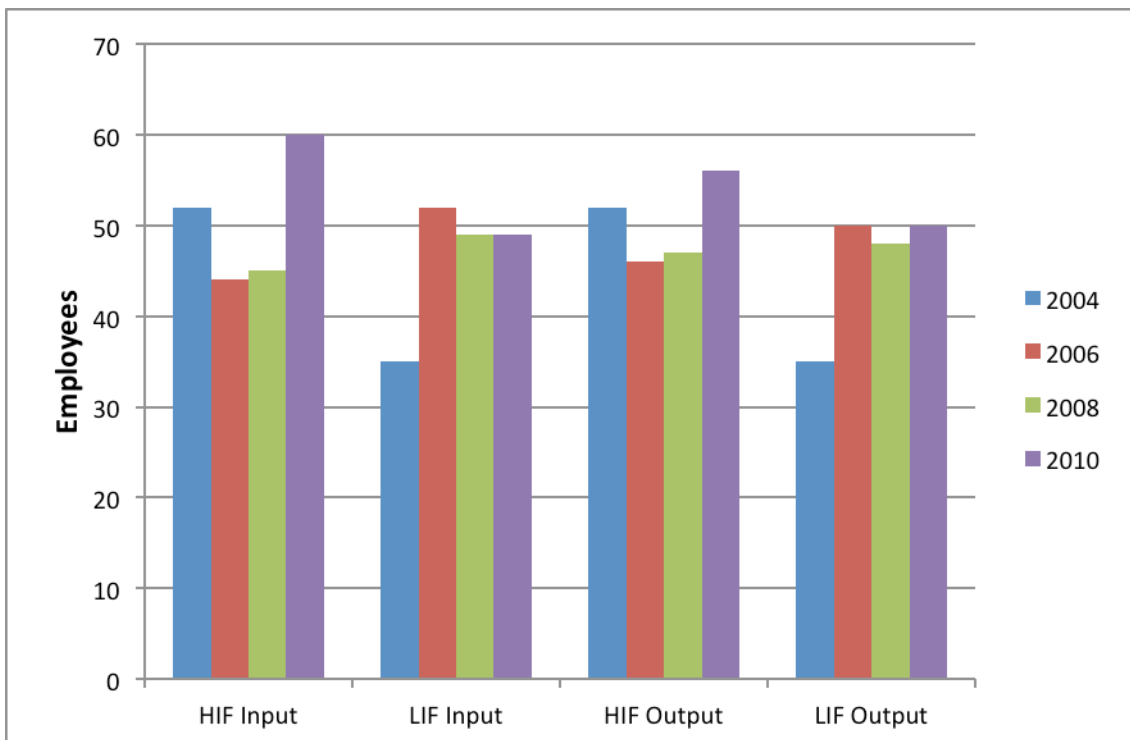


Fig 2.4 Median Employment by HIF and LIF



The figures for employment present a similar story. Mean employment is lower for HIFs by Input than for similar LIFs, but for Output measures there are relatively few differences. The median employment figures for HIFs are

generally higher than, or similar to, LIF measures. The scales of the measures also show the extent to which the results are skewed by large firms (mean employment for LIF by Input is 350, for example, while the median employment is 52). These results suggest that HIFs are not necessarily different from LIFs in terms of their size in any robust way.

Labour productivity

Fig 2.5 and Fig. 2.6 show the comparative differences in mean and median labour productivity between HIFs and LIFs.

Fig 2.5 Mean Productivity by HIF and LIF (£'000s per employee)

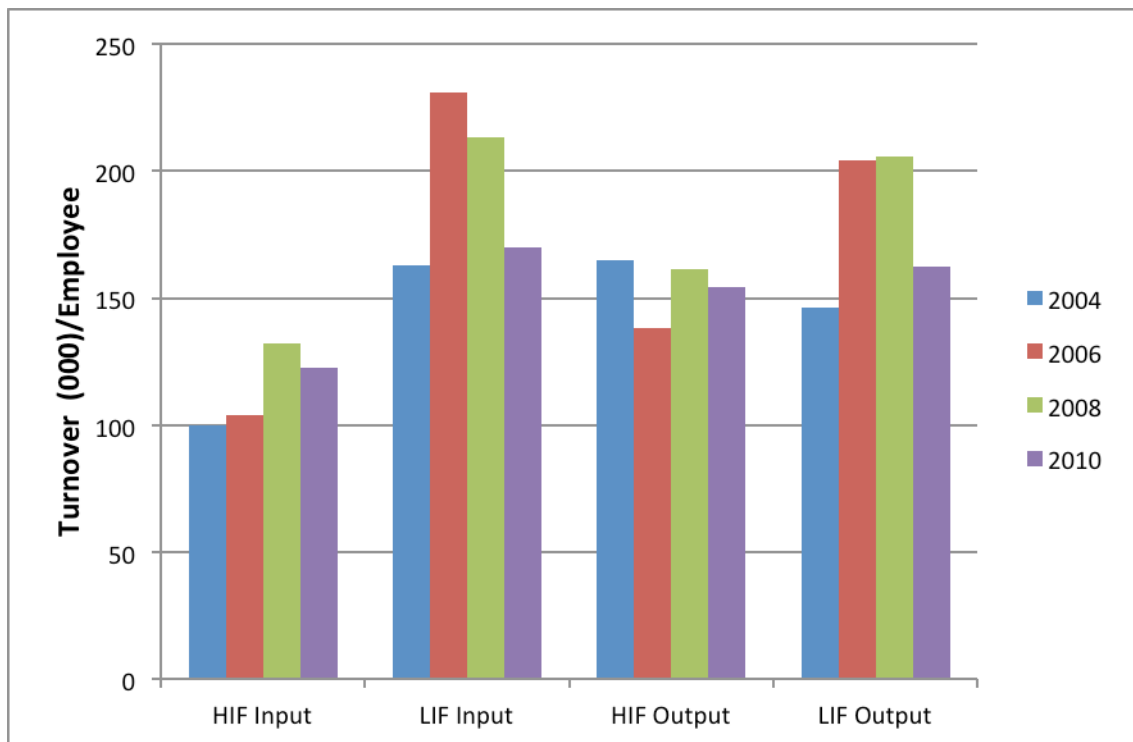
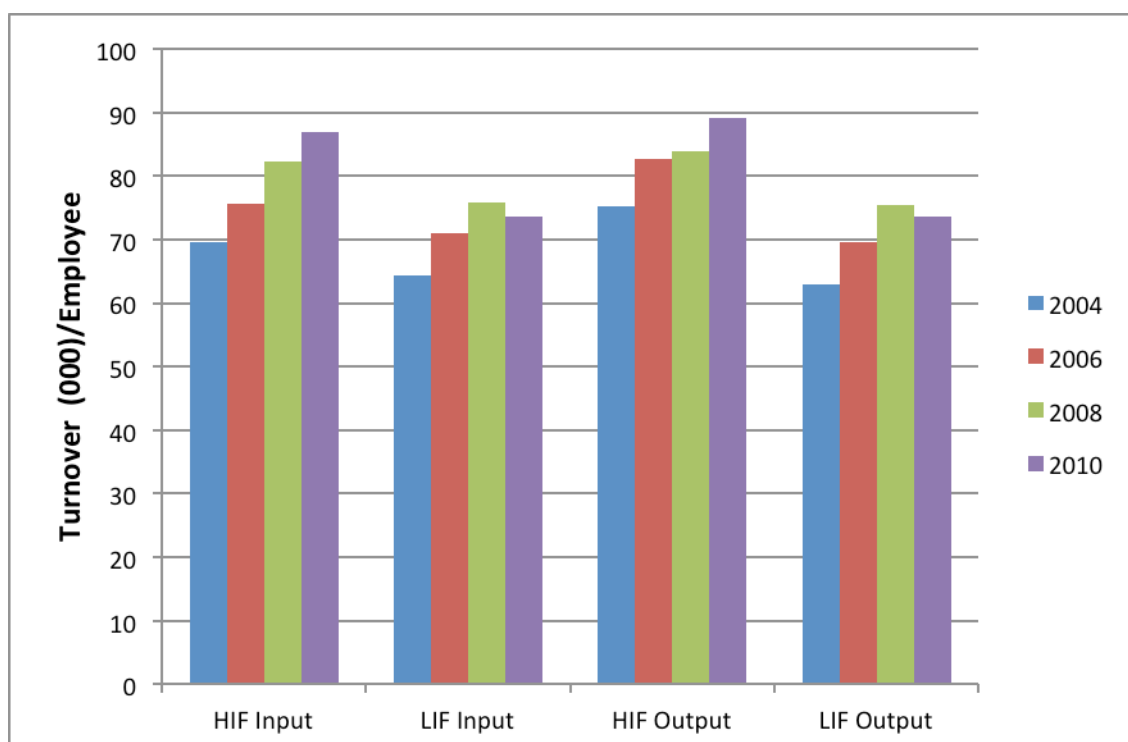


Fig 2.6 Median Productivity by HIF and LIF (£'000s per employee)



The figures for productivity reflect a similar story. Mean productivity is lower for HIFs by Input (which intuitively makes sense as these are investing in R&D). HIFs by output appear to be similarly more productive than LIFs. The median figures show again the skewed nature of some high performers, and suggest HIFs are generally more productive than LIFs. This would be consistent with these firms gaining a productivity benefit from investing in innovation.

Multivariate regressions show that age (capturing size) is positively associated with improved productivity. Similarly employment of science graduates is positively associated with better productivity. We also find that HIF (by output) have higher productivity which is consistent with expectations. HIF (by input), on the other hand, are not significantly different.

Firm Characteristics

Age

Figures 2.7 and 2.8 shows the comparative differences in mean and median firm age between HIFs and LIFs. These figures suggest that while HIFs are younger than LIFs, this is only by a small margin. The differences are robust between years except for 2010, which suggests that there may have been slightly different sampling procedures for this wave of the survey.

Fig 2.7 Mean Age of HIFs and LIFs

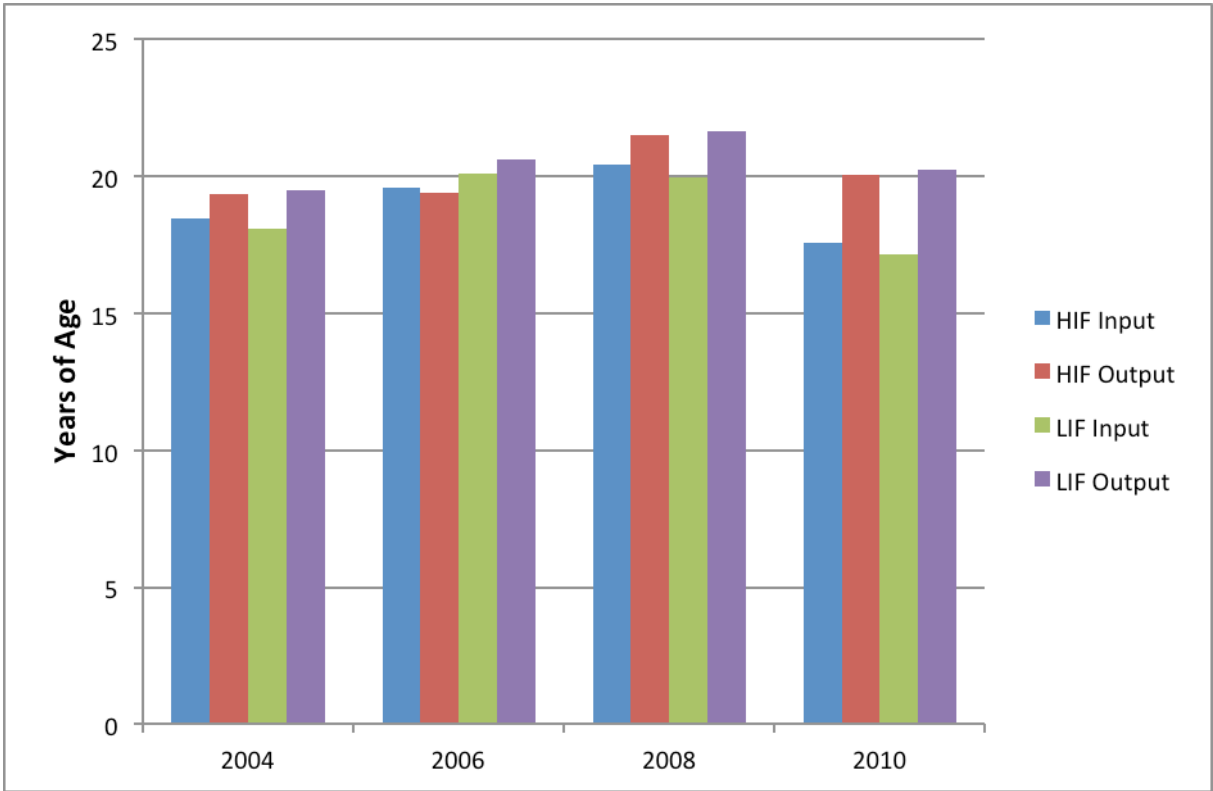
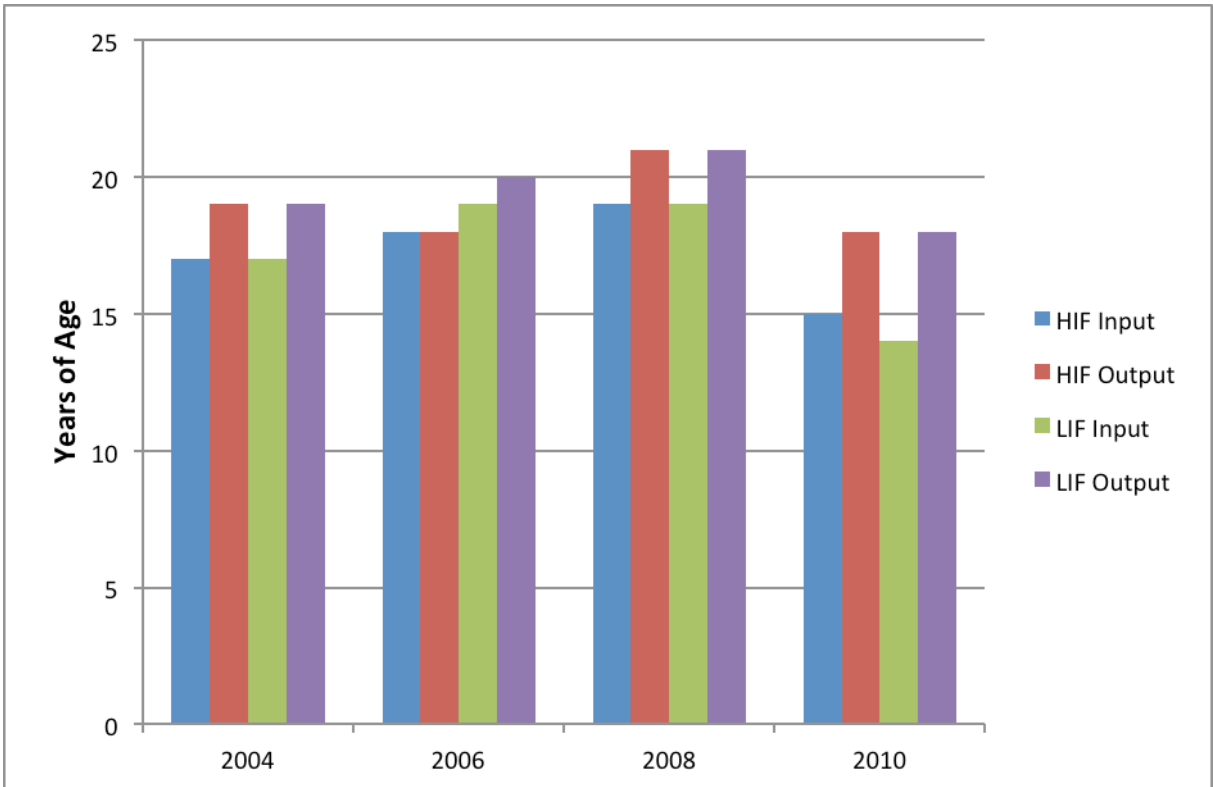


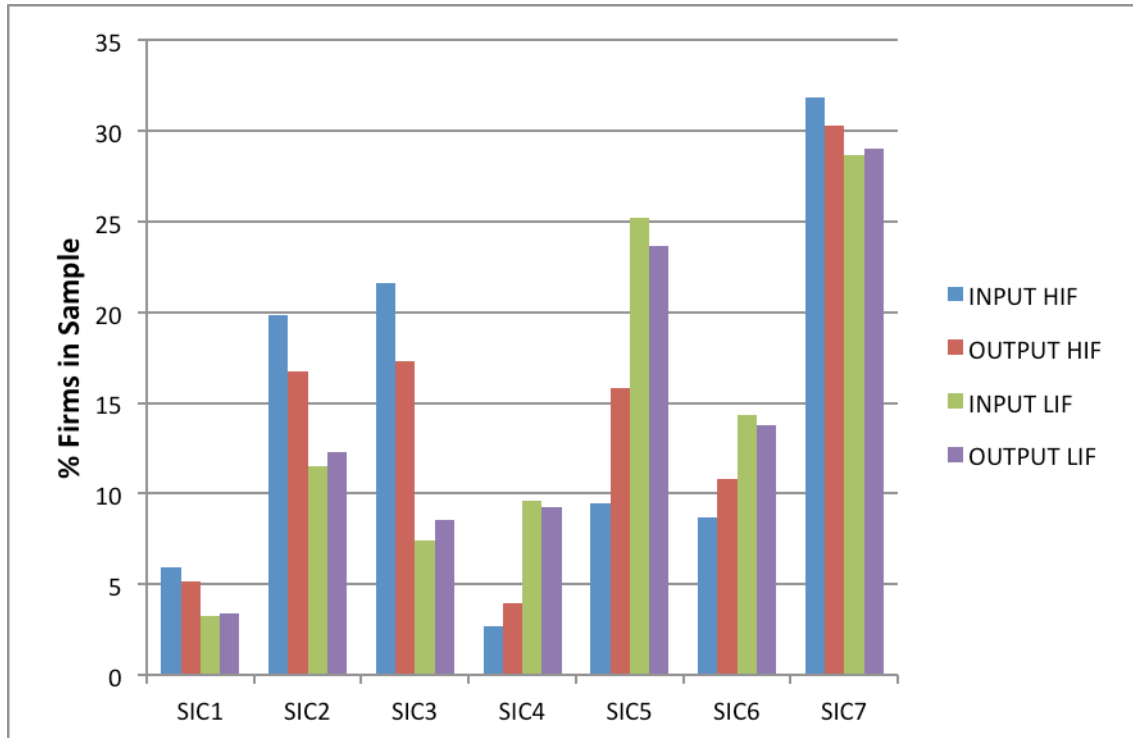
Fig 2.8 Median Age of HIFs and LIFs



Industry

Fig 2.9 shows the comparative differences in industry distributions between HIFs and LIFs.

