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Knowledge spillovers and high-impact growth: Comparing local and foreign firms in the UK

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Abstract This paper is concerned with entrepreneurial high-impact firms, which are firms that generate 'both' disproportionate levels of employment and sales growth, and have high levels of innovative activity. It investigates differences in the influence of knowledge spillovers on high-impact growth between foreign and local firms in the UK. The study is based on an analysis of data from UK Innovation Scoreboard on 865 firms, which were divided into 'high-impact firms' (defined as those achieving positive growth in both sales and employment) and low-impact firms (negative or no growth in sales or employment). More precisely, the paper investigates the influence of knowledge spillovers on high-impact growth of foreign and local firms, from regional, sectoral and firm size perspectives. The findings suggest that (1) firms' access to regional knowledge spillovers (from businesses and higher education institutions) is more significantly associated with high-impact growth of local firms in comparison to foreign firms; (2) because knowledge spillovers are more likely to occur in high-tech sectors (compared to low-tech sectors), firms in high-tech sectors are more associated with high-impact growth. Nonetheless, the relationship is stronger for local firms compared to foreign firms; (3) because small firms have greater need for knowledge spillovers (relative to large firms), there is a negative relationship between firm size and high-impact growth, but the negative relationship is greater for UK firms in comparison to foreign firms. Implications are drawn for policy and research.

Abstrait Ce document porte sur les sociétés entrepreneuriales à impact élevé, qui sont des sociétés qui génèrent des niveaux disproportionnés de croissance d'emploi 'aussi bien' que de ventes, et qui démontrent une haute performance innovante. Il examine les

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différences de l'influence de la diffusion de connaissances sur une croissance à impact élevé entre des sociétés étrangères et locales dans le Royaume-Uni (UK). L'étude se base sur une analyse de données du Tableau de bord de l'innovation du Royaume-Uni de 865 sociétés qui ont été divisées en 'sociétés à impact élevé' (définies comme celles réalisant une croissance positive des ventes et de l'emploi) et sociétés à impact réduit (taux de croissance des ventes et de l'emploi nul ou négatif). Plus précisément, ce document examine l'influence de la diffusion de connaissances sur la croissance élevée de sociétés étrangères et locales, d'un point de vue régional, sectoriel et en relation avec la taille des sociétés. La conclusion suggère que: 1) l'accès des sociétés à la diffusion régionale de connaissances (provenant d'institutions commerciales et d'enseignement supérieur) est. fortement lié à une croissance élevée de sociétés locales par rapport aux sociétés étrangères ; 2) car la diffusion de connaissances survient plus fréquemment dans les secteurs de haute technologie (par rapport aux secteurs de basse technologie), les sociétés appartenant à des secteurs de haute technologie sont davantage liées à une croissance élevée. Néanmoins, la relation est. plus forte chez les sociétés locales par rapport aux sociétés étrangères; 3) car les petites entreprises ont un plus grand besoin de diffusion de connaissance (par rapport aux grandes entreprises), il existe une relation négative entre la taille de l'entreprise et la croissance élevée chez les sociétés du Royaume-Uni par rapport aux sociétés étrangères. Les conséquences pour la politique et la recherche sont tirées.

Keywords Entrepreneurship · High-growth · Local firms · Foreign firms · Small firms · Large firms

Mots clés Esprit d'entreprise · croissance élevée · sociétés locales · sociétés étrangères · petites entreprises · grandes entreprises

Summary Highlights

Contributions: This is likely the first to investigate the differences in the influence of knowledge spillovers on high-impact growth of foreign versus local firms in the UK.

Purpose: The aim of this study is to investigate differences in the influence of knowledge spillovers on high-impact growth between foreign and local firms in the UK.

Basic methods and information/data: The study is based on an analysis of data from UK Innovation Scoreboard on 865 firms, which were divided into 'high-impact firms' (positive growth in both sales and employment) and low-impact firms (negative or no growth in sales or employment).

Findings: One, firms' access to regional knowledge spillovers is more significantly associated with high-impact growth of local firms in comparison to foreign firms. Two, because knowledge spillovers are more likely to occur in high-tech sectors (compared to low-tech sectors), firms in high-tech sectors are more associated with high-impact growth, although the relationship is stronger for local firms compared to foreign firms. Three, because small firms have greater need for knowledge spillovers (relative to large

firms), there is a negative relationship between firm size and high-impact growth, but the negative relationship is greater for UK firms in comparison to foreign firms.

Limitations (if there is any): The study is limited to firms with significant R&D activities.

Theoretical implications and recommendations: The major theoretical implication is that the high-impact growth of local firms in a region is more influenced by knowledge spillovers compared to foreign firms in the same region.

Policy implications: Since foreign firms benefit less from regional knowledge spillovers compared to local firms, initiatives that can help foreign firms integrate more and utilise the local resources more effectively may help the performance of foreign firms. Secondly, policy makers need to understand that foreign firms are less dependent on being in high-tech sectors for their high-impact growth. Thirdly, for foreign firms, high-impact growth is less dependent on being small sized.

Future research: Future studies could consider other high-growth performance measures, such as profitability.

Introduction

Interest in firm growth theory now spans about 30 years. The initial excitement centred on the work of Birch, where job providers were seen to be the smaller, younger firms (Birch 1979, 1987). Once firms grow older, their ability to generate new jobs decline substantially. Birch's work has influenced a whole generation of researchers and generated significant contributions to knowledge, making an impact on both research and public policy promoting small and medium enterprises (SMEs) in many countries (Storey 1994; Lu and Beamish 2006; Mitra et al. 2007; Acs et al. 2008; Acs 2013; Mazzucato and Paris 2014; Lee 2014). In the UK from 1987 to 1988 alone, public expenditure on promoting enterprise was almost £200 million, supporting more than 106,000 unemployed people to start new businesses (Storey 1994). Further, in 2004, the UK government launched the 'encouraging a dynamic start-up market' one of the key pillars of small business policy reflecting the interest on small firms and growth (Stel and Storey 2004).