Fig 2.9 Distribution of HIF by sector in 2008



The breakdown by sector provides some interesting insights into the nature of HIFs. HIFs are more common than LIFs in SIC2 and SIC3 (relating to metals and non-metals manufacturing respectively), but were comparatively less common in SIC4 (other manufacturing), SIC5 (construction) and SIC6 (retail). Surprisingly, while SIC7 (services and knowledge-based activities) shows the highest presence of HIF, there is little difference between propensity toward being HIFs and LIFs, even though this sector is where many R&D activities are located (SIC code 7310 includes R&D based firms and includes biotech and many similar types of firms). We also see some differences between Input and Output measures. HIFs conducting high levels of R&D are more prevalent in SIC2 and SIC3 than HIFs generating high levels of sales from new to market products. HIFs by Output are more common in SIC5 and SIC6, which make sense as construction and retail are more likely to be characterised by new products than R&D intensive categories.

Region

Table 2.1 shows the comparative differences in geographical distributions between HIFs and LIFs as a percentage of firms in the survey.

Table 2.1 Distribution of firms by Region in 2008

	INPUT		OUTPUT	
	LIF (%)	HIF (%)	LIF (%)	HIF (%)
North East	6.89	6.80	7.02	6.28
North West	8.80	8.30	8.81	8.27
Yorks & Humber	8.28	8.34	8.35	8.05
East Midlands	7.81	9.11	7.93	8.66
West Midlands	8.84	8.56	8.62	9.48
East of England	8.46	8.77	8.41	9.00
London	9.39	7.15	9.00	8.74
South East	9.37	10.40	9.61	9.39
South West	8.03	9.07	8.12	8.74
Wales	7.42	7.45	7.33	7.84
Scotland	8.33	8.77	8.19	9.35
Northern Ireland	8.37	7.27	8.63	6.19
Total	100	100	100	100

The regional figures show the variations between various regions by input and output measures. The figures here are for the 2008 wave, though other waves are similar. In several regions (North East, North West and Northern Ireland) LIFs are more prevalent than HIFs using our innovation input measure. Using our innovation output measure this still holds for the North West and Northern Ireland. Regions where HIFs have a relatively high prevalence rate using our innovation input measure include East Midlands, South East and South West. Using our innovation output measure, HIFs are relatively prevalent in East Midlands, West Midlands, East of England, South West and Scotland. This suggests that there are some regional differences in the prevalence of HIFs but these differences are relatively small.

Market and Innovation Orientation

Science Graduate Share of Total Employment

Figs 2.10 and 2.11 show the comparative differences in the science graduate shares of total employment between HIFs and LIFs.

Fig 2.10 Mean Science Graduates by HIF and LIF

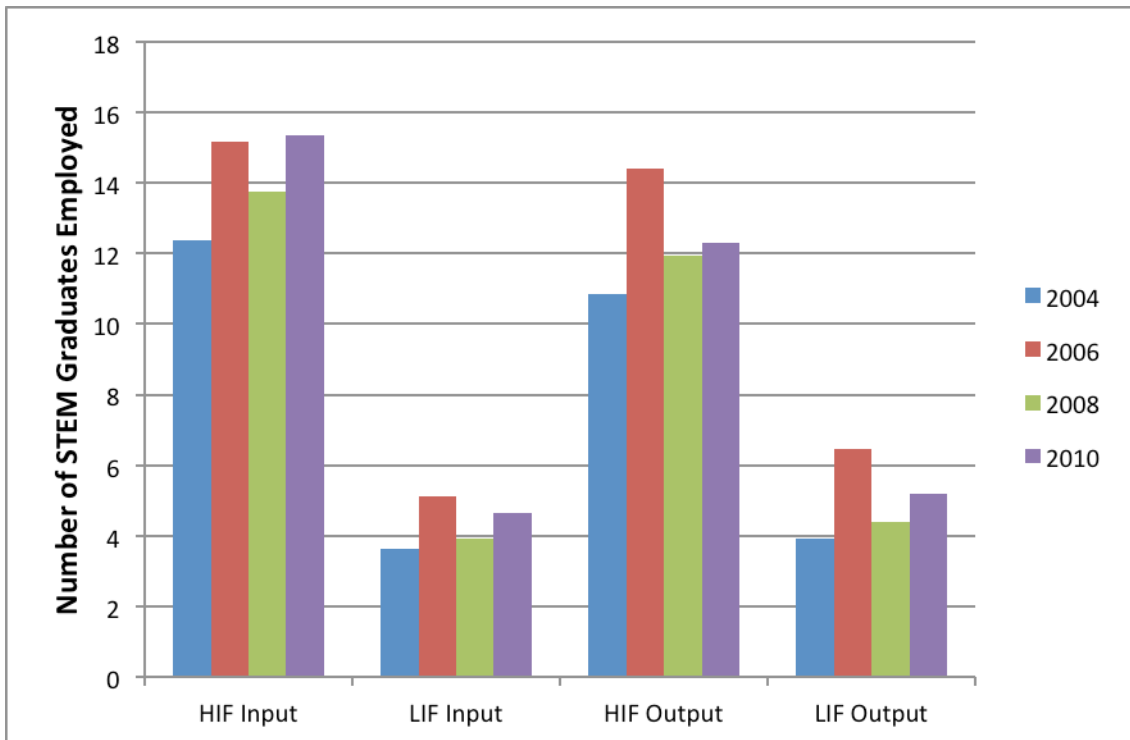
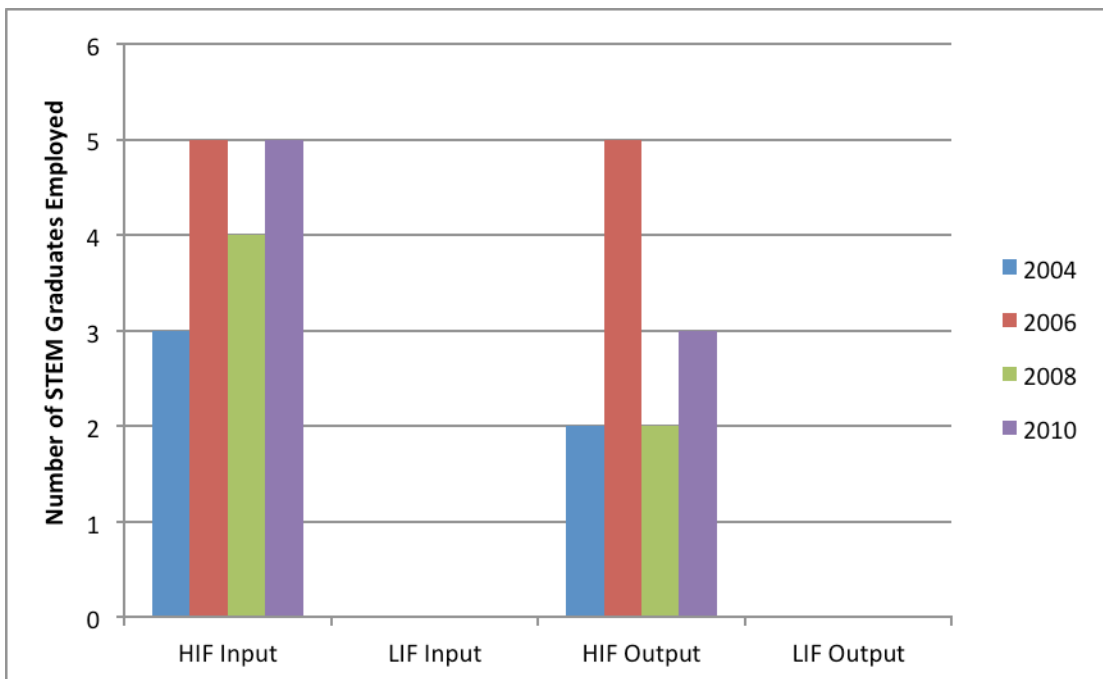


Fig 2.11 Median Science Graduates by HIF and LIF



Note: The median science graduate employment is LIF is zero i.e the data is not missing.

Figures 2.10 and 2.11 show the distribution of science graduates. Figure 2.10 shows that HIFs employ considerably more graduates than LIFs. More specifically, HIFs by Input have higher levels of employment of science

graduates than HIFs by Output. Given that the Input measure consists of R&D spending (which presumably requires science graduates), this finding makes intuitive sense. The median figures in 2.11 show the extent to which the distribution is skewed by very science graduate-heavy firms; in 2006 for HIFs by Input the mean was 15 science graduates, while the median was only five. Similarly, the low level of employment of science graduates among LIFs is striking – the mean employment of STEM graduates among LIFs was zero across survey waves.

Geographic Market Reach

Fig. 2.12 shows the comparative percentage of firms targeting different in geographic markets between HIFs and LIFs.

Fig. 2.12 Geographical Market Reach 2008

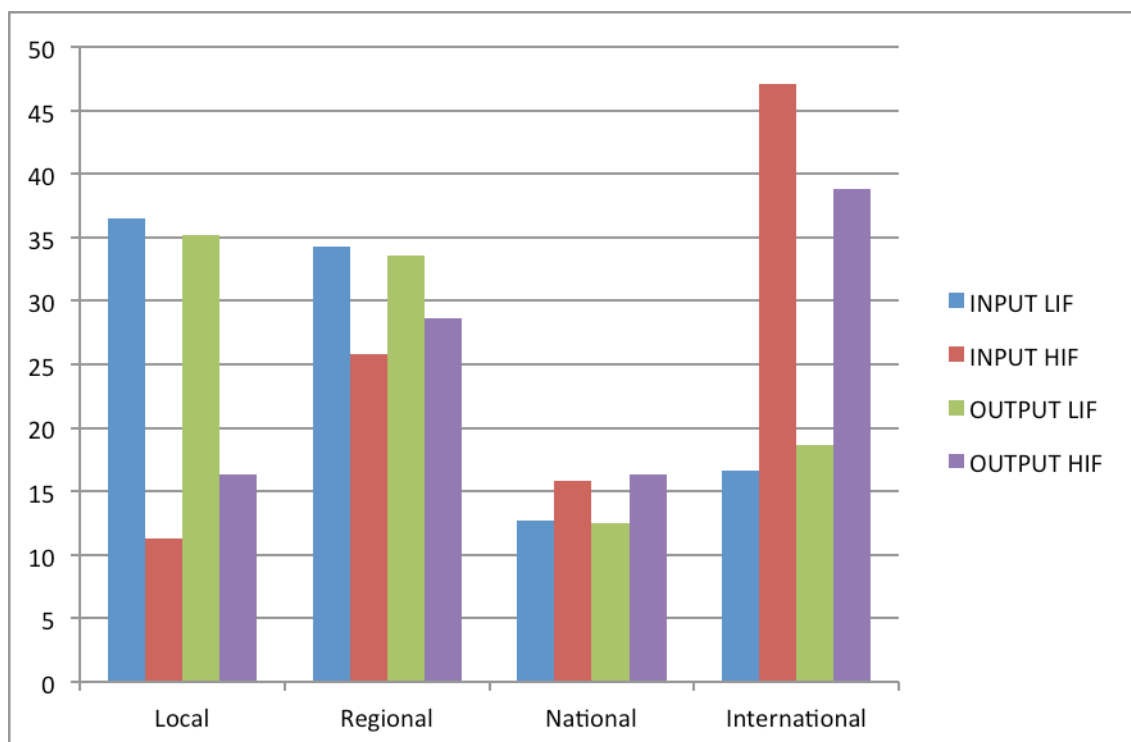


Fig 2.12 shows the geographic market reach of the firms in the sample for the 2008 wave; other waves had similar results. Here we see that HIFs by either measure are far more likely to target international markets. Whereas LIFs are relatively unlikely to compete beyond their own locality or region, HIFs aim more broadly. One interesting finding is that there is relatively little variation between HIFs and LIFs for firms competing nationally - in fact LIFs are more likely to be in international than national markets. This may reflect the relative geographic dispersion of the UK - for a Scottish firm, selling to the South East of England may be as much of a barrier as selling to the Netherlands.

In multivariate regressions we find large and very significant coefficients that are consistent across waves. The coefficients are (2008) HIF (input) 0.614 and HIF

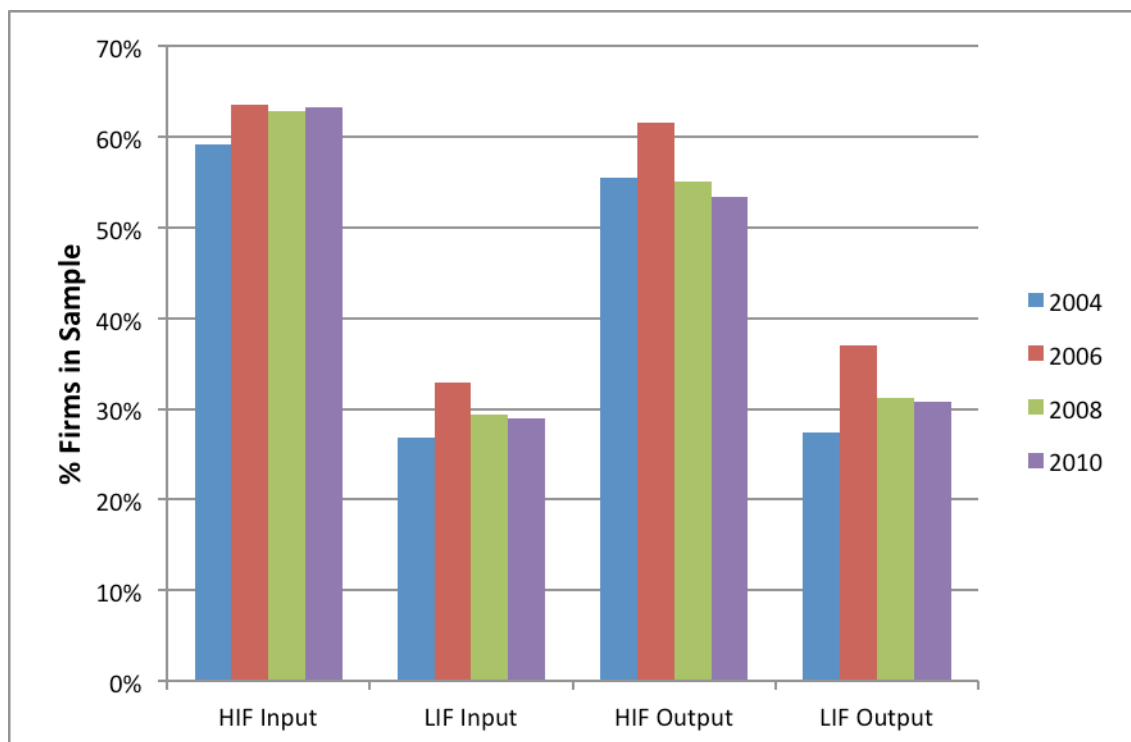
(output) is 0.427 suggesting they are much more likely to be internationally focused. The coefficient for Age and science graduate share are also both positive, though not as large.

Exporting propensity

Fig 2.13 shows the comparative differences in the propensity to export between HIFs and LIFs.

Export Activity

Fig. 2.13 – Level of export activity



This figure shows the levels of export activity among HIFs and LIFs across different years. They show that HIFs clearly outstrip LIFs in export activity. Interestingly the levels of export are higher for HIFs by input compared to HIFs by output, which is rather counterintuitive given the presumptive market orientation of HIFs as defined by output. There was no clear trend in the measures over time, and indeed levels appeared very consistent.

Multivariate analysis suggests the propensity to export initially increases with the age of the firm, peaking around 30 years of age and then diminishing. This relationship disappears in 2010. We also find that firm size is generally associated with an increased probability of exporting, although this association is weaker than for firm age. Across all waves, higher shares of science graduates are associated with a higher propensity to export. Both innovation measures are associated with an increased propensity to export with the

notable exception of the innovation output measure in 2006 where it has a significant and negative association with the propensity to export.

Summary

We have presented basic descriptive information, which has identified a number of key differences between HIF's and LIF's. At the univariate level the key areas of distinction are as follows;

- Firm age distribution, with HIFs being slightly younger.
- Firm size (sales and employment) – The average size of HIFs is smaller than LIFs. However, this is true only when we consider the input measures of innovativeness. Output-identified HIFs are larger on average and median than their LIF counterparts.
- Labour productivity – Here again the expected higher productivity of HIF emerges only for output-measured HIF.
- Industry sector – HIF are concentrated in KIBS and other knowledge intensive sectors, and appear to be scarce in SIC4. Surprisingly, the sector of construction seems to display a high share of HIF compared to other manufacturing sectors.
- Geographic region – There are regional differences in the prevalence of HIFs compared to LIFs. Regions where LIFs are relatively dominant include the North East, North West and Northern Ireland. Regions where HIFs are relatively dominant include East Midlands and South West, and, depending on the innovation measure, West Midlands, East of England, South East and Scotland.
- Science graduate share of total employment – HIF, both measured in terms of input and output, show a remarkable higher share of (science) graduates than their LIF counterparts. This is the strongest evidence emerging from the analysis.
- Exporting – HIF – both in terms of input and output measures – show a far higher propensity to export than their LIF counterparts.
- Market reach – Consistently, HIF show a marked propensity to target international (and regional) markets compared to their LIF counterparts.

This suggests that there are some clear differences between HIFs and LIFs in terms of the types of firms, the markets they operate in and their human capital endowments.

3 Performance: Growth Dynamics and Persistence

Introduction

This chapter focuses on the extent to which Highly Innovative and High Growth firms overlap with one another. It explores their performance in more detail and investigates growth dynamics and longitudinal analysis of changes in performance over time.

High Growth Firms and Highly Innovative Firms: Are they the same?

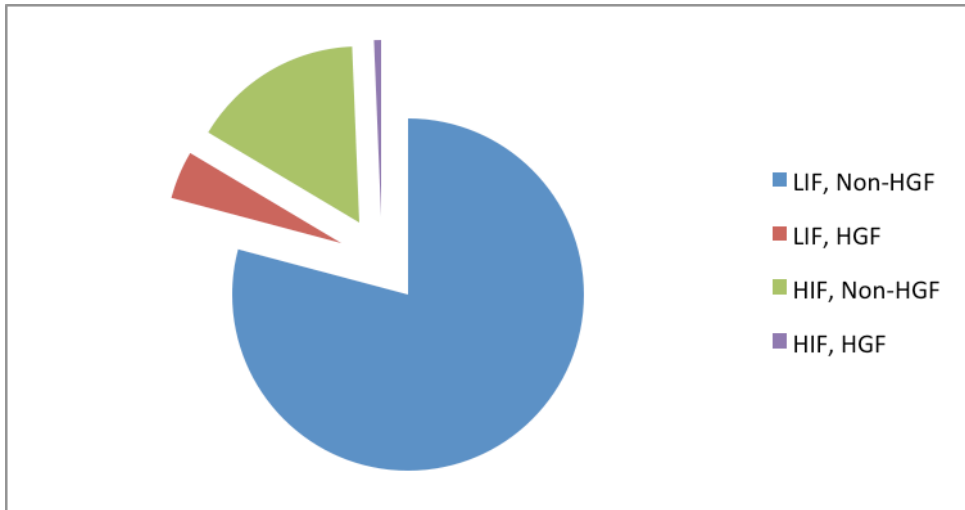
Interest in HGFs has often been based on the assumption that such firms are particularly innovative, but the relationship between growth and innovation remains unclear. In this section we consider three questions: Are HGFs and HIFs the same; are HGFs more likely to be HIFs; and are HIFs more likely to be HGFs? We define HGFs as the top 5% of firms by sales growth and employment growth over the four-year period prior to observation by the CIS.⁴ We use growth figures linked to the cross-sectional waves of CIS data.

The initial starting place for this inquiry is to ask whether HGFs are also HIFs. To do this, we consider the pool of HGFs, HIFs, and see how much overlap there are between the groups. Figure 3.1 presents a breakdown of the distribution of HIFs and HGFs in the population, using the figures from the CIS 6 wave of data.

The analysis here finds that regardless of the definition of HIF or HGF used, there is very little overlap between HIFs and HGFs. In a pool of approximately 12,689 firms, only 101 were both HIFs and HGFs, which is lower than the 127 one might expect (20% of firms are HIF and 5% are HGFs, so one might expect 1% or 127 to be both HGF and HIFs). Depending on the definition of HIF and HGF that is used, the proportion of firms out of the population that were both HIFs and HGFs ranged from 0.54% to 0.79%. As figure 3.1 highlights the proportion of firms in the total population that are both HIF and HGF is very small.

⁴ Other measures, such as one-year and two-year growth periods were used as well, and produced results consistent with the four-year growth measure. This measure was chosen because it represents longer-term growth. Other results are available upon request.

Fig 3.1 HIFs by Input and HGFs by Employment in the Population of Firms, CIS 6



On the basis of this evidence, which is consistent across definitions and CIS waves, there can be little doubt that **HGFs and HIFs are not the same firms.**

Are HGFs more likely to be HIFs?

Whilst it may be established that HGFs and HIFs are not the same, this does not necessarily imply that there is no relationship between high growth and high levels of innovation. To explore this we need to understand whether high growth firms are more likely to be highly innovative. We explore this using descriptive, univariate and multivariate analysis techniques.

If we consider the population of HGFs and the relative propensity of these firms to be HIFs, we find results that vary by the wave of survey and measures used: of the populations of HGFs, anywhere from 8-23% of these firms are also HIFs. However, across the various survey waves, these proportions are not statistically different from the population of firms that are non-HGFs. Only one measure (HIFs defined by input and HGFs defined by employment) shows persistent differences, and this indicates that HGFs are significantly less likely to be HIFs than non-HGFs. This might capture small biotech firms or other research intensive firms, for example, who invest heavily in R&D, but do not grow significantly.

Table 3.1 Percentage of HGFs that are HIFs (CIS 6)

	HIF INPUT		HIF OUTPUT	
	HGF Emp't	HGF Sales	HGF Emp't	HGF Sales
HGFs	10.7	11.0	12.9	15.7
Non-HGFs	17.6	17.6	16.6	16.5

Bold results indicate statistical significance

Multivariate regression techniques support these results (see Appendix), suggesting there is **little evidence that HGFs are more likely to be HIFs.**

Are HIFs more likely to be HGFs?

Conversely, even if HGFs are no more likely to be innovative, are innovative firms more likely to grow rapidly? Using similar techniques we find more nuanced results that are not necessarily surprising. Table 3.2 shows the results for CIS 4 (similarly results are found for other waves), which shows that HIFs defined by input are significantly less likely to become HGFs. However HIFs defined by output are more likely than non-HIFs to be HGFs. This suggests that firms that have already introduced new products to the market are more likely to capture value from their innovative activity than firms focusing on R&D, which is earlier in the innovation process. These results are found across waves but not consistently, as shown in Appendix 3.

Table 3.2 Percentage of HIFs that are HGFs (CIS 4)

Bold results indicate statistical significance

	HGF EMPLOYMENT		HGF SALES	
	HIF Input	HIF Output	HIF Input	HIF Output
HIFs	4.3	5.4	4.6	6.0
LIFs	5.2	4.9	5.1	4.8

The multivariate regressions in Appendix 3 further validate these findings, suggesting that HIFs by Input are less likely to be HGFs, whilst HIFs by Output are more likely to be HGFs.

Persistence in the status of HIFs across UK CIS waves

Whilst our exploration of HIFs thus far has focused on individual waves, it is also possible to explore the persistence of high levels of innovation using the linked balanced panel of CIS firms. The results of this analysis are shown in Table 3.3.

Table 3.3: Persistence of Highly Innovative Firms (Percentage)

		2006		2008		2010	
		Non-HIF	HIF	Non-HIF	HIF	Non-HIF	HIF
2004	Non-HIF	89.47	10.53	90.93	9.07	92.01	7.99
	HIF	41.60	58.40	45.95	54.05	44.78	55.22
2006	Non-HIF			90.76	9.24	92.58	7.42
	HIF			39.22	60.78	40.00	60.00
2008	Non-HIF					93.89	6.11
	HIF					39.39	60.61

The evidence presented in Table 3.3 suggests just over half of HIFs in the initial wave maintained their high levels of innovation. This did not seem to be affected by the recession. Conversely, only a small fraction of non-HIF firms switched to become highly innovative, and the proportion decreased over time. This suggests that firms' lack of innovative activity is strongly path dependent.

Growth Dynamics

Autocorrelation models

A deeper understanding of these growth dynamics can be obtained by looking at the co-evolution of sales growth and employment growth. This allows us to understand firstly, whether a firm that grows in one time period is more (or less) likely to grow in the next time period? We initially explore this separately for sales growth and employment growth (where one period occurs two years after the preceding period, given the biennial structure of the dataset). Secondly, we explore whether sales and employment growth move in parallel, whether one leads to the other, whether they are separate, or whether they move in opposing directions.

Does past growth affect current growth?

The econometric method we use computes an autocorrelation coefficient which tells us whether: (a) there is any statistical relationship between the dynamics of previous sales and employment growth and current sales and employment growth, and, if so, (b) the direction of any relationship. Our baseline model shows that the autocorrelation coefficients of turnover growth and employment growth are largely non-significant (although robustness checks with random effects models find a marginally significant negative autocorrelation for employment growth). This suggests that for the full sample growth in the previous two years is not a strong predictor of current growth. This generally holds for both sales and employment. In other words, we do not find a clear 'success-breeds-success' pattern of growth.

When we focus on the subsample of non-HIFs, we observe that turnover growth displays mild positive autocorrelation, while employment growth displays mild negative autocorrelation. Interestingly, these patterns are reversed for the sample of HIFs - we now observe negative autocorrelation for sales growth and positive autocorrelation for employment growth. This suggests that HIFs have different growth dynamics to non-HIFs - their employment growth is steadier and smoother, while their sales growth is more erratic. One tentative implication is that helping kick-start employment growth in these firms may have knock-on effects in terms of higher employment growth in subsequent years.

Looking at the control variables for the regressions, taken as a whole, there is some evidence that younger and smaller firms enjoy faster growth of turnover and faster job creation rates, in line with previous empirical work. The (lagged) science graduate share is often positive, indicating that a higher share of science graduates helps both sales growth and employment growth.

VAR models

We can build on these autocorrelation regressions to investigate the dynamics of growth processes using VAR (vector autoregressive) models. These VAR techniques allow us to explore how sales growth affects subsequent employment growth, how employment growth affects growth of innovative inputs, how employment growth affects subsequent sales growth, and so on. In short we have four different elements of the chain that links innovation to performance. The econometric technique allows us to explore how each element fits into this chain, if at all, and their ordering. So rather than simply assuming that R&D leads to superior sales growth, or that superior sales growth leads to job creation, we can test the validity of all these potential relationships and capture the strength and direction of any relationships.

Is there a causal relationship between sales growth, employment growth, R&D expenditure and new to market products? And if so, what is the causal chain?

Starting with results for the full sample, we find that lagged employment growth is positively associated with subsequent growth of both turnover and R&D. New hires therefore seem to contribute to higher future sales, and boosts innovation inputs.

The innovation variables (growth of R&D, and growth of percentage of sales due to new products) display a negative autocorrelation, which suggests that growth in innovation inputs or outputs are erratic rather than smooth, with the growth of innovation activity being difficult to sustain over time.

For HIFs, we observe that growth of employees contributes to growth of R&D, indicating that new hires play an important role in boosting innovative inputs. For HIFs we also observe negative autocorrelation in the growth of both innovative inputs and outputs, indicating that HIFs also face problems in maintaining their growth of innovative activities.

For non-HIFs, we observe again that employment growth is associated with subsequent growth of sales, and (there is also evidence that growth of sales leads to subsequent employment growth. These variables are therefore closely intertwined, although overall it seems that the main direction of influence (looking at inter-temporal correlations) is from employment growth to subsequent sales growth.

The (lagged) science graduate share of employment is included as a control variable, and generally has a positive effect on subsequent growth of sales and employment. Rather puzzling, however, we find a negative association between the share of science graduates in total employment and growth of the innovation variables in the case of non-HIFs. This may be because these firms have employed science graduates who are overqualified for their tasks, but the precise reason is unclear.

From a more general VAR analysis we seek to identify the causal chain of events using four variables, namely;

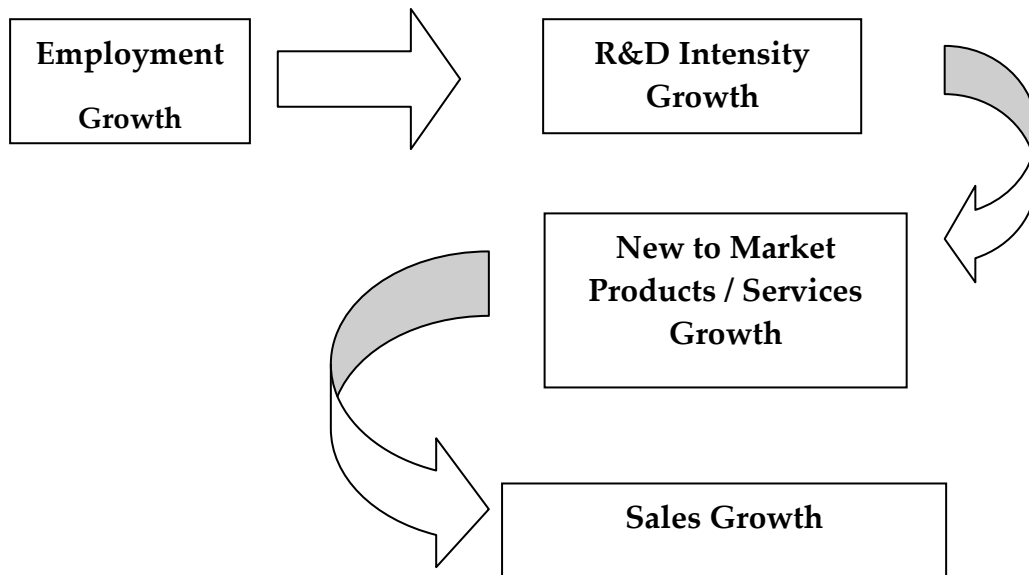
- Sales
- Employment
- New to Market Products and Services Share of Total Sales
- R&D expenditure as a % of Total Sales (R&D intensity)

The results are summarised in Table 3.4 below.

Table 3.4. Summary of General VAR Model Results

Current Lagged	Employment	R&D	New to Market Products / Services	Sales
Employment	-ve	+ve	0	0
R&D	0	-ve	+ve	0
New to Market Products / Services	0	0	-ve	+ve
Sales	0	0	0	-ve

From Table 3.4 we can establish the causal chain of events that ultimately leads to higher sales growth.



HIF growth dynamics

We also conducted additional analysis of the role of innovation on subsequent sales and employment growth amongst HIFs, by exploring if Highly Innovative Firms also experienced high levels of growth. To investigate this, we can look at the effect of innovation on sales and employment growth. Our results show that lagged R&D intensity and lagged new to market products share did not have a consistently significant effect on current sales growth. We did, however, find a significant effect on sales growth of science graduate share. The effect of science and engineering graduate share is non-linear, as evidenced by the negative sign of the quadratic term. This suggests that the returns to having

science grads is highest at the beginning but there are decreasing marginal returns afterwards. With regard to employment growth, however, we did detect a positive effect from lagged science-grad-share, R&D and new to market product shares. Thus employment growth seems to be related to innovative activity for HIFs.

Summary

In this chapter we set out to clarify the relationships between Highly Innovative Firms and High Growth Firms and answer two key questions. Firstly, whether past growth has any identifiable relationship to current growth? Secondly, we explored elements of the potential innovation-performance causal chain, and sought to establish the nature of any potential relationships between sales and employment growth, R&D intensity and new to market products. This allows us to explore how firms get from innovation to superior performance. On sales and employment growth, we found that there is little evidence that past growth materially affects current growth. In short, growth does not carry over from period to period. A firm that is growing today is no more (or less) likely than any other firm to be growing tomorrow.

The analysis established that **there is a causal chain and ordering of the process by which higher levels of innovation can lead to higher levels of performance**. Firms begin the process by employing more staff (and particularly science graduates). This then supports (and rationalises) higher R&D spending as the returns to R&D spending are higher in firms with the talent to manage it. This then feeds through into new to market products and services, which form an increasingly higher share of total firm output. The final piece in this causal chain is superior sales growth.

It is important to highlight that this value creation chain comes to a halt for individual firms. This is consistent with our evidence on lack of growth persistency. We do not find feedback loops, which lead to higher employment growth from higher sales growth. After going through this dynamic causal chain from employment growth, through R&D, the development of new to market products and services, and finally higher sales growth, firms do not renew this cycle. This explains why high growth firms can represent a fairly constant share of the total stock of firms in any time period, but the firms at the top are not persistent. **When one set of firms are moving from new to market products and services to higher sales growth, another set of firms are moving from employment growth to higher R&D spend, and so on. At any given point in time different subsets of the population of firms will be at different point in this causal innovation-performance chain.**

4 Information Use

Introduction

In this chapter we focus on the use of sources of information to support firm activities including; (1) external sources, (2) institutional sources, (3) internal sources, and (4) market sources.

Use of Information

External Sources

Fig 4.1 Use of External Sources of Information among HIFs and LIFs by Input and Output

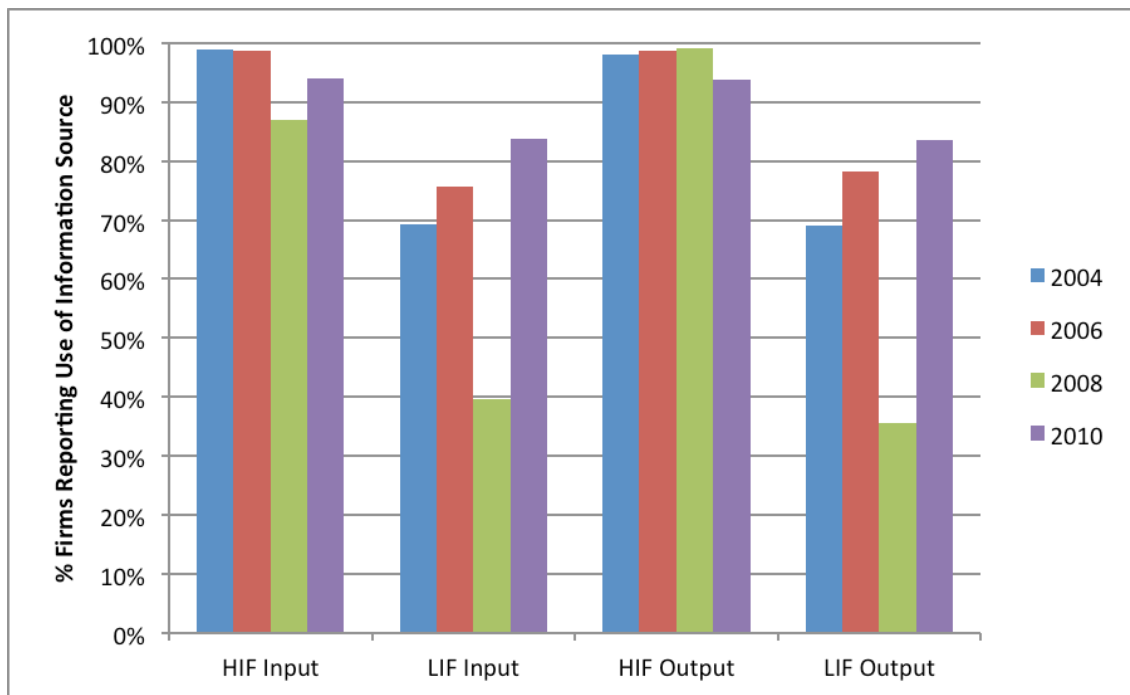


Figure 4.1 shows the percentage of firms drawing from external sources of information to assist in the innovation process. The figure shows that very nearly all HIFs use external information in the innovation process. Furthermore, a majority of all firms, regardless of their HIF or LIF status, use external information. There is little discernible difference between the Input and Output measures, and relatively few obvious changes over time. Overall this suggests that while use of external information is important to most firms, it is a particularly important characteristic of HIFs.