A number of scholars of firm growth argue that most job creation by small firm occurs within a relatively small number of firms—called gazelles (Birch and Madoff 1994; Acs et al. 2008; Acs 2013). In this setting, gazelles are firms that 'move between small and large (size) quickly…(characterised by) great innovation and rapid job growth' (Birch and Madoff 1994: p.163). Acs et al. (2008) extended the work of Birch beyond firms with mainly employment growth, by adding the revenue growth variable to that of expanding employment. Firms showing both revenue and employment growths were referred to as 'high-impact firms' in order to distinguish them from gazelles, especially because they were founder to be rather old compared to gazelles, which are new (Acs et al. 2008). The major conclusion of the work by Acs et al. (2008) is that high-impact firms are relatively old, rare and contribute to the majority of overall economic growth. This perspective on high-impact firms (Acs et al. 2008; Acs 2013; Virtanen and Heimonen 2013) is particularly important at a time of global economic

crisis. However, a critical review of the literature (see below) reveals that there is hardly any study investigating a combination of region, sector and firm size related factors influencing high-impact growth, and especially between local and foreign firms. Such information about these factors could help with the formation of empirically informed policies for promoting high-impact growth of firms that take into account the distinguishing features of indigenous local firms and foreign firms (Nachum and Keeble 2003; Osabutey et al. 2014). Policies on the growth of local and foreign firms can therefore be supported on the basis of empirical evidence. Firm managers may also benefit from a more clear understanding of the region-, sector- and firm-specific factors that could hinder or promote high-impact growth of firms. Managers of such firms can, therefore, design more effective strategies for high-impact growth.

The central research problem addressed by this paper is that of investigating the influence of knowledge spillovers on high-impact growth of local and foreign firms in the UK, from regional, sectoral and firm size perspectives. The paper claims several contributions to knowledge. First, the capacity of firms' to access regional knowledge spillovers (from businesses and higher education institutions) in a region appears to be more associated with high-impact growth for UK firms in comparison to foreign firms. Secondly, the association between being in high-tech sector and high-impact growth was also found to be stronger for UK firms in comparison to foreign firms. Thirdly, although the a negative association was found between high-impact growth and firm size for both local firms and foreign firms in the UK (meaning that small firms grow faster than large firms), this relationship is slightly stronger for local firms, which implies that high-impact growth of foreign firms in the UK is less dependent on firm size.

Taken together, these contributions augment the literature on gazelles and high-impact firms (Birch 1979, 1987; Gallagher et al. 1990; Daly et al. 1991; Birch and Madoff 1994; Acs et al. 2008; Acs 2013; Virtanen and Heimonen 2013) regional knowledge spillovers and firm growth (Audretsch and Lehmann 2005a, b; Audretsch and Dohse 2007; Raspe and Van Oort 2008) and firm ownership—local and foreign firms (Buckley and Casson 1976; Caves 1996; Nachum and Keeble 2003; Osabutey et al. 2014).

The paper begins with a review of the literature on gazelles and high-impact firms. This is then followed by a presentation of theoretical arguments on differences in regional factors, sectoral factors and firm size related factors influencing the high-impact growth of local and foreign owned firms in the same country.

The evolution of the high-impact firm theory

In the 1970s and 1990s, firm growth theories on job creation consisted mainly of the work of the prominent economist, David Birch (Birch 1979, 1987), which argues that small firm growth makes disproportionate contribution to the economy. Various other researchers confirmed one of Birch's key conclusions, namely that small firms account for most new job creation in an economy (Birch 1979, 1987; Gallagher et al. 1990; Daly et al. 1991). In Birch's seminal work, titled *The Job Generation Process (*1979*)*, he developed an 'economic micro-scope' (Landström 1996) that went beyond aggregate employment statistics so as to explain how the behaviour of individual firms leads to employment changes. Employing Dun and Bradstreet database in the USA, Birch initiated the systematic study of small businesses. Prior to his research, only a few

economists had studied small businesses in spite of their contribution to a large fraction of employment (Brock and Evans 1989). Accordingly, Birch found that

- In the USA, about 60% of all jobs were created by firms employing fewer than 20 people, and almost 50% of the jobs were generated by small independent entrepreneurs. In contrast, large firms had less than 15% of all net new jobs.
- It was not all the small firms that were job generators. Rather, it was the smaller, younger firms that created jobs, and job generation abilities of firms declined once they were up to 4 years old.

Birch concluded that 'whatever they are doing, however, large firms are no longer the major providers of new jobs for Americans' (Birch 1981, p.8). These seminal contributions have since then triggered a large canon of research, public policy measures and debate on the role played by small firms in employment creation (Gallagher et al. 1990; Daly et al. 1991; Acs et al. 2008). Researchers in other countries have long replicated Birch's findings, with results of the UK (based on Dun and Bradstreet), indicating that small firms make a disproportionately large contribution to net job creation, although the contribution is not as high as estimated by Birch (Gallagher et al. 1990; Daly et al. 1991). Birch's initial idea of small firms as job creators has now evolved into a burgeoning literature on firm growth, such as 'gazelles', i.e. new, rapidly growing firms in terms of employment or revenue growth (Birch and Madoff 1994; Acs and Mueller 2008), and high-impact firms, which are older but fast growing firms in terms of both employment and revenue (Acs et al. 2008).

Gazelles

Birch's work has also been subject to some criticism especially from Brown et al. (1990). In a book titled *Employers Large and Small*, they argued that 'Perhaps the most widespread misconception about small businesses in the United States is that they generate the vast majority of jobs and are therefore the key to economic growth. … Small employers do not create a particularly impressive share of jobs in the economy, especially when we focus on jobs that are not short lived' (Brown et al. 1990: p.1–2).

Subsequently, in early 1990s, attempts at finding common ground between David Birch and James Madoff were made culminating in the emergence of another conceptual category of firms called 'gazelle'. Gazelles were defined as firms with significant revenue growth (Birch and Madoff 1994; Nylund et al. 2014; Senderovitz et al. 2015). It was argued that the difference between the role of small and large firms in creating jobs is of less significance. The firms that create most jobs are gazelles, which are not necessarily small or large. 'These gazelles move between small and large quickly—at various times in either direction—and to classify them by their size is to miss their unique characteristics of great innovation and rapid job growth' (Birch and Madoff 1994: p.163). Since then, this perspective on gazelle has attracted attention from prominent entrepreneurship scholars (Parker et al. 2005; Acs and Mueller 2008; Mazzucato and Paris 2014; Lee 2014; Nylund et al. 2014; Senderovitz et al. 2015). In 2005, Parker et al. (2005) take the study on gazelles further by developing a theory of dynamic management strategies of gazelles. Based on a dataset from Britain containing information on over 100 gazelles, they advance a framework that

emphasises dynamic, rather than static, management strategies as key to the growth of gazelles (Parker et al. 2005). Mazzucato and Paris (2014) explore conditions under which high-growth firms matter for translating R&D investments into economic growth and how this depends on firm-specific and industry-specific factors. They find that the R&D–firm growth relationship is sensitive to the changing competitive environment over the industry's history. Lee (2014) investigates the obstacles perceived by potential high-growth firms by comparing two sets of firms: (1) firms in periods of high growth and (2) potential high-growth firms, which are similar but not achieving high growth. The findings suggest that potential high-growth firms tend to feel held back by the economy, cash flow, their management skills and obtaining finance. Another recent paper by paper by Acs and Mueller (2008) found that business start-ups with less than 500 employees have persistent employment effects over time and across large, diversified metropolitan regions. Therefore, Acs and Mueller (2008) conclude that gazelles and characteristics of the region are important for employment growth. Another important point is that gazelles account for almost all the job creation in the economy (Birch and Madoff 1994; Acs and Mueller 2008).