Institutional Sources

Fig 4.2 Use of Institutional Sources of Information among HIFs and LIFs by Input and Output

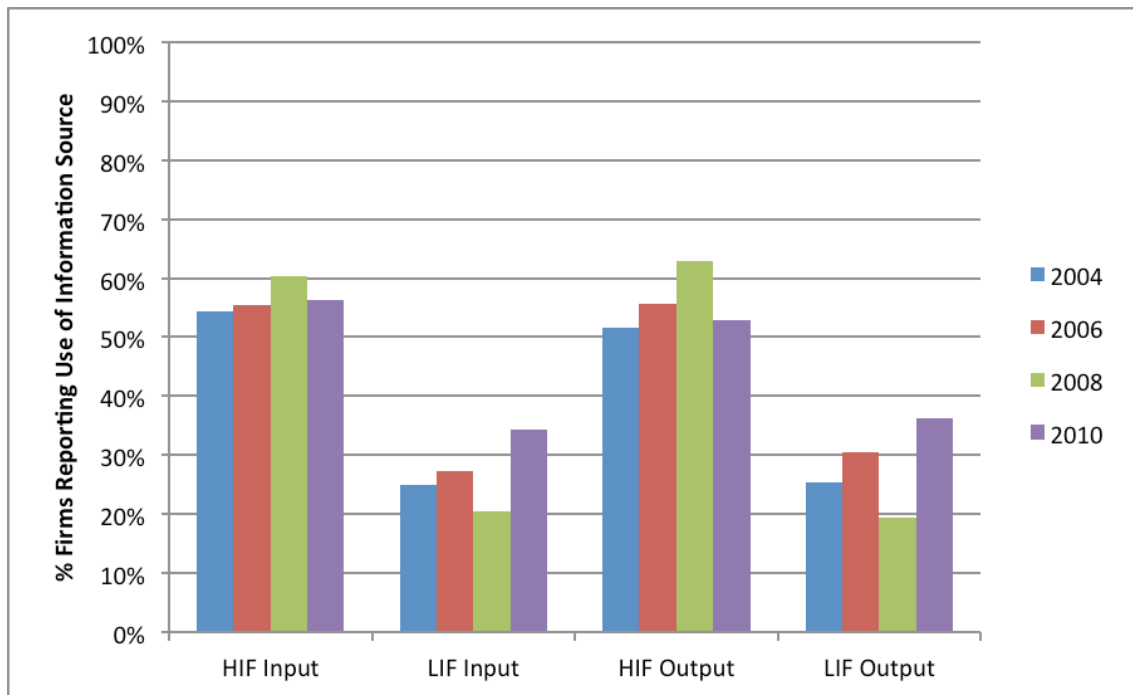


Figure 4.2 charts use of institutions such as universities, government research organisations, agencies such as Business Link and private research organisations as sources of information. The evidence shows that more than half of HIFs had interactions with these institutions, while approximately one-quarter of LIFs used these as sources of information. There were few clear differences between the definitions of Input and Output. There appears to be a small increase in use of information by LIFs following the recession.

Internal Sources

Figure 4.3 Use of Internal Sources of Information among HIFs and LIFs by Input and Output

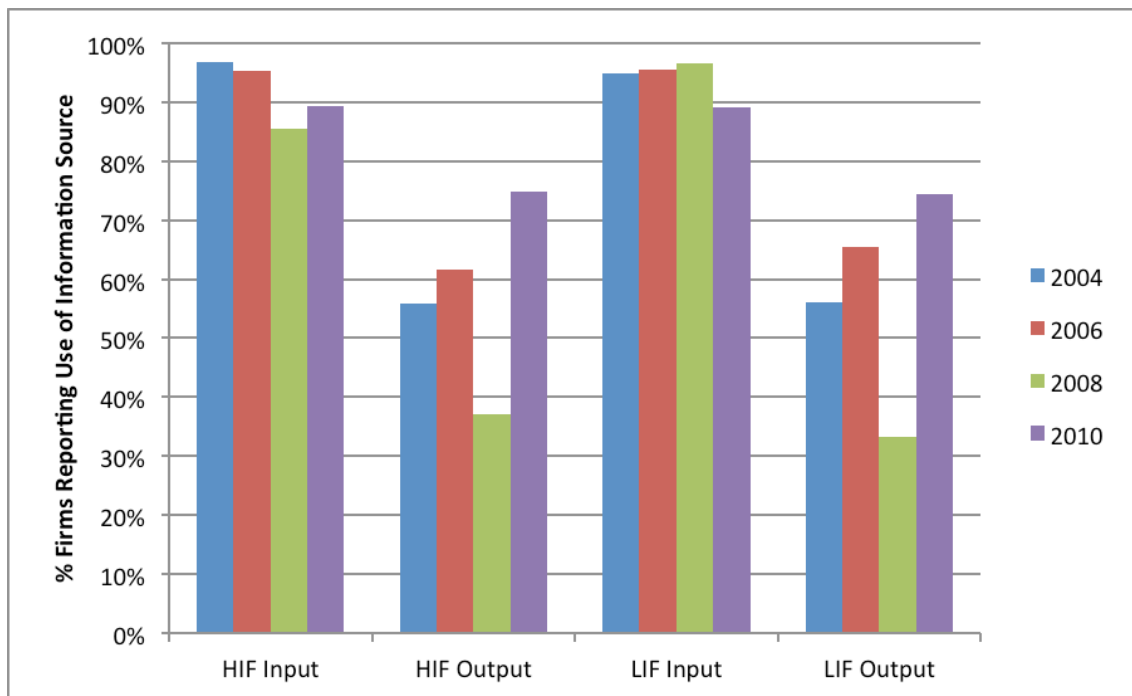


Figure 4.3 measures the use of information internal to the firm (or group of firms) in the innovation process. The levels of information use seen here are very high, with nearly 90% for HIFs and approximately 50-60% for LIFs exploring this information source. Again there appears to be little difference between the use of information among Input and Output measures. There does appear to be a general increase in use of internal information among LIFs, but this is not necessarily consistent across years.

Marketing Sources

Fig 4.4 Use of Marketing as Sources of Information among HIFs and LIFs by Input and Output

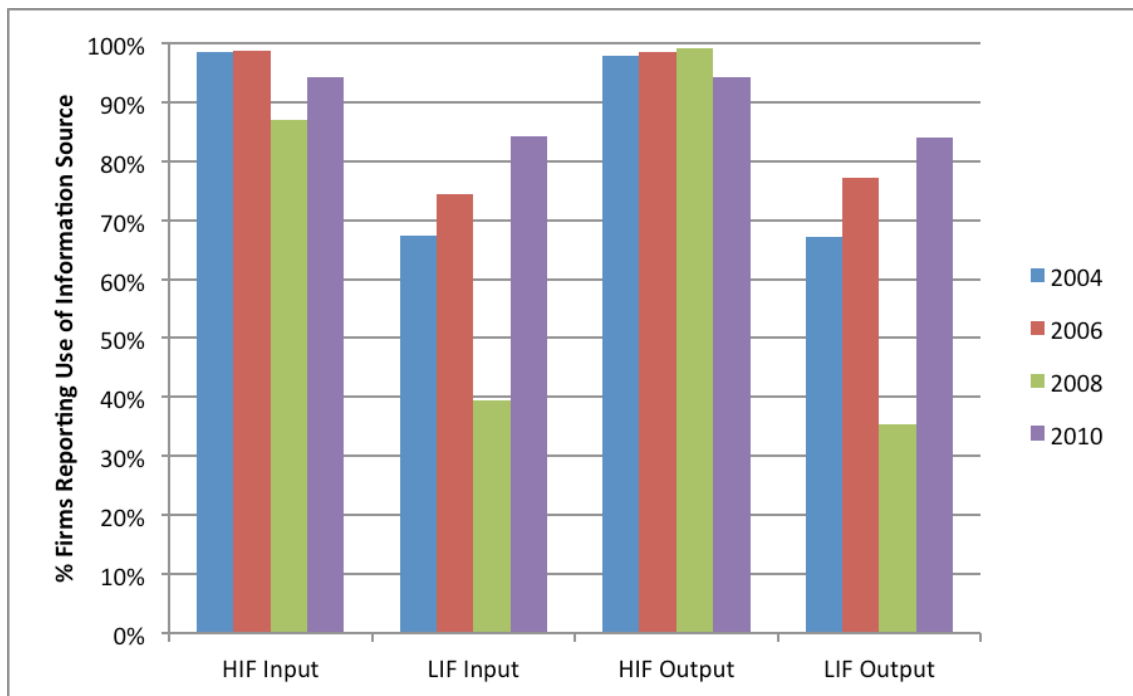


Figure 4.4 shows the use of markets as sources of information among HIFs and LIFs. We find a majority of firms use markets as sources of information for innovative activity. This finding is interesting because it suggests that even HIFs in terms of R&D spending use market information in their innovation processes. While this may have been more expected for HIFs by output, there is little clear difference between output and input for these firms. Again we find a broad trend of increasing use of sources of information over time by LIFs.

Trade Sources of Information

Fig 4.5 Use of Trade Sources of Information among HIFs and LIFs by Input and Output

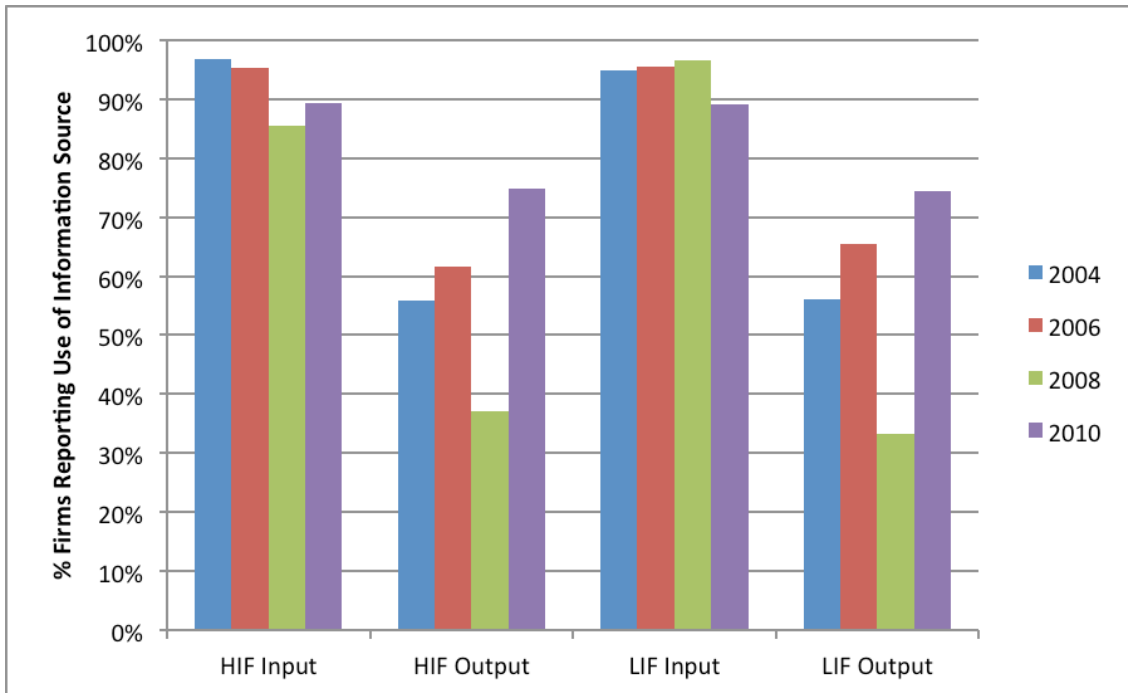


Figure 4.5 captures the use of information from professional organisations, trade bodies, and conferences. This figure shows similar trends to the others in that HIFs tend to show higher use of these information sources than LIFs, though in this case the margin between the two is smaller. There are no clear differences between Input and Output measures. Similarly to the other sources there are upward trends in LIFs over time, albeit not consistently.

Determinants of Use of Information

In this section we estimate a series of probit models to explore the use of different information sources. For ease of interpretation we report and discuss the marginal effects. The core variables in each model are:

- Firm age (and its squared term)
- Industry sector
- Science graduate share of total employment
- Firm employment size (and its squared term)
- Innovation input measure dummy
- Innovation output measure dummy

Separate models are estimated for each external information source for 2004, 2006, 2008 and 2010 and results are reported in the Appendix Tables 4.1 to 4.5.

External information sources

Here we find that age of firm has a positive association with use external information, but only in the earliest year, 2004. The relationship was non-linear and increasing at a faster rate for older firms. Industry was an important factor between 2004 and 2008, but it did not appear to be associated with use of external information in 2010 (during the recession). In general other-manufacturing, construction and service sector firms use less external advice than utilities, metals manufacturing and non-metals manufacturing. Firm size tended to have a non-linear association with use of external advice acting in a positive way initially and then reducing for very large firms.

The key findings were that firms with a higher share of science graduates and innovating firms were associated with higher use of external sources of advice. The magnitudes of these associations were quite substantial in both cases and the core associations held across years.

Market information sources

Here we find that firms' age had no association with use of external market information. In general other manufacturing, construction and service sector firms were associated with a lower use of external marketing advice than utilities, metals manufacturing and non-metals manufacturing, although these differences diminished over time. Firm size tended to have a non-linear association with use of external marketing advice acting in a positive way initially and then reducing for very large firms.

The key findings in this analysis were that firms with a higher share of science graduates and innovating firms were associated with higher use of external marketing related sources of advice. The magnitudes of these associations were again substantial in both cases and the core associations held across years.

Internal information sources

Firms' age was found to have a positive association with the use of internal sources of information, but only up to 2006. This relationship was non-linear and increasing at a slower rate at older ages. Industry was an important factor between 2004 and 2008, but it did not appear to be associated with use of internal sources of information in 2010 (during the recession). The results suggest other-manufacturing, construction and service sector firms used internal sources of advice less than utilities, metals manufacturing and non-metals manufacturing. Lastly, we find that firm size had a non-linear association with the use of internal sources of advice acting in a positive way initially and then reducing for very large firms.

Again we find that firms with a higher share of science graduates and innovating firms were different and were associated with higher use of internal sources of advice. The magnitudes of these associations were quite substantial and the core associations held across the waves of the survey.

Institutional information sources

Firms' age has a positive association with their use of institutional information, but only in the 2004 wave of the survey. This relationship was non-linear and increased at a faster rate at older ages. Industry was an important factor between 2004 and 2008, but it did not appear to be associated with use of external information in 2010 (during the recession). Other-manufacturing, construction and service sector firms used less institutional sources of external advice than utilities, metals manufacturing and non-metals manufacturing. Firm size tended to have a non-linear association with use of external advice acting in a positive way initially and then reducing for very large firms.

Again we find that firms with a higher share of science graduates and innovating firms were different and were associated with higher use of external sources of advice. And again we find that the magnitudes of these associations were substantial and held across years.

Summary

In this chapter we have presented basic descriptive information, which identified a number of key differences between HIF's and LIF's in terms of the extent to which they access different sources of information. At the univariate level we can conclude that:

- Overall, on average and across all types of information sources, HIF make a more intensive use of information sources
- There is no remarkable difference between Input and Output measures of innovation in the use of information sources unlike in the case of some of the indicators illustrated in Chapter 2.
- The most remarkable differences between HIF and LIF concern the use of institutional information sources.

From our regression analysis we find the following;

- In general firm age was not significantly associated with using external information. Where it was, this positive age-information use relationship tended to dissipate over time. This suggests that the youngest firms are just as likely to access external information to support their business activities as other firms.
- Manufacturing firms tended to be associated with much wider use of external information use than construction and service sector firms.
- Information use was positively associated with firm size, albeit this relationship diminished for very large firms. This suggests that small firms may be at a disadvantage in this respect, possibly because they lack the financial resources to develop and sustain external relationships.
- Firms with a higher share of science graduates were associated with more use of all sources of external information.

- Innovating firms, regardless of whether we use our input or output measure of innovation, were associated with a significantly higher use of all sources of external information. In general these associations tended to increase over time.

5 Co-operation

Introduction

This chapter focuses on the patterns and determinants of cooperation that firms engage in with different partners: (1) internal (firms belonging to the same group); (2) market/private (clients, suppliers, competitors and consultants); (3) institutional/public (HEI and government). The next section reports the descriptive results on patterns of cooperation with each type of partner. The following section then discusses the results of the logit model estimations on the firms' characteristics, which are most associated with the likelihood of cooperation with different partners.

Patterns of cooperation

Internal

Fig 5.1 Cooperation with Internal Partners among HIFs and LIFs by Input and Output

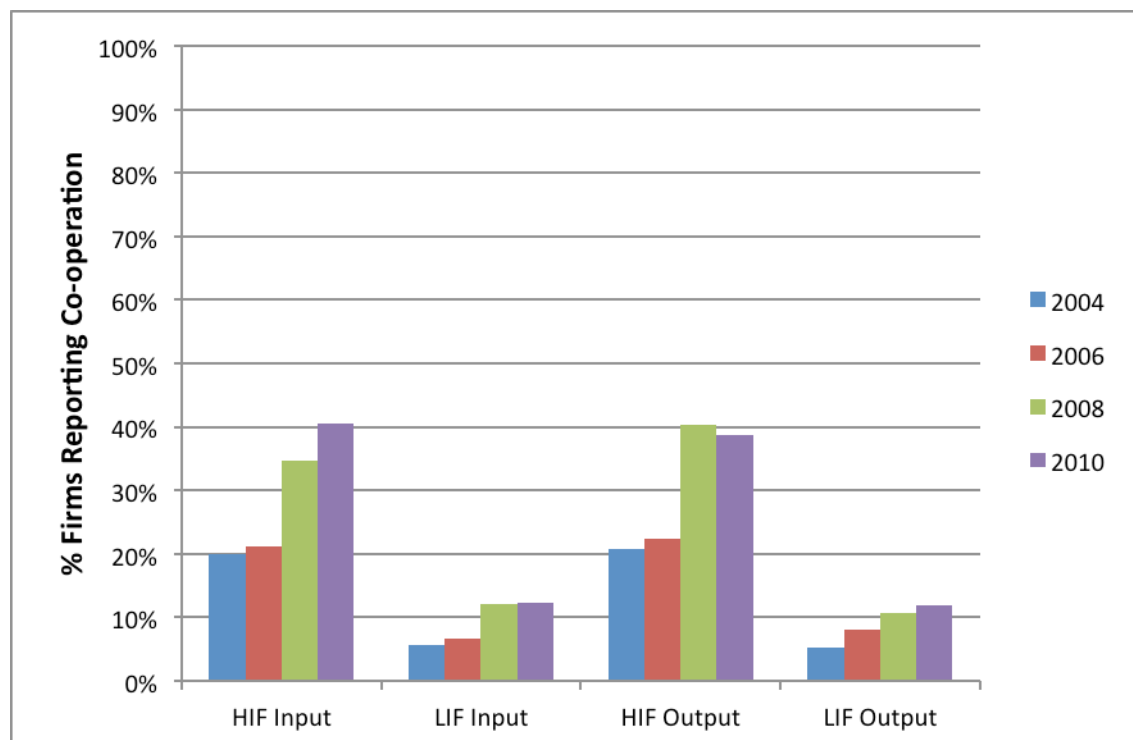


Figure 5.1 shows that collaboration with internal partners is considerably more frequent for HIFs than LIFs, reaching approximately 40% for HIFs and just over 10% for LIFs. There appears to be a trend toward increasing levels of internal

collaboration as time passes, and little difference between Input and Output measures.

Market-related Cooperation with Clients

Fig 5.2 Cooperation with Clients among HIFs and LIFs by Input and Output

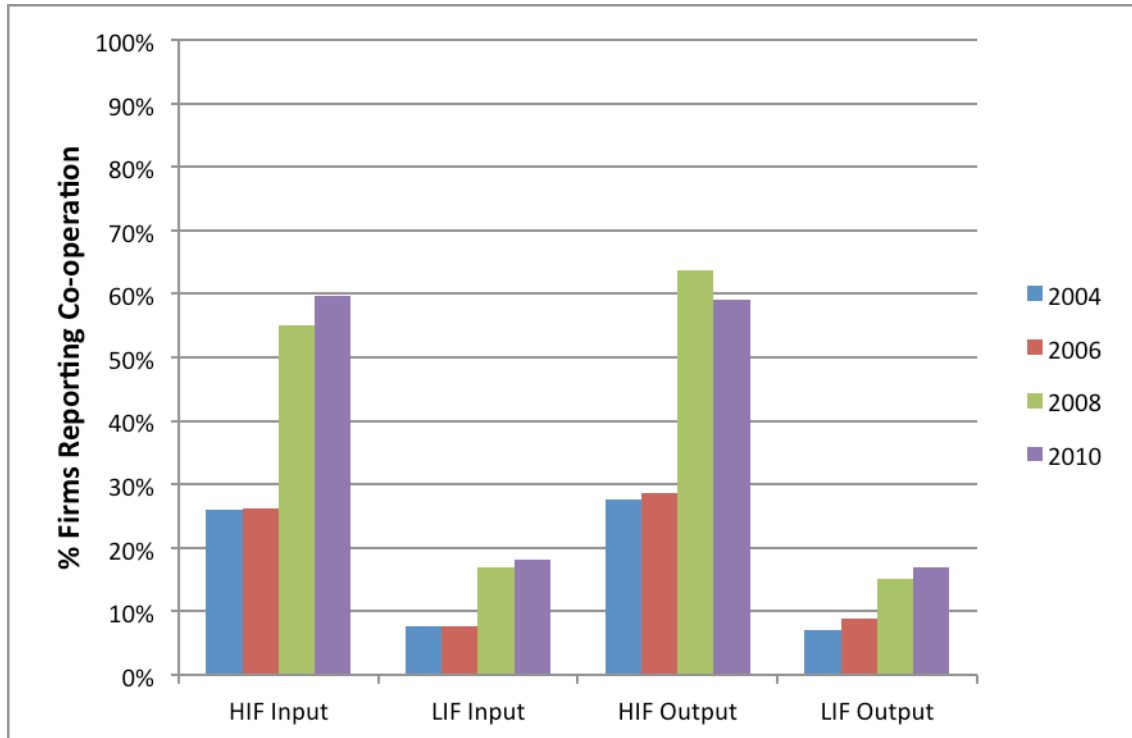
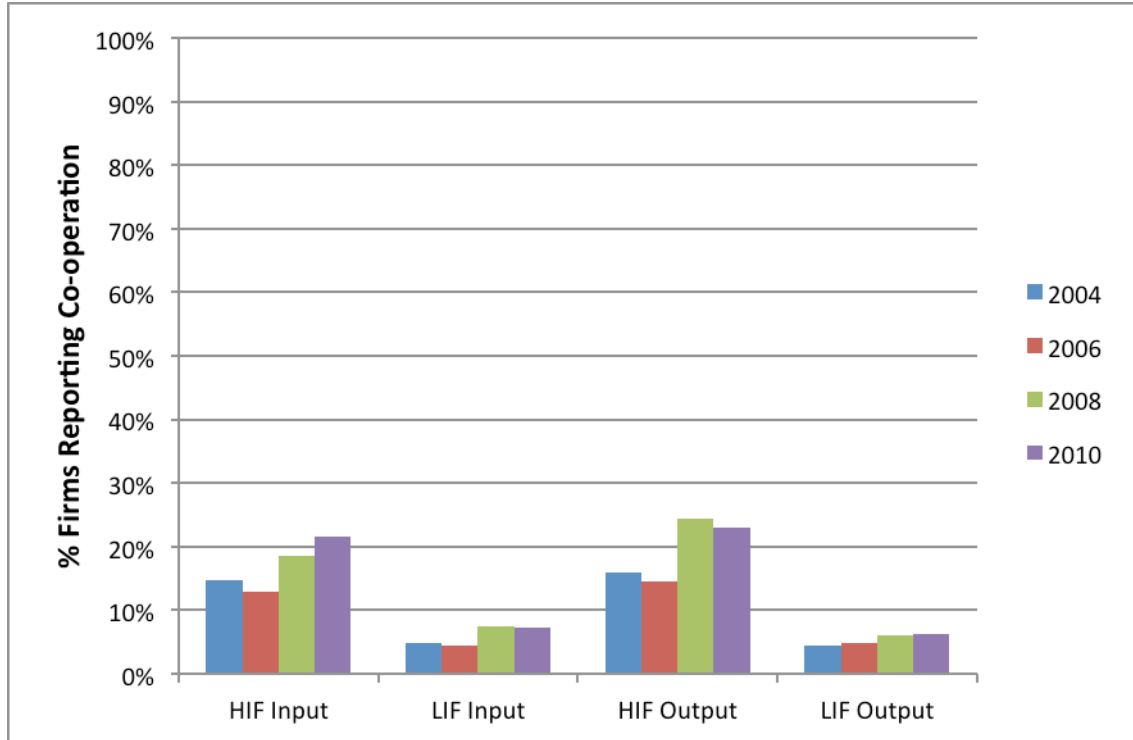


Figure 5.2 shows firms' cooperative activities with their clients. The overall frequency of collaboration is fairly low, but is markedly higher for HIFs than for LIFs. There appears to be a general, if inconclusive, trend toward increasing levels of collaboration over the various time periods for HIFs, with a large increase for HIFs in 2008 and 2010. There are few major differences between Input and Output measures. These results suggest that collaboration with clients is relative infrequent but is important for HIFs in the later surveys.

Cooperation with Competitors

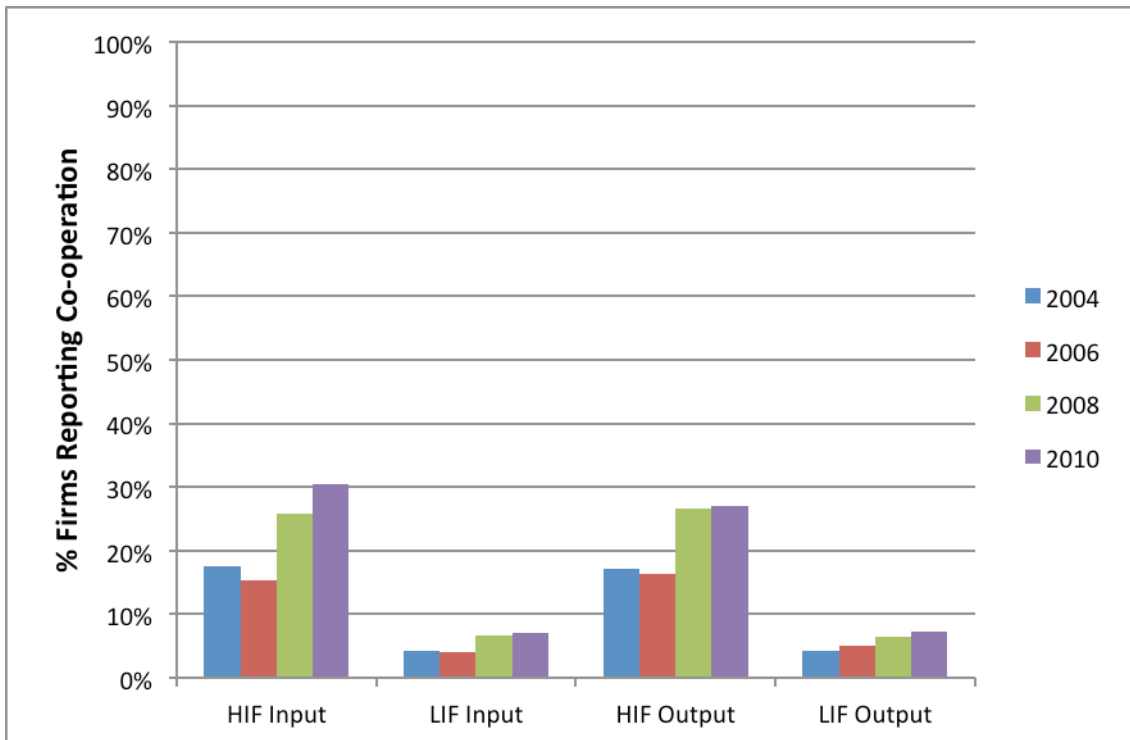
Fig 5.3 Cooperation with Competitors among HIFs and LIFs by Input and Output



Next we examine firms' cooperation activities with competitors. Again we find that the overall frequency of collaboration is fairly low, but is higher for HIFs than for LIFs. There appears to be a general, if inconclusive, trend toward increased collaboration, and few major differences between Input and Output measures.

Cooperation with Consultants

Fig 5.4 Cooperation with Consultants among HIFs and LIFs by Input and Output

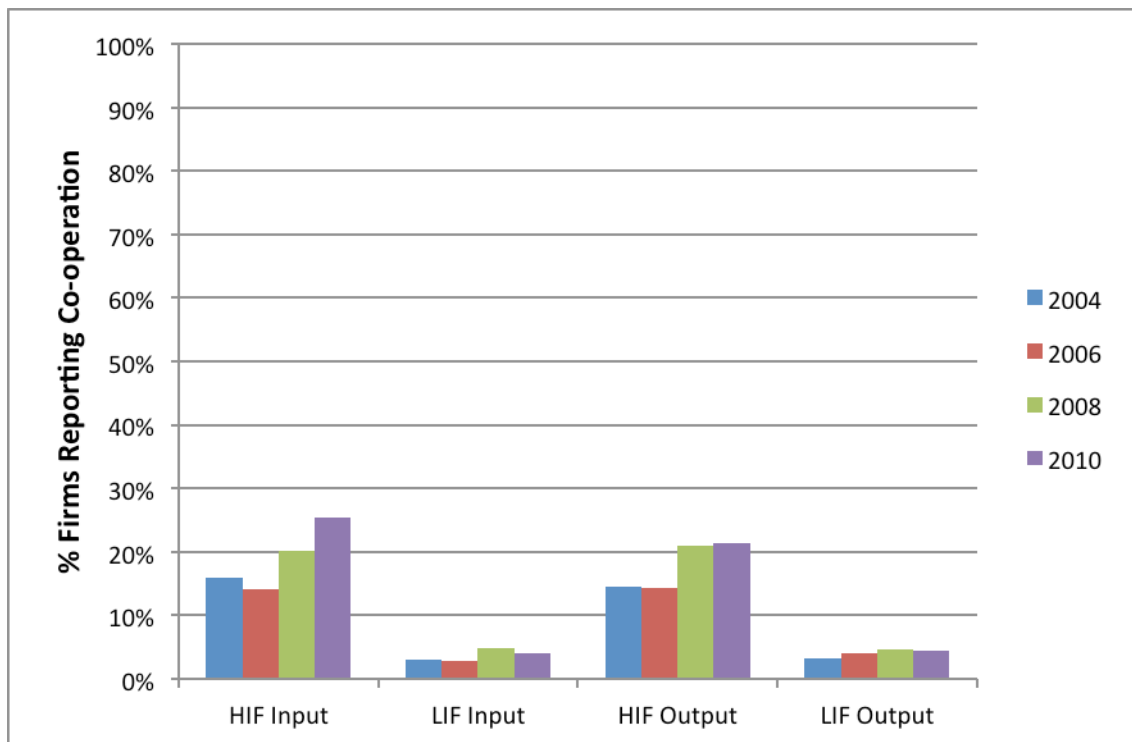


We next consider firms' cooperation with consultants. The overall frequency of collaboration with consultants is higher than for collaborations with clients and competitors for HIFs, but the figures for cooperation with LIFs is similar to the other collaboration measures, suggesting broadly lower collaboration levels among LIFs. There appears to be a similar general trend toward increased collaboration over time for HIFs, and few major differences between Input and Output measures.

Institutional

Cooperation with HEIs

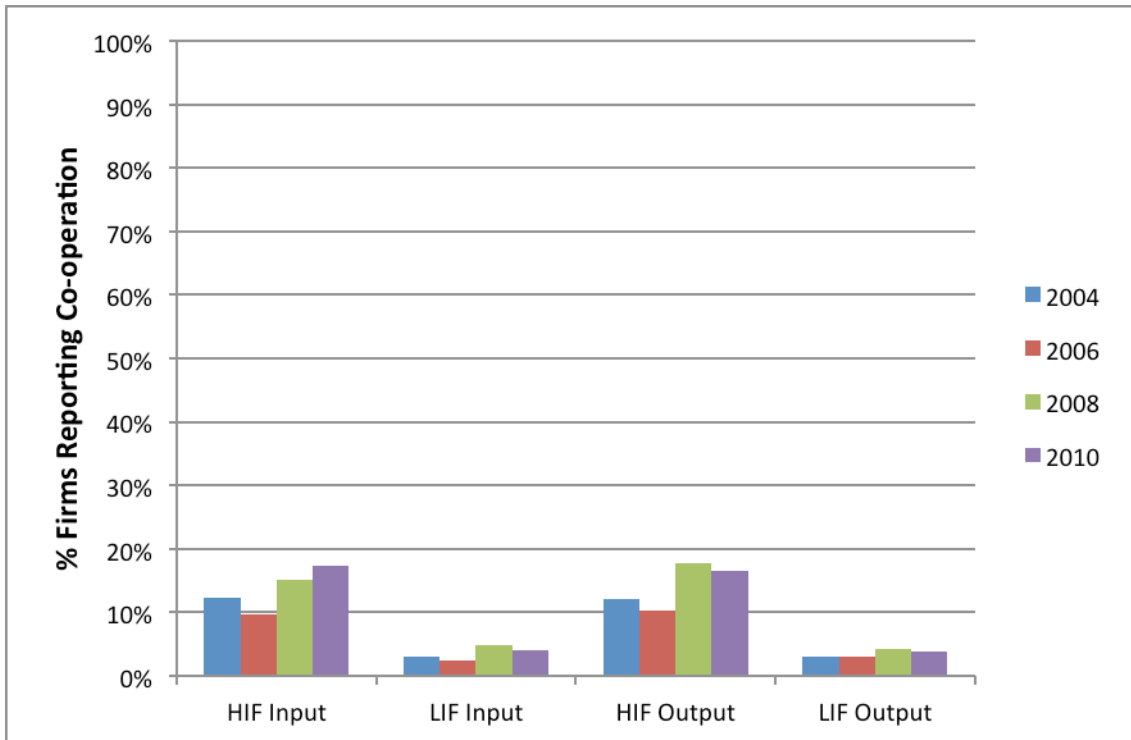
Fig 5.5 Cooperation with HEIs among HIFs and LIFs by Input and Output



The data on collaboration with universities shows that it is relatively less common than some other measures, though HIFs are disproportionately more likely to cooperate with universities. Rates of collaboration with universities remained low over time for LIFs, but appeared to increase for HIFs.