From gazelles to high-impact firms

Zoltan Acs, William Parsons and Spencer Tracey in their work titled *The High-impact Firm: Gazelles Revisited (2008)* extended the scope of Birch and Madoff's (1994) findings. They argue that although Birch's research is important, very little is known about what high-impact firms, before they become high-impact firms. To distinguish their research from that of Birch, they went beyond Birch's definition of gazelles to include firms with significant revenue growth *and* expanding employment, referring to such firms as 'high-impact firms' (Acs et al. 2008). Based on a critical analysis of dataset drawn from the American Corporate Statistical Library (ACSL), which covers data from both public and private sector sources over a 12-year period, they found that 'High-impact firms are relatively old, rare and contribute to the majority of overall economic growth. On average, they are 25 years old, they represent between 2 and 3 percent of all firms, and they account for almost all of the private sector employment and revenue growth in the economy' (Acs et al. 2008). Acs et al. (2008) conclusions support Birch's observation that high-growth firms account for almost all the job creation in the economy, although their measures were not entirely comparable. They also found comparable findings with regard to firm size, but not firm age. High-impact firm are not new firms, and they are found in all firm-size classes. High-impact firms are rare and contribute to the majority of overall economic growth (Birch and Madoff 1994; Acs et al. 2008).

Research issues

However, it is argued here that the research on the subject still remains unsatisfactory at least for three key reasons. First, existing theories on gazelles and high-impact firms are important in helping us to understand which firms create jobs, and how they impact on the economy (Birch and Madoff 1994; Acs et al. 2008; Acs 2013; Virtanen and Heimonen 2013). But these theories do not take into consideration the importance of region-specific factors' affecting high-impact growth of indigenous and foreign firms.

By region-specific factors, reference is being made to knowledge spillovers related to local business R&D (Acs 2002; Knudsen et al. 2007). This is of crucial importance especially in a time when economic policies are developed at the regional level (European Commission 2007). Such information will allow regional policy makers to understand the different roles local resources play in the growth of local and foreign firms, thereby helping to design more informed policies specifically for local and foreign firms. Secondly, it is not clear whether *sector-specific factors* have any differences in their impact on the growth of local and foreign firms. These factors often refer to the extent to which high-tech and low-tech sectors rely on research and development (Butchart 1987; Doloreux 2004; CCC 2004). At a time when many regional policies prioritise high-tech over low-tech sectors, it is important to understand whether such prioritisation should also apply to both local and foreign firms. Thirdly, there appears to be a lack of understanding of the differences in the influence of varying *firm-specific factors* (firm size) for the high-impact growth of local and foreign firms in the UK. Such information could help both policy makers and managers of local and foreign firms in the UK to understand whether the smaller- or larger-sized firms are more associated with high-impact growth. Hence, in spite of large and growing literature on high-growth firms (see Table 1), which has examined their effect on job creation (Birch 1979, 1989; Daly et al. 1991; Birch and Madoff 1994; Acs et al. 2008; Acs 2013), characteristics of their executives and founding teams (Shuman et al. 1985; Feeser and Willard 1990; Willard et al. 1992; Sims and O'Regan 2006), their likelihood of being spin-offs and small sized (Feeser and Willard 1989; Keen and Etemad 2012), their regional dimension (Acs and Mueller 2008; Sena et al. 2013), characteristics of high-growth firms in Africa (Goedhuys and Sleuwaegen 2009), there is hardly any study that compares differences between local and foreign firms in the same country, in terms of region-specific, sector-specific and firm-specific factors influencing their high-impact growth.

Consequently, we argue that differences in factors influencing high-impact growth between local and foreign owned firms in the same country remain by and large obscure (see Table 1). Identification of these differences provides the basis for generating new hypotheses related to the research problem and the development of a conceptual framework.

Knowledge spillover theory

Over a hundred years after Alfred Marshall's (1890, 1920) initial conceptualization of knowledge spillovers, there is still interest in the study of knowledge spillovers (Jaffe 1989; Acs 2002). In Marshal's (1920) groundbreaking work titled the *Principles of Economics*, he argued for the role of knowledge spillovers as one of the explanations for agglomeration economies. Marshall's (1961) argument suggests that concentration of firms within a region in close proximity facilitates knowledge spillovers between firms and therefore growth of that industry in the region. Marshall's theory is interpreted to relate to knowledge spillovers, particularly because of one of his well-known statement: 'the mysteries of the trade become no mysteries, but are as it were in the air.' (Marshall 1920: p.225). Marshall's approach suggests that spillovers tend to work better within industries (Loesch 1954). Decades later, Arrow (1962) recognized

Table 1 Studies related to high-impact firms and their weaknesses in relation to the research problem