Cooperation with Government Research Organisations

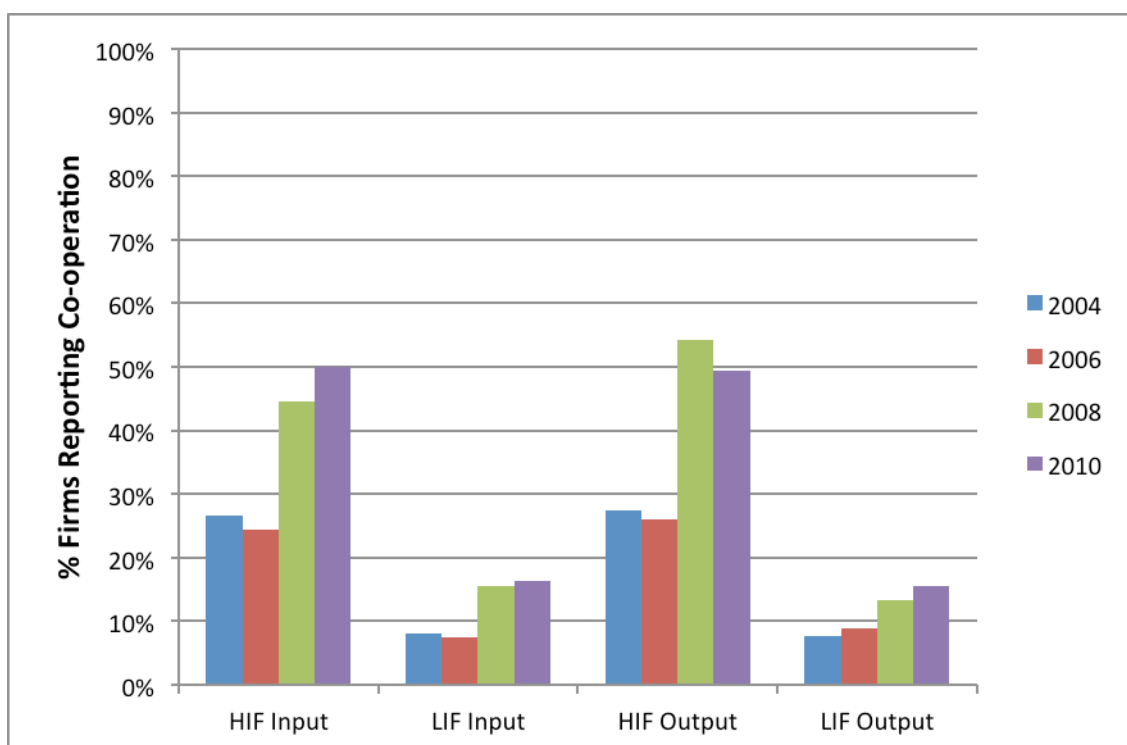
Fig 5.6 Cooperation with Government Research Organisations among HIFs and LIFs by Input and Output



Cooperation with government research organisations is the next measure to be considered. The frequency of these interactions are fairly low, though as with the other measures HIFs collaborate more frequently than LIFs. Again there is relatively little difference between Input and Output measures; this is somewhat unexpected as HIFs determined by Input (i.e. high levels of R&D) might be expected to collaborate more with these research organisations than firms that are introducing new products onto the market.

Cooperation with Suppliers

Fig 5.7 Cooperation with Suppliers among HIFs and LIFs by Input and Output



Some of the highest levels of collaboration in this dataset are observed for collaboration with suppliers, suggesting that innovation throughout the supply chain is a key component of innovative behaviour among HIFs (although similarly to internal collaboration LIFs also show high levels of collaboration). There again seems to be a general trend toward increased collaboration, particularly for HIFs in 2008 and 2010, and few differences between Input and Output measures.

Determinants of cooperation

In this section we report the results of a series of logit models estimations for the cooperation patterns with different type of partners (internal, market/private and institutional). For ease of interpretation we report and discuss the marginal effects. As with the previous analysis, the core variables in each model are as follows:

- Firm age (and its squared term)
- Industry sector
- Science graduate share of total employment
- Firm employment size (and its squared term)

- Innovation input measure dummy
- Innovation output measure dummy

Separate models are estimated for each cooperation partner for 2004, 2006, 2008 and 2010.

Internal cooperation (within group)

The results of the logit model in the Appendix Table 5.1 show no significant association of age of firms with the likelihood to cooperate internally. This is persistent over time. Interestingly, firms with a higher share of science graduate employees tended to cooperate within their group more. This tendency was persistent over time, though not very strong. There is a positive, non-linear association between size and the likelihood to cooperate within groups. This is likely to be due to the cooperation ties established between large firms and their affiliates. We find a significant, positive and persistent association of firms' innovation intensity, both in terms of input and output, with the probability to cooperate internally. There is no significant sectoral specificity in the probability to cooperate internally, with the exception of the service-sector. Overall, firms' characteristics that are significantly – albeit weakly - associated with internal cooperation are the share of science graduate, innovation intensity and size.

Market-related cooperation

For market-related cooperation we find robust evidence on the role of size, innovation intensity and share of science graduates. All these characteristics are positively associated with the likelihood of cooperating with clients, suppliers, competitors and private consultants. The size effect is consistently not linear, which means that for very large firms this association vanishes. The regression coefficients suggest these associations are positive and significant, though not very strong. Over time the results tend to be consistent. The exception for all types of cooperation is the year 2006, when innovation intensity measured by output turns out to be negatively related to probability to cooperate – unlike the input variable.

The most interesting result is the strong sectoral specificity of these relationships: while no significant sectoral specificities are detectable for cooperation with suppliers and competitors, the choice of consultants or clients as cooperation partners has a degree of sectoral specificity with service-sector firms less likely to cooperate.

Institutional cooperation

The same firms' characteristics (size, innovation and share of science graduates) hold a persistently positive and significant relation with the probability to cooperate with institutional partners (government and HEI). The significant differences lie in the sectoral specificity. While cooperation with

government is not sector specific – due most likely to horizontal-like type of government intervention for which cooperation might be a spillover effect – cooperation with HEI is typically manufacturing-specific. These results hold over time – with the usual exception of 2006 for the innovation output indicator.

Summary

This chapter has presented basic descriptive information on the specificity of HIF versus LIF in terms of cooperation behaviour and choice of partners. At the univariate level the key areas of distinction are as follows:

- Overall, on average and across all types of cooperation partners, HIF tend to establish more frequent cooperation
- There is no remarkable difference between Input and Output measures of innovation in the propensity to cooperate.
- The most remarkable differences between HIF and LIF are in the cooperation with HEI and public research organisation, and with suppliers, showing that two different patterns of cooperation emerge: on the one hand the ‘institutional’ model, on the other one a ‘vertical chain’ model, more related to upstream, than downstream, cooperation.

The regression analysis has highlighted that:

- In general firms’ age is not significantly associated to the propensity to cooperate for innovation. This evidence holds over time, indicating that there is no structural link between age and cooperation in the UK.
- Cooperation partners and the establishment of cooperation agreement with external partners turns out to be sector-specific in some cases, namely for cooperation with clients, consultants and HEI. While services are less likely to cooperate with clients compared to primary sectors, manufacturing firms are more likely than their primary and tertiary counterparts to cooperate with HEI.
- Firms’ size is generally positively, significantly and persistently associated to the likelihood to cooperate, regardless the type of partners. The relation is however not linear. This suggests that small firms may be at disadvantage in establishing cooperation agreements – assuming that this foster their innovation propensity and performance.
- Firms with higher share of science graduates tend to cooperate more, *ceteris paribus*, and with any kind of partner. This holds over time.
- Innovation is positively associated with the tendency to cooperate with any partner. This holds whether we look at input or output measure and over time, with the exception of year 2006 when the output indicator is negatively associated with cooperation.

6 Barriers to Innovation

Introduction

This chapter explores the extent and determinants of perceived barriers to innovation, distinguishing amongst (1) financial; (2) knowledge access-related; (3) demand and market-related and (4) regulation-related barriers. The next section introduces the descriptive evidence on the frequency of perception of barriers, while the following section reports the results of logit models estimations on the firms' characteristics that are most associated with the probability of perceiving barriers as very relevant.

Perception of barriers to innovation

Financial obstacles

Fig 6.1 Cost of Innovation as a Barrier to Innovation

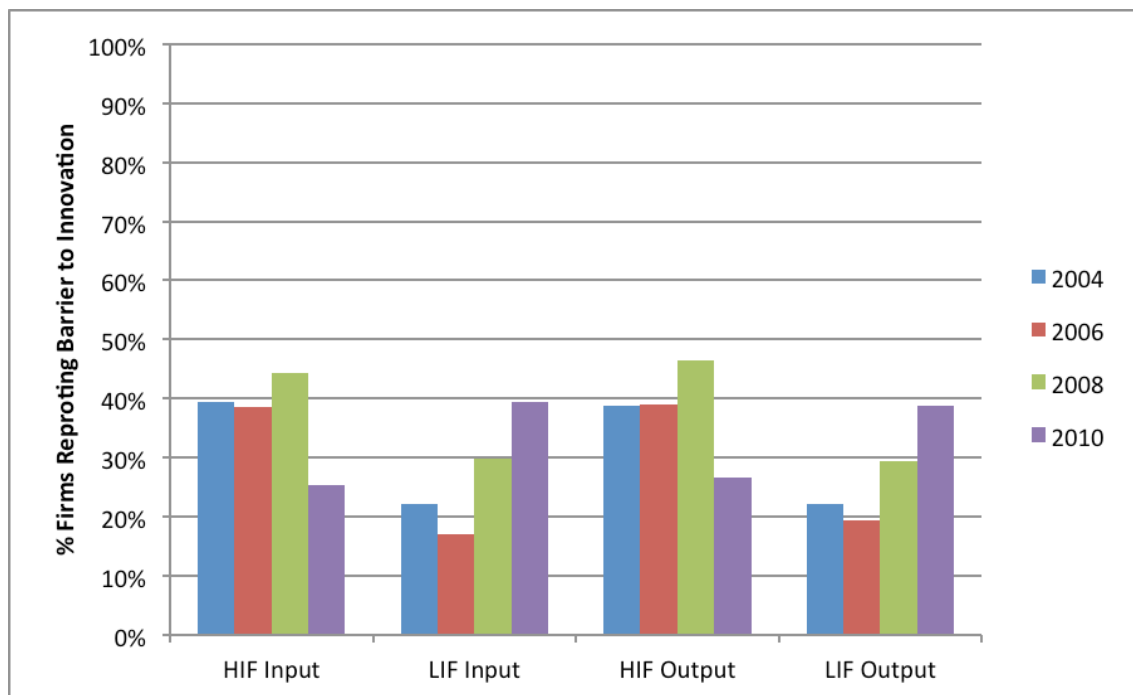
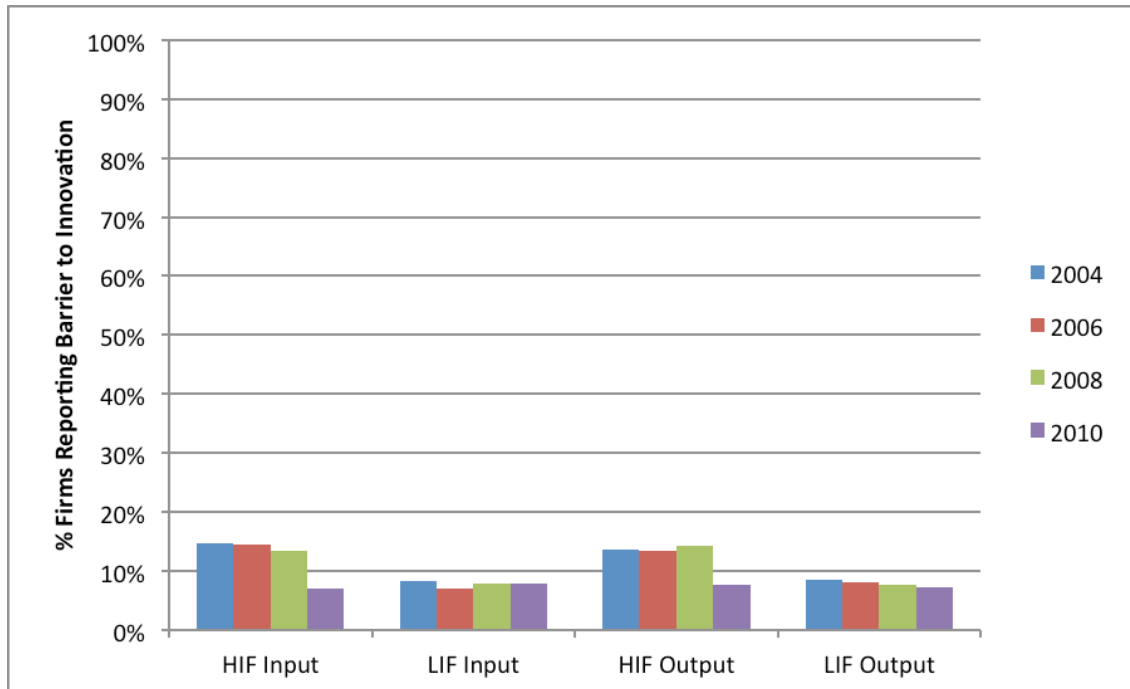


Figure 6.1 shows the percentage of firms who reported cost of innovation and financial issues as barriers to innovation. This is by far the most frequently cited reason given why firms do not carry out innovative activity. The figures show that even HIFs cite cost as a reason for not innovating more, though nearly as many LIFs also cite financial obstacles. This suggests that cost of innovation is a major factor differentiating HIFs and LIFs. The figures also show increases in numbers of LIFs reporting cost as a barrier in 2010, during the recession. This result may be a consequence of the smaller sample size surveyed in 2010 and should be interpreted with care.

Knowledge-related obstacles

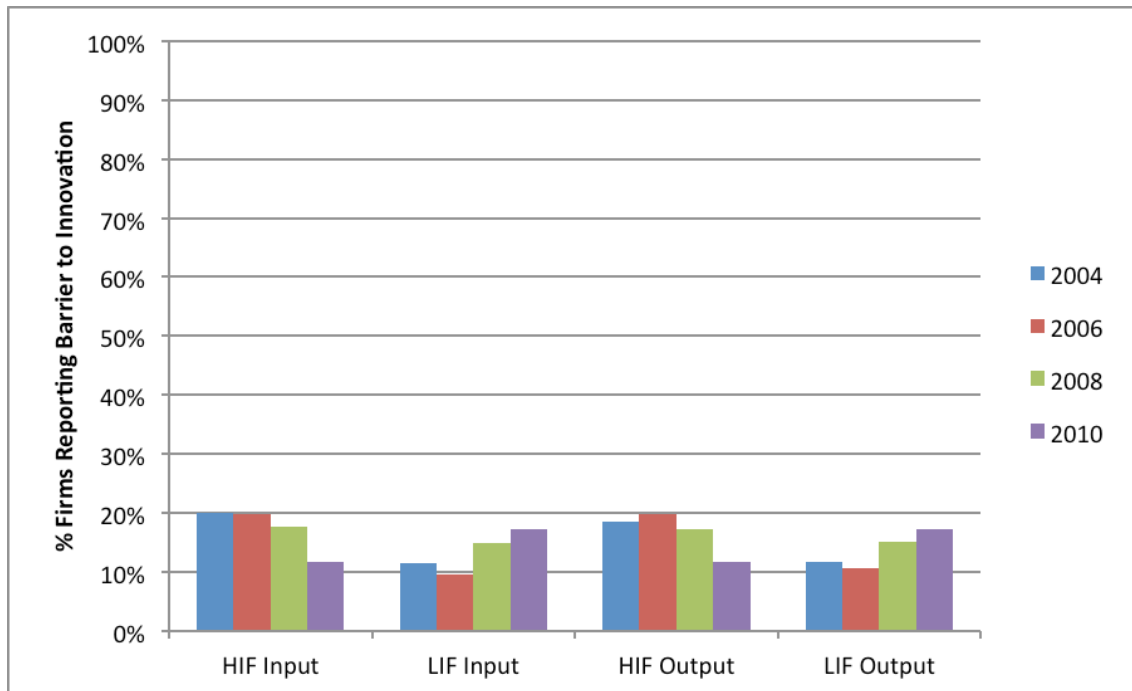
Figure 6.2 Lack of Knowledge as a Barrier to Innovation



Lack of knowledge appears to be a relatively less daunting concern to firms compared to cost. Comparatively few firms reported this as being a problem, suggesting that firms may either have the knowledge they need, or lack the knowledge they need and are unaware of it. The difference between LIFs and HIFs is small, with HIFs reporting more barriers than LIFs.

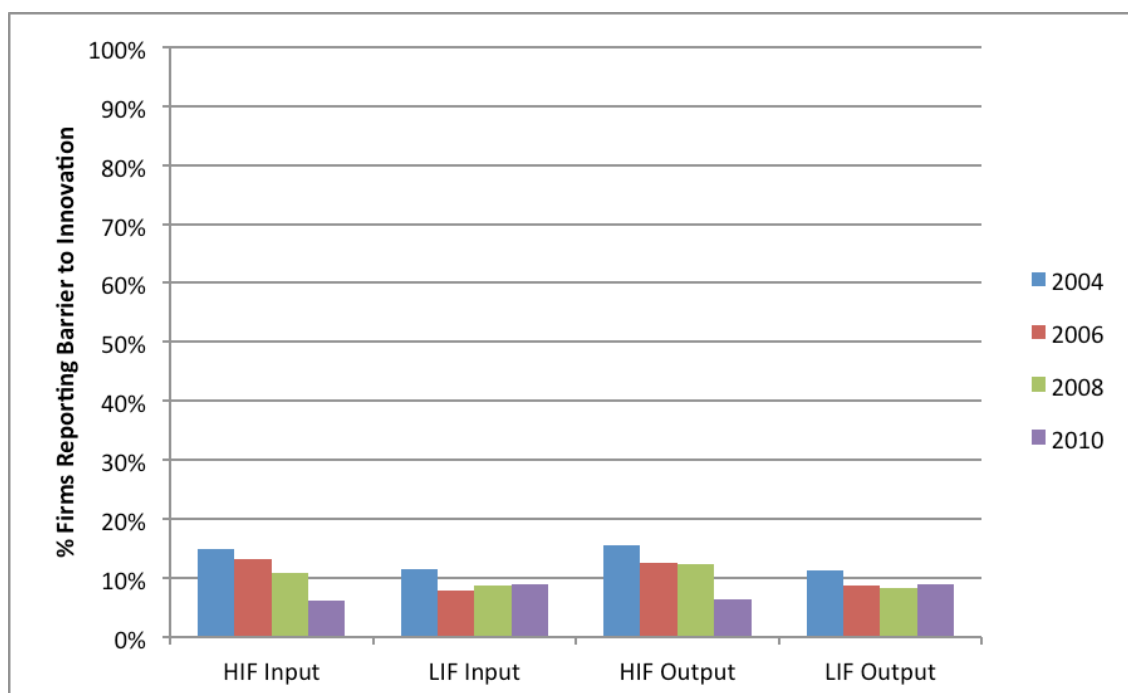
Market-related obstacles

Figure 6.3 Lack of Market Understanding as a Barrier to Innovation



Lack of demand and market understanding appears to be a relatively similar type of concern to lack of knowledge. For most of the sample approximately one-fifth of firms reported this as being a problem, suggesting that most firms perceive they have the knowledge and potential demand they need, suffer more from financial constraints. The difference between LIFs and HIFs is small, with HIFs reporting more barriers than LIFs but only barely.