Author	Key finding	Gap
Birch (1979)	Small firms make disproportionate contribution to job generation in the USA.	[a]
Birch (1989)	Small firms make disproportionate contribution to job generation in the USA.	[a]
Shuman, Shaw and Sussman (1985)	Most executives of high-growth firms tend to have prior experience in starting three or more ventures.	[a]
Feeser and Willard, (1989)	High-growth firms are more mostly spinoffs of large corporations and tend to compete in technologies and markets closely related to those of their parent firms.	[a]
Feeser and Willard (1990)	Compared to other firms, high-growth firms are more likely to (1) have larger size of founding team, (2) maintain their initial product/focus and (3) be export oriented.	[a]
Gallagher et al. (1990)	Consistent pattern of small firms as net generators of jobs and large firms as net losers in the UK.	[a]
Brownet al. (1990)	Small employers do not create a particularly impressive share of jobs in the economy, especially when we focus on jobs that are not short lived.	[a]
Daly et al. (1991)	In the UK, in job generation terms, although small firms are advantaged and have numerically dominant performance, it is important that large firm performance should not as a result be overlooked.	[a]
Willard, Krueger, and Feeser (1992)	Founder and non-founder managed high-growth firms have no difference for a number of performance measures (i.e. sales, firm sales growth, net income, return on sales, return on equity, or sales per employee).	[a]
Birch and Madoff (1994)	Gazelles account for almost all the job creation in the economy.	[a]
Gundry and Welsch (2001)	High-growth firms tend to (1) have emphasis on technological change and market growth, (2) show willingness to make sacrifices on behalf of the business, (3) have plans for business growth and (4) use organizational designs that are team-based .	[a]
Parker, Storey and Witteloostuijn (2005)	Conclude that dynamic, rather than static, management strategies are keys to high growth.	[a]
Chan, Bhargava and Street (2006)	High-growth firms irrespective of size tend to have identical frequency of challenges related to 'managing business growth', 'leadership', 'financial management', 'customer management' and 'human resource management'.	[a]
Sims and O'Regan (2006)	High-growth firms tend to be managed by CEOs that are under 40 years old.	[a]
Acs and Mueller (2008)	Gazelles and characteristics of the region are important for employment growth.	[a]
Acs et al. (2008)	High-impact firms are relatively old, rare and contribute to the majority of overall economic growth.	[a]
Goedhuya and Sleuwaegen (2009)	Firms that engage in product innovation, have their own transport means and are connected to the internet through their own website are especially characterized by higher growth rates.	[a]
Keen, and Etemad (2012)	High growth are primarily small- and medium-sized enterprises.	[a]
Sena, Hart and Bonner (2013)	Results suggest the importance of spillovers generated by nearby firms for high-growth firms.	[a]

[a] Hardly compare differences between local and foreign firms in terms of region-specific, sector-specific and firm-specific factors influencing their high-impact growth

spillovers associated with knowledge due to its being non-exclusive and non-rival. However, it was in the 1980s that the distinguished work of Paul Romer (Romer 1986) on endogenous technological change that not only provided a revolutionary analysis of technological change but also developed an influential approach to the study of 'knowledge spillovers'. This perspective on technological change and innovation in economic theory further developed by the works on endogenous growth theory of the second wave (Romer 1990; Grossman and Helpman 1991) starting with Romer (1990), with his novel formulation of technological knowledge as non-rival and partially excludable. These works put the accumulation of knowledge and its 'spillover' into productive capacity through technological change as a central theme in the new theory of endogenous economic growth.

In the field of economics, goods can be considered to have two fundamental attributes: the degree to which they are rivalrous and the degree to which they are excludable (Cornes and Sandler 1986). Goods that can be considered as purely rival are those whose use by one firm or person impedes their use by another. In contrast, a purely non-rival good has the characteristic that its use by one firm does not limit its use by another (Romer 1990). As for excludability, then this is a function of technology and the legal system. For instance, a code of a computer program can be made excludable by using legal system that disallows copying (Romer 1990). Therefore, traditional economic goods can be considered as both rivalrous and excludable, because their owners can stop others from using them. However, the remarkable case for technological knowledge as Romer argues is its property of being 'non rival' and only 'partially excludable'. This proposition as Romer (1990) argues is based on two principles: (1) technology is considered a non-rival input; (2) technological change happens because of profit-motivated investments in knowledge creation by private economic agents. The first point suggests that technology bestows benefits that are only partially excludable, which cannot be completely appropriated. The second point suggests that the exploitation of scientific ideas commercially almost always necessitates considerable 'investment of resources' as concluded by a large number of research works on industries and innovation, such as aircraft (Constant 1980), semiconductors (Dosi 1984) and metallurgy (Mowery and Rosenberg 1989). This Marshall-Arrow-Romer (MAR) spillover tends to occur more in an industry.

Nevertheless, notwithstanding the development in identifying technological spillovers by theorists of endogenous (Romer 1990; Grossman and Helpman 1991), it is however characterized by certain weaknesses. These are as follows:

1. The theory assumes that to create new technological knowledge, the total stock of knowledge in an economy is accessible to everyone in involved in research freely. This assumption has not been confirmed by the literature on regional knowledge spillovers (Acs 2002; Acs and Varga 2004), because new technological knowledge is often in such a 'tacit' form that its availability is constrained by geographic proximity and extent of interaction among the innovation actors (Edquist 1997).
2. Knowledge generating inputs are not uniformly dispersed across space. For example, empirical research by Jaffe (1989), Acs (2002) and Acs and Mueller (2008) indicate that knowledge production by businesses and universities is not evenly distributed across space and have implications on innovation and firm growth.

As such, Acs (2002) argues that the non-excludable part of the stock of the knowledge in an economy can be considered to have two parts: a portion that is

accessible perfectly, which consists of established knowledge elements (that can be accessed through scientific publications, patent applications, etc.) and a tacit component, which is accessed through actors in an innovation system. Therefore, even though geographic proximity is not of much concern in transmitting established knowledge components (explicit knowledge), the transmission of the tacit component, which often needs social interaction, becomes an important source of regional advantage for regions that have high research activities, since a significant portion of the knowledge remains largely 'regional'. Thus, a number of researchers argue about the localized nature of knowledge spillovers, which is often referred to as the knowledge spillover theory.

According to Maskell and Malmberg (1999), the development of the notion of knowledge spillovers and geography can be found in works of Pred (1966) on information in urbanization economies; the work of Hägerstrand (1967) on innovation diffusion as a spatial process and Utterback (1974) on innovation in industry and technology diffusion. Therefore, scientific investigation related to the confluence of knowledge spillovers and geography has a long history and has now manifested itself in the more recent theories of localised knowledge spillovers (Jaffe 1989; Feldman and Florida 1994; Acs 2002; Audretsch and Dohse 2007).

The regional knowledge spillover theory highlights the significance of regional linkages for a firm's generation of knowledge from external sources (Jaffe 1989; Acs 2002; Stuart and Sorenson 2003). Regional knowledge spillovers are defined as 'knowledge externalities bounded in space', which allow firms operating in proximity to key knowledge sources to introduce innovations at a faster rate than rival firms located elsewhere (Breschi and Lissoni 2001). Knowledge takes the form of university spillovers and regional business R&D (Acs 2002; Stuart and Sorenson 2003; Knudsen et al. 2007). According to Breschi and Lissoni (2001), localised knowledge spillovers can be broken down into three logical chains (Breschi and Lissoni, p.258):

(a) Knowledge generated within innovative firms and/or universities is somehow transmitted to other firms;
(b) Knowledge that spills over is a public good, i.e. available to those wishing to invest for searching it out, and may be exploited by more than a few users at the same time;
(c) Despite (b), knowledge that spills over is mainly 'tacit', i.e. highly contextual and difficult to codify, and therefore is more easily transmitted through face-to-face contacts and personal relationships, which require spatial proximity; in other words, it is a public good, but a local one.

Thus, the rational connection between the geography and knowledge spillovers in the theory of regional knowledge spillovers is the argument that the transmission of knowledge is greatly supported by face-to-face contacts (Maskell and Malmberg 1999). Therefore, knowledge is regarded as a local public good, which is more likely to be shared by co-located agents, relative to distant ones (Acs 2002). Regional knowledge spillovers are thus theorized as 'free knowledge flows' (Breschi and Lissoni 2001) that are diffused through a variety of means through which the 'original' producer of the knowledge is not fully compensated by users of the knowledge. Since knowledge spillovers are often tacit in nature, the spillover of new economic knowledge is consequently regarded as being inhibited by geography, because tacit knowledge tends

to be transferred more easily through face-to-face interaction. Therefore, knowledge spillovers are more favoured by proximity of economic agents geographically and constrained by distance (Audretsch 1998). Therefore, in order to address the research problem, in the following section, we develop a conceptual framework on the extent to which knowledge spillovers matter for high-impact growth of foreign and local firms, from regional, sectoral and firm size perspectives.

Knowledge spillovers and high-impact growth: A conceptual framework and hypotheses

To develop the conceptual framework of the research, we draw on the following literature; regional knowledge spillovers and firm growth (Audretsch and Lehmann 2005a and b; Audretsch and Dohse 2007; Raspe and Van Oort 2008), and high-impact firms (Acs and Mueller 2008; Acs et al. 2008). These literatures put together give us the theoretical basis for proposing differences/similarities in the influence of knowledge spillovers on high-impact

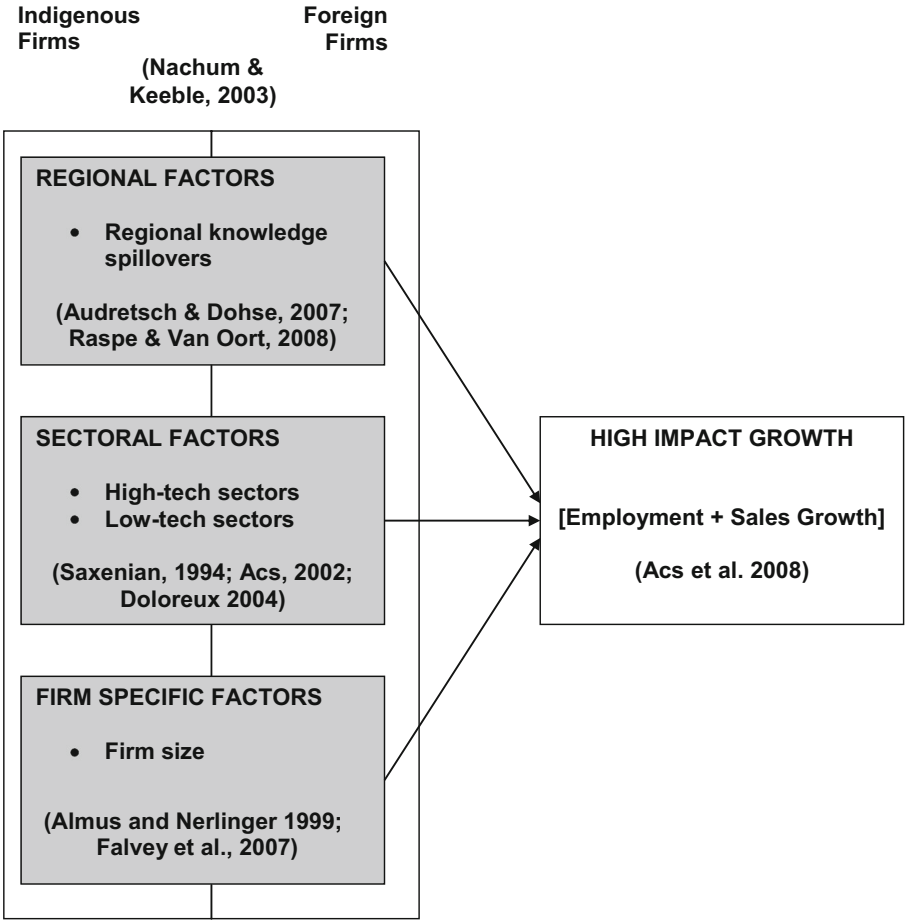


Fig. 1 Framework for comparing factors influencing high-impact growth of indigenous and foreign firms

growth of local and foreign, from a regional, sectoral and firm. Figure 1 presents our conceptual framework. The region-specific factors are local human capital, business R&D and university R&D (Jaffe 1989; Acs 2002; Stuart and Sorenson 2003; Knudsen et al. 2007). The sector-specific factors relate to the nature of technology developed by firms—high-tech and low-tech sectors (Doloreux 2004). Finally, the firm-specific factor is firm size (Birch 1979, 1989; Evans 1987a, b; Hall 1987; Almus and Nerlinger 1999).

This model integrates high-impact firm literature (Acs et al. 2008), regional knowledge spillovers and firm growth theory (Audretsch and Dohse 2007; Raspe and Van Oort 2008) and international business theory on firm ownership (Nachum and Keeble 2003; Osabutey et al. 2014). The aim is thus to empirically examine the effect of various factors on high-impact growth of local and foreign firms. What follows is a discussion of each component of the model so as to develop specific hypotheses on differences on the effect of the three factors on the growth of local and foreign firms located in the same country.

Firms' absorptive capacity and regional knowledge spillovers

Although knowledge spillovers are important for innovation, another stream of research stresses the importance of firm level R&D in enhancing firms' capacity to absorb and utilize knowledge generated elsewhere (Cohen and Levinthal 1989, Griffith et al. 2004). This literature suggests the existence of a complementary relationship between firm's own R&D and the firm's capacity to access knowledge spillovers (Guellec and van Pottelsberghe de La Potterie 2004). By investing in R&D, a firm can improve its awareness and understanding of useful external knowledge available for adoption, thus increasing its absorptive capacity (Cohen and Levinthal 1989).

Hence, firms bestowed with greater levels of absorptive capacity tend to be more aware of the presence of knowledge spillovers (Escribano et al. 2009). For example, a firm, whose R&D employees have not engaged in scientific research, is more likely to ignore the presence of scientific research available from local universities and local businesses, even where a large amount of public knowledge could be acquired. Likewise, a company vigorously researching the possibility of developing a new product is more likely to understand the knowledge available in local universities and the products developed by its local rivals. Therefore, firms with greater absorptive capacity (R&D) will be more capable of efficiently accessing and utilizing the external knowledge flows available to them in their regions, by integrating them more efficiently with internally generated flows, for developing new innovations.