Fig 6.4 Regulation as Barrier to Innovation



This measure refers to other potential factors preventing innovation, such as regulation, standards, or lack of interest from customers. As before there are (small) increases in reported barriers to innovation after the recession for LIFs and a decrease for HIFs that are picked up in the 2010 survey.

Determinants of perception of barriers to innovation

In this section we report the results of a series of logit models estimations for the firms' characteristics that are most associated to the perception of financial, knowledge, market and regulation barriers. For ease of interpretation we report and discuss the marginal effects. Again, the firms' characteristics are proxied by the core variables included, as above, in each model:

- Firm age (and its squared term)
- Industry sector
- Science graduate share of total employment
- Firm employment size (and its squared term)
- Innovation input measure dummy
- Innovation output measure dummy

Separate models are estimated for each type of barriers for 2004, 2006, 2008 and 2010.

Financial obstacles

The Appendix 6.1 reports the logit estimations of firms' characteristics affecting the probability of perceiving financial barriers as relevant. Age is not significantly associated to the perception of financial barriers (except for the 2008 CIS wave). The human capital endowment of science graduates is positively – albeit very weakly - related to the encountering of financial obstacles, and this result is persistent over time. HIFs, both in terms of input and output, are significantly and relatively strongly more likely to perceive financial barriers as relevant. This result is broadly persistent over time. The sign and significance of the sectoral dummies show that the perception of financial barriers is very sector-specific. In particular, non-service sectors are less likely to perceive financial constraints as a bottleneck to innovate.

Knowledge barriers

The data in Appendix 6.2 shows the results of the effects of firms' characteristics on the perception of obstacles related to the access to knowledge and information on markets and technology. Here, surprisingly, there are not significant sectoral specificities. The only variables that turn out to be significantly and positively associated to the perception of knowledge barriers are the share of science graduates and the innovation variables. Here too HIFs – both in terms of input and output – tend to perceive knowledge barriers as relevant more frequently than their LIF counterparts. This relation is weaker than the one emerged for financial barriers. This relation is persistent over time – with one exception only in 2006.

Market-related barriers

While the age of firms does not affect the perception of demand and market related barriers, consistently with the previous results on other types of obstacles, obstacles related to the lack of interest by customers or the presence of incumbent firms in the market is indeed sector-specific. Non-service sectors are less likely to perceive these types of obstacles as substantially affecting their innovation activities. As for financial and knowledge-related obstacles, HIF firms are more likely to perceive demand and market structure as impeding factors, although the coefficients are lower than the case of financial obstacles. These are seen for 2004 and 2006 but not for 2008 and 2010 wave. Interestingly, the size of the firm does not affect the perception of market-related barriers. This is somewhat surprising as we would expect smaller firms to suffer more from market structure and the dominance of larger incumbents.

Regulation barriers

With regulation-related barriers, they seem to be affected only by the firms being an innovator, both in terms of input and output. All the other firms'

characteristics, including sectoral affiliation, are not significant or weakly so. This suggests that the need to meet regulation barriers, both national and international, turns out to represent a bottleneck (or is perceived as such) by HIF.

Summary

This chapter has presented basic descriptive information on the specificity of HIF versus LIF in terms of perception of barriers to innovation. At the univariate level the key areas of distinction are as follows:

- Overall, HIF and LIF tend to perceive obstacles to innovation in a similar way, with a slightly higher incidence of obstacles perception for HIF.
- There is no remarkable difference between Input and Output measures of innovation in the perception of barriers.
- The most remarkable differences across types of barriers are in the financial obstacles, which appear to be the most constraining obstacle, for both types of firms.

The regression analysis has highlighted that:

- Firms' age does not affect the perception of (any type of) barriers. This evidence holds over time
- The perception of market-related barriers – i.e. lack of demand or the presence of large incumbent firms – is, plausibly, sector-specific, along with financial obstacles (albeit more weakly). Knowledge and regulation barriers are perceived as relevant indistinctively across sectors.
- Except for regulation barriers, the more firms are endowed with science graduates the more they tend to perceive barriers to innovation as relevant. This is structural across CIS waves.
- The strongest result is related to the HIFs. Being highly innovative – both in terms of input and output – is associated with a significantly higher probability to perceive barriers as relevant. This is particularly strong for financial obstacles and is relatively persistent over time.
- Size, in general, does not influence whether firms perceive barriers as relevant, except for knowledge barriers which seems to be marginally more relevant for smaller firms.

7 Conclusion

In this study we exploited four waves of the UK Community Innovation Survey and the Business Structure Dataset to explore the characteristics, behaviour and performance of a subsample of Highly Innovative Firms, compared to a control group of Less Innovative Firms. The analysis integrated two methodological approaches: cross-sectional analysis of individual waves of the UK Community Innovation Survey (CIS), and then, panel analysis of a dataset that combines Community Innovation Survey data with longitudinal data from the BSD dataset. Univariate and multivariate econometric models were run, together with a large number of robustness checks. Having rejected findings that were sensitive to the statistical methods or particular waves of the survey, we can be reasonably confident that the main findings reported in this study are robust.⁵

As the previous chapters have shown the analysis generated a wide range of findings that illuminate our understanding of HIFs. In this concluding chapter we will review those findings and then consider what they imply for our understanding of innovation in the UK, before drawing policy conclusions. To do this we will contextualise the findings in the light of previous academic research on innovation to highlight important overlaps and differences. An important part of this will involve relating the findings to the various models of innovation that are used to inform policy.

Main Findings

1. HIFs are similar to LIFs in most regards, but employ more STEM graduates and are more internationally focused.

The first main finding is that, for the most part, we do not find that Highly Innovative Firms (HIFs) are readily distinguishable from Less Innovative Firms (LIFs) using traditional firm demographic measures. It is often assumed that there is a particular class of small, young entrepreneurial firms in specific high-technology, science-intensive, sectors concentrated in particular geographic settings, that consistently drive innovation and growth in the economy. We do not find evidence to support this.

Instead we find that in general HIFs are no older or younger, no bigger or smaller, and are found in similar sectors and in all regions. While many HIFs are found in high-tech sectors, those sectors also contain many LIFs, and many HIFs are found in low tech sectors.

⁵ The results from the 2010 CIS wave are interpreted with more caution, due to a possible difference in the sampling procedure.

There are some small regional differences, but HIFs are found throughout the country. We do find that LIFs are relatively more dominant in less developed regions of the UK such as the North East, North West and Northern Ireland. HIFs, on the other hand, are relatively more dominant in the East Midlands and South West, and by single innovation measures in the West Midlands, East of England, South East and Scotland.

This is an important positive message, as there is a widespread belief that HIFs are concentrated around particularly technology hubs. Our analysis does not show particular regions being disproportionately favoured. If anything, London, which is often considered to be a hub of HIFs, has slightly fewer than expected HIFs.

We do, however, find that HIFs can be distinguished from LIFs using more specific metrics. A particularly strong finding is that they have a significantly higher share of employment accounted for by science (STEM) graduates. Importantly, we find that the employment of STEM graduates consistently has a large positive influence on a range of performance metrics. **Firms with more science graduates in their total workforce are associated with more R&D, more new to market products, more external co-operation and greater use of external information.** This is an important finding with implications for UK science and higher education policy.

Conversely, the lack of science graduate employment in LIFs is particularly striking. We find very limited employment of STEM graduates in LIFs, suggesting they may lack internal technical capabilities and also the absorptive capacity to access technology from elsewhere in the economy. Our analysis shows that **the median number of STEM graduates employed by LIFs is zero.**

The significantly greater employment of STEM graduates is likely to be an indicator of more sophisticated human resource investment rather than just investment in science graduates. While the skills needed for innovation will almost inevitably have a high technological component, they also require complementary 'soft skills' of an organisational, managerial and marketing nature. Hence employment of STEM graduates may also be picking up investments in these complementary non-STEM skills, rather than STEM alone. Recent research has shown that overall levels of skills needed across the economy are growing (BIS, 2011) and success is driven by complementary skill sets (Couerduroy et al, 2013). For example, Coad and Timmermans, (2012) find the most successful entrepreneurial ventures are founded by scientists who then team up with someone with a managerial background.

HIFs also tend to be much more internationally orientated than LIFs and more focused on exporting to international markets. By contrast LIFs tend to sell into local and regional markets. This international focus tends to be driven by older, larger firms employing more STEM graduates. So while HIFs are not necessarily concentrated in high-tech, science-intensive sectors, we do find HIFs in all sectors with scientifically qualified workforces. Employing these STEM graduates seems to enable firms to network with other institutions, and

sell innovative products and services in international markets, more successfully.

From a policy perspective this international, export focus is encouraging. Exporting firms have higher levels of productivity and generate higher quality jobs. As Bernard et al., (2007, p. 105) highlight “Across a wide range of countries and industries, exporters have been shown to be larger, more productive, more skill- and capital-intensive, and to pay higher wages than non-exporting firms. Furthermore, these differences exist even before exporting begins.” Exporting firms also benefit local regions by generating local jobs in non-traded local services through a ‘local multiplier’ effect (Moretti and Thulin, 2012).

2. High levels of growth are not persistent.

While a small percentage of firms in any particular period are responsible for a large proportion of overall growth, we do not find the same firms across consecutive periods. Nor do we find Highly Innovative Firm status to be associated with being a High Growth Firm. **HIFs, especially when measured by output, grow faster than the average firm, but are not more likely than other firms to be in the top 5% of fast growing firms.**

These findings are consistent with previous research suggesting firm growth is approximately as persistent as our ability to predict a coin toss (Coad, 2009). This research suggests that where exceptional firm growth does deviate from a random walk, it tends to be associated with a very tiny subsample of atypical firms, for example, in the US the tiny number of firms backed by large, technologically sophisticated, professional VC funds (Shane, 2008:164).

For the firms in our sample, by contrast, in any period of time we will find a small percentage of high growth firms driving the majority of employment growth, but this performance is only weakly carried forward into the next period. With any population of people tossing coins we would similarly expect to find a small percentage of high performance people, and again we would not expect this ‘high performance’ to be carried over into the next period. In fact, we find a small negative autocorrelation between growth in sales and employment in some of our regressions, suggesting firms that grow in one period are slightly less likely to grow in the next.

These results suggest it is misleading to assume that a specific small percentage of high performance firms consistently drive employment growth in the economy. While high growth firms may be high performance, by definition, and high performance firms may be highly innovative, by another definition, it does not follow that HIFs will be high growth, or that high growth firms will be highly innovative. This is not surprising as the association of HIFs with HGFs conflates levels and rates of change. In general levels, (such as size, productivity, profitability, height or weight) tend to be much more persistent than rates of change. Across the economy however, there is solid evidence that innovation does lead to macro-economic growth, even if the relationship at the firm level is much less clear.

3. Highly Innovative and Less Innovative status is persistent

The majority of firms in the sample maintain their Highly Innovative or Less Innovative status through the waves of the survey. Only a small percentage (approximately 10%) of LIFs in our sample become HIFs, while the majority of HIFs in 2002 that we can track through the survey's waves remain HIFs in 2010. This does not mean that there is no movement between the subsamples, only that such movement is substantially less than we find with the growth analysis.

This finding is consistent with previous work showing that differences in R&D intensity across firms are highly persistent. Because a large proportion of R&D spending goes on salaries, reducing R&D investments can be very costly for firms as it can cause them to lose their accumulated investments in human capital. Importantly we find that this persistent innovator status is strongly conserved from 2008 to 2010, suggesting few HIFs have been adversely affected by the recession drastically enough to curtail their Highly Innovative status.

4. The Growth Process

The fourth main finding relates to the processes that drive growth. Using VAR techniques we have been able to unpick and explore the processes of growth. The analysis suggests that **the growth process starts with increased employment, which then leads to future increases in R&D spending and New to Market Products, which in turn lead to future increases in Sales.** These results are very similar to analysis we have carried out with a larger UK dataset and more sophisticated econometric techniques that allow us to analyse causality rather than correlations (Coad et al., 2013). This suggests the underlying causal chain is similar to the temporal chain we have identified. Interestingly we do not find in that analysis that profitability is associated with future improvements in performance, suggesting profits are taken as windfall gains rather than reinvested into the firm. Importantly, we do not find evidence for a feedback loop from increased sales to increased employment, which explains why the growth process is episodic rather than self-reinforcing and persistent.

5. HIFs perceive more barriers to innovation than LIFs.

HIFs, on average, tend to perceive more barriers to innovation than other firms. These perceived barriers do not seem to affect their relative performance compared to LIFs who, surprisingly, perceive fewer barriers to innovation. Part of the literature has highlighted the presence of "revealed barriers", which firms detect only when increasing their innovation effort (D'Este et al., 2012; Pellegrino and Savona, 2013). Understanding the relationship between perceived barriers and actual barriers remains difficult and is subject to

significant disagreement in the academic literature because of a lack of counterfactual data on the outcomes that would have happened to the firms had the perceived barriers not been in place.

We also find significant differences in views about which barriers to innovation are perceived to be the most problematic. HIFs are particularly concerned about financial constraints and the cost of innovation, which increases in 2010. This contrasts with relatively limited concerns about the costs and impacts of regulation. These findings are consistent with previous research on HIFs that suggests their growth can be constrained by problems accessing managerial and technical skills, and accessing financing (Cowling, 2012; Siepel et al., 2012; Hutton and Nightingale, 2009; Coad et al., 2013).

The inverted relationship between perceived barriers and actual innovative performance is also consistent with previous research on managerial cognition and entrepreneurial biases (Lee and Cowling, 2012; 2013). These biases in managerial perceptions suggest a degree of scepticism about the value of self-reported survey evidence of barriers to innovation. Managers and entrepreneurs may not necessarily have a good understanding of what is influencing their performance, and in particular may underestimate the influence of the external competitive environment on outcomes.

On a less positive note, **we find that the recession is associated with an increased perception that there are barriers to innovation but paradoxically for LIFs not HIFs**, when we compare the 2010 survey to previous surveys. Moreover, we find that the positive impact that innovation has on performance across a range of performance metrics declines in this survey. Care must be taken in interpreting these results, but the findings are consistent with a weaker economy subject to financial constraints and decreased demand. These findings are concerning, but they do not reflect the catastrophic impact of the recession on investment in innovation and firms performance in the Eurozone (see Filippetti and Archibugi, 2011).

Addressing the Research Questions

These findings allow us to answer the research questions set out in the introduction:

- *Are HIFs better performing than LIFs? Are they also high growth firms, or high performance firms in terms of the magnitude of their output, employment and productivity?*

We find that there is very little overlap between HIFs and High Growth Firms. HIFs do grow more than LIFs, but are no more likely than other firms to be in the top 5% of high growth firms. By our input measure, Highly Innovative Firms are less likely to be High Growth Firms.

- *Do HIFs differ from LIFs in terms of their core characteristics?*

We do not find significant differences between HIFs and LIFs in terms of their core characteristics, with the exception that HIFs tend to employ more science graduates, be more export orientated and more networked and collaborative.

The employment of more science graduates is strongly associated with greater exploitation of external sources of information and the formation of co-operative arrangements with other organisations.

- *Do HIFs use external sources of information to support their activities to a greater (lesser) extent than LIFs?*

We find that HIFs are much more extensive in their external engagement.

- *Are HIFs more (less) likely to develop co-operative ties with external agents? Do they collaborate more closely with scientific institutions, such as universities and publicly-supported research establishments? If they do, are there any sectoral or regional patterns to their collaborations, and how are they influenced by firm characteristics?*

We find that HIFs collaborate much more strongly with scientific institutions, and that this is significantly enhanced by having STEM employees. In our regressions sectoral and regional control dummies tend to be insignificant, suggesting a lack of sectoral or regional patterns in collaborations.

- *Do HIFs experience more barriers to innovation than LIFs?*

We find that HIFs perceive more barriers to innovation than LIFs, despite their superior performance. They are particularly concerned about financial issues, and skill issues, and relatively unconcerned about the impact of regulation. Paradoxically, LIFs tend to perceive more barriers during recessions. Care must be taken in extrapolating from perceived to actual barriers, but these findings are consistent with other studies.

It is important to note that firms, including HIFs, experiencing significant barriers to growth, are not necessarily inconsistent with a healthy economy. In a competitive market economy inefficient firms that seek external funding, for example, will be refused and some may exit the market as a consequence. This 'culling' process is an important source of productivity enhancement. However, in a recession where over-exposed banks are attempting to reduce their exposure to risk, constraints on lending can be much more problematic.

- *Have HIFs been adversely influenced by the recent recession?*

This question is difficult to answer. The 2010 survey contains a smaller data set and in some instances it is unclear if the differences in outcomes for the survey reflect differences in the survey methods or in the economy. However, we do find evidence of an economic shock. Firms are more likely to source external information. We do not find evidence that firms are failing to maintain their HIF status. HIF status is strongly conserved for firms between 2008 and 2010, which is important as it reflects continued investments in intangibles (i.e. R&D spending). These findings contrast with the evidence of significant contractions in innovative investments in some Eurozone countries during the recession (see Filippetti and Archibugi, 2011).