This hypothesis that the effect of knowledge spillovers depends on a firm's own internal R&D effort has already been investigated (Griffith et al. 2004, Vandenbussche et al. 2006). For example, a recent effort by Abreu et al. (2008) tried to link firm's own R&D with innovation performance at the regional level. They used British firm-level datasets in order to measure the importance of firms' absorptive capacity in influencing regional innovation performance. Specifically, they find that a larger share of R&D employees is positively related with greater regional innovation performance. Similarly, Escribano et al. (2005) draw on a sample of over 2200 innovative Spanish firms to examine the relationship between firms' absorptive capacity and their ability to benefit from knowledge spillovers. Their findings suggest that firms with higher levels of absorptive capacity are likely to enjoy knowledge spillovers by more efficiently turning them into innovative outcomes.

However, the scope of the above studies is not the same as ours, as they do not examine the extent to which firms' access to regional knowledge spillovers is associated with the

high-impact growth performance of local and foreign firms. Therefore, this paper focuses on firms' capacity to access knowledge spillovers in a region and its effect on high-impact growth of local and foreign firms in the same country.

Regional spillovers and high-impact growth of foreign and local firms

The knowledge spillover literature argues that firms in regions with greater levels of knowledge spillovers particularly from local businesses and higher education institutions (HEIs) have greater rates of firm growth (Audretsch and Lehmann 2005a, b; Audretsch and Dohse 2007; Raspe and Van Oort 2008). The reason why knowledge spillovers influence growth is because knowledge spillovers are associated with innovation (Jaffe 1989; Acs 2002). The influence of innovations on firm growth is through the creation of new demand and the taking over of market shares at the disadvantage of other firms (Niefert 2005). Consequently, because knowledge spillovers are associated with innovation (Jaffe 1989; Acs 2002) and innovation matters for firm growth (Niefert 2005), there is a rapidly growing literature on the effect of regional knowledge spillovers on firm growth (Audretsch and Lehmann 2005a, b; Audretsch and Dohse 2007; Raspe and Van Oort 2008; Chyi et al. 2012). The findings of many empirical studies on regional knowledge spillovers and firm growth suggest that firm growth, whether measured in terms of employment growth or sales growth is positively affected by knowledge spillovers (Audretsch and Lehmann 2005a, b; Audretsch and Dohse 2007; Raspe and Van Oort 2008; O'Mahony and Vecchi 2009; Chyi et al. 2012).

Considering that both local and foreign firms are attracted to regions with key knowledge inputs in order to gain access to its specialised knowledge resources (Dunning 1993; Nachum and Keeble 2003; Osabutey et al. 2014), one can argue that knowledge spillovers are likely to influence their high-impact growth performance. Foreign firms are therefore also attracted to regions with knowledge resources, as some of their needs can be met locally (Nachum and Keeble 2003). This is because international business theory suggests that gaining access to immobile resources (such as technologies) available in foreign countries is an important rationale for firms to invest outside their home country (Dunning 1993; Wesson 1997; Kuemmerle 1998).

Nevertheless, even though foreign firms are also likely to be positively influenced by regional knowledge spillovers, we still expect the association between regional knowledge spillovers and high-impact growth to be greater for local firms because of at least three reasons. First, previous empirical studies (not focussed on high-impact growth) suggest that local firms have greater connections to regional sources of knowledge spillovers such as local businesses and universities, due to their closer social connections to the business and academic communities (e.g. see Stuart and Sorenson 2003). Secondly, past research found that the resource base of local firms (e.g. finance, expertise, equipment, etc.) can constrain collaborative options with foreign firms because of dissimilar technologies/technological distance (Osabutey et al. 2014). Thirdly, empirical studies have shown that foreign firms are less dependent on resources located in a host country region (Caves 1996; Nachum and Keeble 2003; Osabutey et al. 2014) because their shortcomings are often complemented by their access to resources from their parent companies (Nachum and Keeble 2003). Foreign firms tend to have intangible assets such as technologies that local firms do not have (Caves 1996), and therefore have less need for interacting with firms in host regions for acquiring technology. Fourthly, foreign firms have greater cost disadvantages arising from

unfamiliarity with the local environment (Buckley and Casson 1976; Caves 1996; Nachum and Keeble 2003; Guler and Guillen 2010) which suggests that local (indigenous) firms will benefit more from regional knowledge spillovers due to more established social connections (Stuart and Sorenson 2003). These observations lead to the hypothesis that regional knowledge resources are critical for high-impact growth, especially for local firms.

Similarity:

> **H1a:** High-impact firms will be associated with greater access to regional knowledge spillovers compared to low-impact firms for both local and foreign firms located in the same country.

Difference:

> **H1b:** However, local high-impact firms will be more associated with access to regional knowledge spillovers than foreign high-impact firms located in the same country.

Sectoral spillovers and high-impact growth of foreign and local firms

The MAR externalities discussed earlier concerns knowledge spillovers in an industry. A good example is the high-tech industry in Silicon Valley. Through firms' spying, imitating and fast movement of labour between firms and between firms and universities, ideas are quickly shared within the high-tech industry. However, the level of knowledge in a sector tends to depend on the sector's R&D investment and on other similar technological sectors (Bottazzi and Peri 1999). Hence, since high-tech industrial sectors have higher R&D investments in comparison to low-tech sectors (Butchart 1987; OECD 2011), knowledge spillovers are more likely to occur in high-tech sectors (Acs 2002). Thus, Doloreux (2003) argues that firms in low-tech sectors have less need for knowledge spillovers (Doloreux 2003) since they have develop less complex technologies, while firms in high-tech to medium-tech sectors have higher need for knowledge spillovers (Jaffe 1989; Acs 2002; Stuart and Sorenson 2003; European Commission 2012) since they have to develop more complex technologies. This implies that low-tech sectors have less need for regional knowledge spillovers compared to high-tech and medium-tech sectors. Thus, a report on *high-tech SMEs in Europe* (European Commission 2002: p.21) contrasting the contribution of high-tech and medium-tech sectors with low-tech sectors, observes that

> In general, high-tech industries perform better than low-tech industries with respect to various variables (output, employment, productivity, etc.). This seems to be a long-term stable phenomenon, even though the actual composition of high-tech industries changes over time. A statistical exercise utilizing an OECD[1] database and covering the manufacturing sectors of the OECD member countries found that high-and medium-tech industries performed distinctly better than low-tech industries in terms of employment and productivity growth over the period 1970 to 1991. A repetition of this approach covering 14 European countries, the USA, and Japan and referring to the

[1] Organization for Economic Cooperation and Development (OECD).

period from 1990 to 1997 revealed similar results, although the composition of high-tech industries had slightly changed.

Similarly, the report on *EU SMEs* in 2012[2] observes that

> …productivity growth is mainly observed in the high-tech and medium-tech manufacturing and knowledge-intensive service sectors (p.14) …and sectoral labour productivity levels are higher when the sector shows higher investment rates, higher export rates, and when the sector belongs to high-tech and medium high-tech manufacturing and knowledge-intensive services (p.63)…(and) the best performing countries have a relatively high proportion of SMEs in high-tech and medium high-tech manufacturing and knowledge-intensive services.

Extending the above studies (which do not compare local and foreign firms in terms of high-impact growth), we argue that in comparison to those in low-tech sectors, firms in high-tech and medium sectors are more likely to be associated with high-impact growth because of their knowledge and innovation advantages (Acs 2002; Stuart and Sorenson 2003; European Commission 2012), and this holds for both local and foreign firms.

However, due to the greater advantages in accessing regional knowledge resources that local firms have in comparison to foreign firms, we further argue that the positive relationship between firms' operation in high-tech sector and its probability of experiencing high-impact growth is likely to be greater for local firms. This is because greater access to regional knowledge spillovers is likely to push them into generating more innovations, which can have a positive influence on their growth. By way of contrast foreign have less need for external knowledge spillovers, since they are often a part of larger firms, which supply them with key resources (Nachum and Keeble 2003). Thus, it is proposed that

Similarity:

> **H2a:** High-impact firms are more likely to be in high-tech/medium-tech sectors compared to low-impact firms for both local and foreign firms.

Difference:

> **H2b:** However, local high-impact firms will exhibit greater tendency to be in high-tech/medium-tech sectors than foreign high-impact firms located in the same country.

Firm size, spillovers and high-impact growth of foreign and local firms

One key finding on firm growth literature is that of the negative relationship between the growth rate of firms and their size. This finding suggests that small firms, particularly SMEs grow faster than large firms (Evans 1987a, b; Hall 1987; Almus and Nerlinger 1999). This appears to support Birch's contention that small firms are important creators of jobs in an economy (Birch 1979, 1989). One reason for this is that small firms tend to have

[2] European Union.

innovation advantage due to their less bureaucratic structure (Rothwell 1989; Scherer 1991) ability to utilise regional knowledge spillovers (Audretsch and Lehmann 2005a, b; Audretsch and Dohse 2007). Thus, empirical works on knowledge spillovers suggests that small firms are more likely to rely on knowledge spillovers, especially because of their limited ability to invest resources in knowledge production (Audretsch and Vivarelli 1996). Therefore, this observation suggests that one should expect a positive influence of regional knowledge spillovers on business performance, especially small firms.

However, the picture becomes less clear when firms are divided into local and foreign firms located in the same country. It is argued here that smallness of size is less likely to be associated with high-impact growth of foreign firms. Small foreign-owned firms incur higher setting up and transaction costs in a host country compared to local firms due to the unfamiliarity with the local environment (Buckley and Casson 1976; Caves 1996; Kinoshita 1998; Nachum and Keeble 2003) and greater lack of local social connections (Stuart and Sorenson 2003). These disadvantages can however often be offset by their firm-specific advantages (Kinoshita 1998; Nachum and Keeble 2003; Osabutey et al. 2014). Foreign firms incur sunk costs at the initial stage; thus large firms are considered to have better access to capital in comparison to small firms to off-set such costs (Horst 1972; Kinoshita 1998). Many researchers have concluded that large foreign firms have more advantages investing abroad compared to small firms (Horst 1972; Lall 1986; Blomstrom and Lipsey 1991). Horst's (1972) seminal work on foreign direct investment (FDI) from USA to Canada suggests that size is the key explanatory attribute of the positive coefficient that explains investment. Firm size was also found to be significant for foreign investment in a study on Indian firms by Lall (1986). More recently, some researchers on Japanese firms have found that if destinations go beyond Asia, firm size plays a significant role in Japanese investments (Horaguchi 1992; Trevino and Daniels 1994). This discussion leads us to the third hypothesis:

Similarity:

> **H3a:** High-impact firms are more likely to be associated with small size than low-impact firms for both local and foreign firms.

Difference:

> **H3b:** However, local high-impact firms will have greater tendency to be small sized in comparison to foreign high-impact firms located in the same country.

The arguments are summarised in Table 2.

Data and methods

Data and geographic level of analysis

The key database used in this study is the 2009 UK R&D Scoreboard, which is an international league table of the companies investing mostly in R&D. UK R&D Scoreboard presents data on investment in R&D and financial performance of the most active UK-owned and foreign-owned firms operating in UK. With a focus on highly

Table 2 Summary of hypotheses and arguments

Hypotheses	Arguments
Similarity: ***H1a:*** *High-impact firms will be associated with greater access to regional knowledge spillovers compared to low-impact firms for both local and foreign firms located in the same country.* Difference: ***H1b:*** *However, local high-impact firms will be more associated with access to regional knowledge spillovers than foreign high-impact firms located in the same country.*	This is due to greater social connections that local firms have in their home region (Nachum and Keeble 2003; Stuart and Sorenson 2003); and because foreign firms tend to have intangible assets such as technologies that local firms do not have (Caves 1996), and consequently have less need for interacting with firms in host country regions for acquiring technologies and knowledge spillovers.
Similarity: ***H2a:*** *High-impact firms are more likely to be in high-tech/medium-tech sectors compared to Low-impact firms for both local and Foreign Firms.* Difference: ***H2b:*** *However, local high-impact firms will exhibit greater tendency to be in high-tech/medium-tech sectors than foreign high-impact firms located in the same country.*	This is because high-tech/medium-tech sectors have greater R&D (Butchart 1987; CCC 2004) and regional knowledge spillovers (Saxenian 1994; Acs 2002; Doloreux 2004; European Commission 2012) and are therefore more innovative (compared to low-tech sectors). However, because foreign firms have less need for R&D (Caves 1996) and regional knowledge spillovers (Nachum and Keeble 2003), they are therefore less likely to be associated with high-impact growth.
Similarity: ***H3a:*** *High-impact firms are more likely to be associated with small size than Low-impact firms for both local and Foreign Firms.* Difference: ***H3b:*** *However, local high-impact firms will have greater tendency to be small sized in comparison to foreign high-impact firms located in the same country.*	This is because small firms have less bureaucratic structure (Rothwell 1989; Scherer 1991) and are more active in utilizing regional knowledge spillovers (Audretech 1989; Acs 2002) compared to large firms. However, the relationship is however expected to be stronger for local firms, because foreign firms incur sunk costs at the initial stage; thus large foreign firms are considered to have better access to capital in comparison to small ones to off-set such costs (Horst 1972; Kinoshita 1998).

innovative firms, the R&D Scoreboard provides reasonably rich data for testing some of the theoretical hypotheses developed above. The Scoreboard data has a geographic aggregation level of European nomenclature of territorial units of statistics (NUTS) 1, making regional analysis of such data more appropriate for economic policy, especially because regional level is important for economic strategies in Europe (Lambert 2003; Adams and Smith 2004; European Commission 2007).