Discussion

The core message of these findings is that while both growth and innovative performance are highly skewed they differ in fundamental ways: innovative activity is a long run process in which firms' positions within skewed distributions are persistent through time, while high growth is a short run process, where firms' positions within skewed distributions are highly erratic. It is therefore misleading to conflate the small subset of HIFs with the small subset of HGFs and assume a small subset of HIFs drives the majority of employment growth in the economy by growing themselves. In fact it is more useful to regard HGFs and HIFs as distinct. While HIFs grow more than LIFs, they do not overlap with HGFs any more than their proportion in the economy would suggest

If one assumes that superior firm-level capabilities are the main driver of firm growth then it is natural to assume that high-growth firms will also be highly innovative, and their superior firm-level capabilities will persistently drive the majority of job creation. This is not the case.⁶

A key policy message of this analysis is that policy makers should avoid directly conflating high growth firms with highly innovative firms, and recognise that periods of high firm growth are episodic and peter out. This makes it difficult to formulate policy metrics around individual firms, or groups of firms. Innovative performance, on the other hand, is persistent and drives aggregate growth, but does so in complex ways. Our results strongly suggest the High Growth Firm category is problematic for policy makers. It is absolutely clear that Highly Innovative Firms grow faster on average than Less Innovative Firms, but this superior growth may not necessarily be the spectacular growth associated with a tiny subset of High Growth Firms.

Long run persistence versus short run volatility

The persistence of innovative performance reflects how innovation depends on long term investments in building innovative capabilities. These innovative capabilities do not guarantee success: they only allow firms to start an uncertain development process. Persistent, long-term investment is needed for learning to take place; for customers to understand technical products and services; for relationships to develop within distributed systems of innovation; for technologies to be improved; and for the organisational changes that are often needed to exploit new technology to take place.

As a result, the persistence of R&D investment, continuing over many years is often a better predictor of outcomes than the absolute level of R&D spending at a particular point in time (Cefis and Orsenigo, 2011; Lööf et al., 2011). Controlling for past labour productivity, Swedish firms persistently investing in R&D have, on average, 13% higher productivity than firms with no R&D

⁶ High-growth firms are not exclusively high tech or highly innovative. A key stylised fact about them is that they found in all sectors (and in some studies are under-represented in high tech sectors), nor are they necessarily young, or necessarily small (see also, Brown and Mason, 2010).

spending, and 9% higher productivity than firms that occasionally invest in R&D. More importantly they have a 2% higher growth rate in productivity than other firms (Löf et al., 2011, 185).⁷

Growth, on the other hand, is also skewed, but is a more intermittent, sporadic activity. It is subject to random, unforeseen setbacks and influenced by factors outside managers' control (Coad, 2009). For example, competitors can launch better products, customers can change their requirements, or substantially expand or contract their orders, and firms' plans to expand into new markets can go awry. Growth is therefore more erratic than innovative performance, with periods of growth followed by periods of contraction and vice versa.

The contribution of innovation to economic growth is a long run, gradual background process, driven by the superior, but not typically spectacular, growth of highly innovative firms. By contrast, the rapid firm level growth associated with High Growth Firms tends to be a short run series of largely unrelated episodes of growth and contraction. Hence, policy makers should focus on the aggregate contribution of many highly innovative firms that achieve above average growth rates. These firms make a more significant contribution to UK GDP, than the episodic contribution of a small subset of high growth, and largely less innovative firms.

The Importance of Complementary Assets

The reasons there is only this limited direct relationship between innovation and firm growth is because there is a difference between firms creating value and firms capturing value (Teece, 1982). As highlighted earlier, firms need assets to create value, such as persistent investments in innovative capabilities. However, they also need "complementary assets" to capture the value their innovations created. For example, assets like well known brands, sales forces, links to customers, managerial skill, financial resources, production facilities, channels to market, intellectual property protection, economies of scale and scope in production, etc (Teece, 1982).

Firms that innovate but lack these complementary assets may not capture the benefits of innovation. Because innovation is an increasingly distributed process, and innovative firms won't necessarily have all the complementary assets in place they need, the firms that innovate (create value) are not necessarily the same firms that capture that value. Moreover, firms can have the complementary assets needed to capture the value created by other firms, further complicating the link between innovation and growth.

⁷ Cefis and Ciccarelli (2005) analysis of persistent R&D spenders in the UK finds they are similar to the HIFs in our sample: they are larger, more export orientated, more skill intensive, have higher sales and value added per employee, and are more likely to belong to a multinational group (Löf, et al., 2011, 185). Löf et al., (2011, 203) similarly find persistent R&D spenders in Sweden are larger, more human and physical capital intensive, more export orientated and more likely to be owned by a multinational firm.

The difference between value creation and value capture in our data is indicated by the differences in performance between the input and output based measures of innovation. R&D spending, our input measure, is an indicator of value creation that does not necessarily imply the firm has complementary assets to capture value. On the other hand, our output measure, sales from innovative products and services, indicates firms' ability to capture at least some value from sales. This output measure of innovation is less persistent than our value creation related input measure. The differences in performance between the two measures indicate the impact of complementary assets. For example, we find that innovative firms measured by output (i.e. that have complementary assets) tend to perform better and are more likely to collaborate up and downstream than innovative firms measured by inputs (i.e. value creation). These findings suggest too many innovative UK firms have unbalanced business models that under-emphasise value capture.

This distinction has a number of important implications:

- Firms may innovate, but the benefits of that innovation may spill over into the rest of the economy and accrue to their customers, suppliers, competitors or unrelated firms elsewhere in the international economy. This is why the indirect contribution of innovation to economic growth is typically more significant than the direct contributions generated by the growth of innovative firms.
- Secondly, the connections between innovation and economic growth, and innovation and firm growth are indirect and long term. Innovation does not generate growth in the economy only through innovative firms growing.
- Thirdly, the inability to capture all the value of innovation reduces the incentives to innovate, and can potentially cause innovative investment to fall below its economically optimal level. This is one reason why public returns to innovation are generally higher than private returns.
- Lastly, the mismatch between value creation and value capture increases the risk of 'systems failures' within a National System of Innovation where the trade off between incentivising innovation and encouraging its diffusion are misaligned.

The core findings of this study – that innovative firms grow more but are no more likely to be HGFs; that HIFs employment of STEM graduates is associated with stronger performance; the nature of the growth process found in the VAR analysis; and the superior performance of HIFs measured by output compared to HIFs measured by input - are all consistent with the importance of the distinction between value capture and value creation. However, the distinction is rarely incorporated into the models of innovation that inform public policy. These tend to assume the ability to capture value is in place, and therefore miss its importance.

Models of Innovation

UK innovation policy is developed through pragmatic learning, independent evaluations and through the use of models of innovation that allow empirical evidence to be contextualised and turned into policy implications. The findings of this report do not fit particularly well with existing models. The traditional Solow growth model, discussed in the introduction, for example, assumes technology is generated outside the economic system and assumes firms converge on a long run capital-labour ratio determined by the prevailing technology. The analysis instead shows the endogenous generation of innovation by firms in the economy. Rather than a harsh Darwinian selection environment, in which high quality firms displace poor quality firms, we instead find a lack of convergence and poor productivity firms remaining in the economy for extended periods.

A second model of innovation, drawing on endogenous growth theory, assumes more realistically that private investment in R&D drives technical change, which leads to increasing returns to scale, and therefore firm growth and economic growth. It also assumes (correctly) that technology has a partly public-good nature, and the benefits of investments in innovation spill over to other firms in the economy. The problem with this theory is that R&D levels and R&D growth do not have a particularly strong connection to firm growth or productivity growth at the firm level, and no strong immediate relation to growth at the economy level. In some instances countries spending more on formal R&D can perform worse in comparisons (i.e. the USSR v Japan in the 1970s) (Freeman, 1995).

Schumpeterian models of innovation-driven growth draw on Schumpeter's theory that entrepreneurs have unique insights that allow them to recognise opportunities, create new innovations, and exploit them in new firms. These Schumpeterian firms then grow to displace existing incumbent firms, (who are themselves former innovators), and disrupt existing industries.

This model has many benefits: it is simple, it avoids policy makers having to make discretionary choices, and has led to significant indirect benefits through increasing public investment in research. The distinction in neo-Schumpeterian models between R&D intensive 'frontier innovation' and less R&D intensive 'imitation innovation' helps explain why R&D and productivity growth at the firm level and R&D and growth at the economy level have a weak and in the second case sometimes negative relationship. Fast growing firms and nations are often catching up with the technological frontier, and therefore tend to adopt less R&D intensive forms of innovation. Moreover, the model highlights the need for broader economic conditions to be in place to allow innovation to generate growth, such as competition policy that encourages entry and exit, investments in higher education, and appropriate credit and labour markets (Aghion et al., 2005).

There are, however, a number of problems with this model. The model typically assumes 1) entrepreneurs find fully formed innovations that are radical enough to disrupt existing industries; 2) innovations come from new knowledge, which has its ultimate source in university research; 3) value capture is unproblematic and innovations are best commercialised in new entrepreneurial firms that grow and displace existing firms; so that 4) higher growth is associated with a higher

rate of firm turnover and entrepreneurial market entry. As a result, it implies that innovation is an inventive *event* that generates new innovations in a fully formed state. Instead, innovation is better understood as a distributed, long-term *process* of experimental adaptation that turns primitive, early stage inventions into commercially viable innovations and often continues after the product is launched (Rosenberg, 1976).

By assuming innovations emerge in a fully formed state, the Schumpeterian model over-emphasises new-to-the-world radical innovations, and misses the economic importance of incremental changes and the diffusion of established, new-to-the-firm technology. Hence it is really a theory of invention rather than innovation, or a theory of innovation with the innovation process left out. Moreover, by assuming firms capture all value of their innovations, the Schumpeterian model misses how much is available for other firms to exploit. The data on the persistence of R&D investment suggests that firms don't just produce innovations and then stop, but have to keep investing to modify and incrementally improve their technology. The misleadingly sharp distinction between innovation and diffusion under-estimates the costs of this activity and therefore how easy it is for firms to improve their innovative performance (Rosenberg, 1976).

The Schumpeterian model also over-estimates the importance of R&D, research and hence universities as sources of innovation. The data in the report shows that HIFs are not just found in sectors with high R&D intensities, and while universities are important sources of information and collaboration, they are less important than most other sources. Moreover, the model sees universities as sources of new innovations, rather than organisations that generated talented graduates and support firms solving problems that emerge during their own innovation processes.

Lastly, by assuming innovations emerge in a commercially viable form, and value capture is unproblematic, the model also mistakenly assumes that new firms will have an absolute advantage, and be the best places to commercialise new technology. Our results suggest that younger and smaller firms do have some advantages related to their flexibility, but also disadvantages related to their lack of complementary assets. Younger firms tend to have higher sales growth and employment growth, are more likely to be HIFs, and more likely to translate their HIF status into HGF status. Older and larger firms, on the other hand, are more likely to have an extended market reach and be exporting. These relative strengths and weaknesses suggest different kinds of firms will therefore be more or less appropriate under different conditions.

Policy Implication: Post-Schumpeterian Innovation Policy

Addressing the weaknesses of the Schumpeterian policy model would involve complementing a focus on value creation with much greater emphasis on value capture and the importance of complementary assets. It would complement a focus on R&D and the production of radical, new to the world innovations with a greater attention to incremental adaptation and diffusion of existing innovations,

distributed along complex supply chains. And lastly, it would involve a greater appreciation of the incremental, experimental, uncertain nature of innovation, and hence the need for persistent investment in upstream capabilities and skills. We expand on these points below.

1. Balance the current focus on value creation with more focus on value capture.

Currently UK innovation policy is aimed at creating value, typically in the form of new to the world innovations. The lack of attention to value capture can help explain some of the problems that have affected policies that focus on value creation alone. For example, support for university spin-outs often produces firms that lack the complementary assets they need to capture value, with the result that many fail to achieve their potential. Few of these firms grow, and many are acquired by larger foreign firms with more complementary assets who are better positioned to exploit the technologies the firms create. A greater emphasis on value capture may lead to these policies being rethought.

Supporting firms to build complementary assets would also enhance their ability to exploit other firms' innovations, which would help diffuse productivity enhancing technology and upgrade the long tail of weaker firms in the UK economy. However, an additional focus on value capture complicates policy making, as it needs to take account of the trade-off between providing incentives for firms to innovate (which leads to policies that support firms capturing benefits), and encouraging wider public benefits through the diffusion of technology (which encourages firms having more limited ability to capture benefits).

2. Enhance capabilities and skills.

The second policy implication follows from the first and involves emphasising the value of enhanced capabilities and skills. The analysis suggests that many LIFs lack the basic capabilities to create and capture value, and are often seemingly unaware of constraints on their innovative potential. Policies that help them upgrade their capabilities, such as continuing support for the diffusion of STEM graduates and post graduates throughout the economy might be beneficial. The results highlight the value of investment in STEM graduates, which is likely to be an indicator of more sophisticated HR practices, and hence of high quality management.

The **chain of influence** found in the VAR analysis also suggests policy should consider the upstream capabilities that need to be in place. For example, policies that attempt to increase sales directly may be ineffective if they do not take into account the need for prior investments in people and skills. Indirect policy interventions to increase sales by increasing employment might therefore be useful as complements to policies directly focused on growth. Without this upstream capability policy may not be effective, particularly if it incorrectly assumes feedback loops in the chain are in place. For example, tax breaks intended to free cash for reinvested may end up allowing entrepreneurs to achieve their target income earlier, and hence reduce, rather than increase, economic activity (Dosi, 2011; Cowling, 2009).

3. STEM and Universities

The third key policy message of the analysis is **the importance of STEM graduates and skills more generally to the economy**. The findings of the report highlight again that the value of public investment in research comes primarily through the production of trained graduates and post-graduates, who have the ability to solve complex technical problems and network more effectively, as well as from the production of technology or university spin out firms. It is the production of ‘talent not technology’ to borrow the title of a previous study (Salter et al., 2000).

The findings on the value of STEM graduates in this report suggests policy makers would benefit from thinking of the UK science-base as a set of institutions that contributes as much to the *demand* for innovation than its *supply*. Outside the pharmaceutical industry, university research is a much less important source of innovation than firms’ internal activities and links to customers and suppliers. However, public investment in research generates talented graduates who work in industry, and use their problem-solving skills to reduce the costs and increase the economic benefits of innovation. This increases the *demand* for innovation and encourages its exploitation and diffusion.

It would therefore be useful to change how we think about the typical innovative firm. The typical Highly Innovative Firm in the UK is often thought of as a university biotech spinout in Cambridge or London that directly draws on scientific research. Our analysis suggests it might be more useful to think of it as an engineering company which could: (i) be based anywhere in the UK; (ii) draw on the university system to source STEM graduates; and (iii) innovate in collaboration with its customers and suppliers, within complex, international supply chains and networks. Thinking of innovative firms in this way focuses attention on the role of universities in producing talent, rather than technology, and on the importance of balancing value creation and capture in the complex inter-firm networks that support innovation in the UK.

While university research is a vital part of the UK innovation system, and is regularly exploited by a wide range of HIFs, engagement with other firms along supply chains is a more important contributor to innovative activity that is enhanced by the employment of STEM graduates. University research is important, but the less photogenic production of highly skilled, well-trained graduates should remain the key priority. This suggests that concentration of research funding in a smaller number of institutions to boost radical innovation may be economically counter-productive if the overall quality and quantity of STEM graduates being produced is reduced.

4. **While firm growth is important for policy, High Growth Firms are not.**

The final policy recommendation emerging from this study is the suggestion that the emphasis on High Growth Firms is misplaced. The erratic nature of growth means that such firms do not provide a useful framework for developing policy. Thinking high growth firms lead to a high growth economy involves a

composition fallacy and conflates net and gross job creation. Firms both create and destroy jobs, with high levels of job creation often correlated with high levels of job destruction, reflecting unproductive churn in the economy, rather than economic growth. While encouraging firm growth is a useful policy objective, and much more useful than encouraging entrepreneurial market entry (Nightingale and Coad, 2013), the results of this study suggest it requires a nuanced approach that takes account of the causal chains involved. The lack of feedback loops that would make growth self-sustaining, and the importance of firms developing complementary assets to capture value, suggest the focus on HGFs, which do not persistently grow, is unhelpful.

Conclusion

In conclusion, the contribution of highly innovative firms to the economy is not simple. Innovation contributes to economic growth through a long run process, and is based on a persistent investment in innovative capabilities. Firm growth on the other hand is a short run phenomenon in which firms move in and out of growth in an erratic way. While it is useful to recognise that both innovation and growth are highly skewed, it is also important to recognise this difference, as the small percentage of firms that generate the majority of growth in any particular period will not be the same firms later on.

Recognising these differences helps avoid a composition fallacy that conflates the growth of the economy with an economy with many high growth firms. The long lags between investment in innovation and its rewards and the difference between value creation and capture all complicate the connection between innovation and economic growth. As a result, the relationship is much like the relationship between the tide coming in (innovation-driven macro-economic growth) and boats bobbing up and down on waves (firm growth). That a small percentage of boats will be buoyed up higher than others is not a particularly informative metric, with the consequence that HGF status is not particularly useful for policy makers.

To create and capture innovative value, firms need to persistently invest in capabilities and complementary assets. The research has shown these are strongly linked to employment of STEM graduates who enable firms to link to external institutions and develop new products and services for international markets. Employment growth more generally starts the processes that drive growth, with investments in new employees preceding increased investment in innovation, the generation of sales from new products and services, and finally increases in overall turnover. Importantly, we do not find evidence for a feedback loop that would start this process again, which explains why growth is episodic, rather than persistent in the UK. Together these results suggest policy makers should recognise the importance of innovation, but also recognise that

the growth of the overall economy requires attention to how firms capture value, not just how they create it.

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