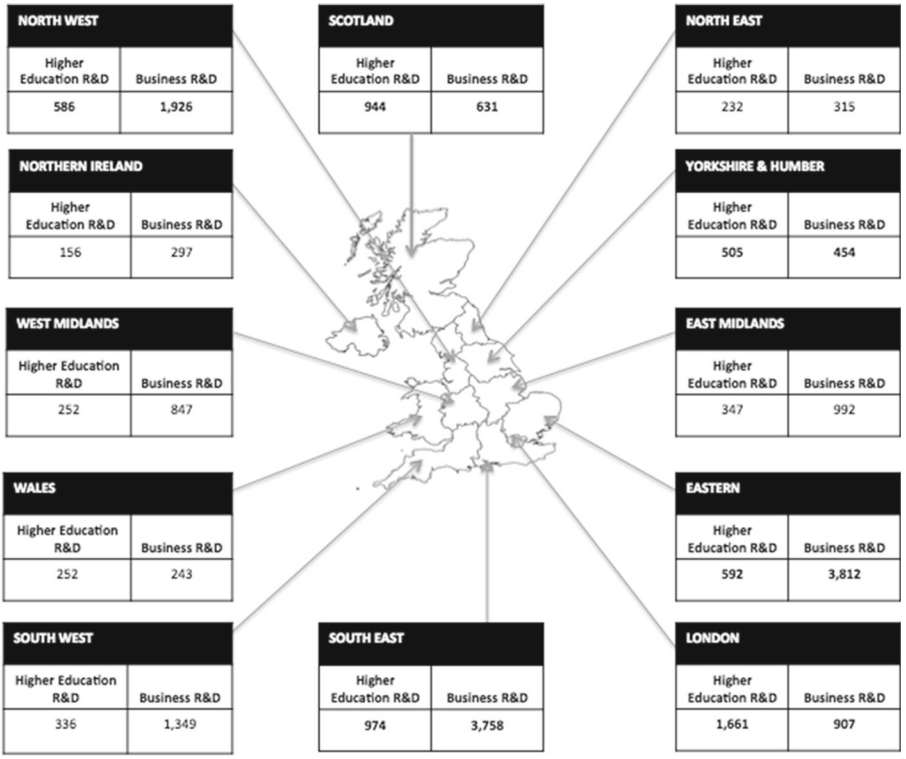
The data is analysed using cross tabs and bivariate statistical analysis based on chi-square, which are commonly employed in studying firm growth (e.g. see Shuman et al. 1985; Feeser and Willard 1989; Feeser and Willard 1990; Willard et al. 1992; Gundry and Welsch 2001; Chan et al. 2006; Sims and O'Regan 2006; Keen and Etemad 2012).

Variables and measurements

The R&D Scoreboard firms were thus sampled based on the following criteria: (1) firms must have 4-year employment growth data available; (2) firms with 4-year sales

growth data available; (3) located with UK NUTS 1 regions. This yielded a total of number of 865 firms. Below, definitions of variables and their sources are provided:

- *High-impact growth index*—the high-impact firm definition was operationalised as firms with both sales and employment growth over a 4-year period (Acs et al. 2008). Thus, this paper develops an index termed *high-impact growth index* (*HIGI*) which measures the extent to which a firm achieves both positive employment and sales growth over a 4-year period. The index has a Cronbach's alpha score of 0.7, which indicates reasonable level of reliability as used in other entrepreneurship studies (Manimala 1999; Abubakar 2013; Abubakar and Mitra 2013) Thus, in measuring high-impact growth, we only used sales and employment growth as this is commonly used in other studies, and not measures like firm profitability (Acs and Mueller 2008; Acs et al. 2008; Acs 2013). Our sample was selected from R&D Scoreboard firms, many of which take a very long time to profit due to heavy R&D and length of time needed for product development. So, employment and sales growth in the short term at least may not correlate with profitability (Markman and Gartner 2002). Therefore, especially for high-impact firms, which is often exceedingly strenuous, Markman and Gartner (2002) in a paper titled *Is Extraordinary Growth Profitable? A Study of Inc. 500 High-Growth Companies* found that employment and sales growth are not related to firm profitability.
- *Ownership*—the R&D Scoreboard data classifies firms as UK-owned (which stand for 'local' firms) and foreign firms, which stand for 'foreign-owned firms'. Thus, we use a dummy that takes the value of 1 if the firm is a UK local firm and 2 if the firm is a foreign firm.
- *High-impact firms and low-impact firms categorisation*—based on the HIGI, firms that achieved both sales and employment growth over the 4-year period were thus classified as high-impact firms (Acs et al. 2008), while those that could not achieve sales and employment growth over the 4-year period were classified as low-impact firms. Accordingly, out of a total of 498 UK (local) firms, a total of 235 high-impact firms were identified and 263 low-impact firms. Similarly, out of a total of 367 foreign firms in our sample, we identified a total of 75 high-impact firms and 292 low-impact firms.
- *Absorptive capacity*—we have argued earlier that in order for firms to take advantage of knowledge spillovers, firms need to invest in their own R&D (Cohen and Levinthal 1989; Griffith et al. 2004; Guellec and van Pottelsberghe de La Potterie 2004). Therefore, in line with the literature, such as Griffith et al. (2003, 2004) and Guellec and van Pottelsberghe de La Potterie (2004), we proxy the absorptive capacity of a firm with its R&D intensity, which is measured as R&D spending over total sales.
- *Access to regional knowledge spillovers (from businesses)*—knowledge spillovers from regional businesses were measured using 2009 data on regional R&D performed within businesses (BERD) at the regional level (Acs 2002; see Fig. 2 for the BERD data). The data was acquired from the Office for National Statistics (ONS 2009). However, the ONS (2009) on BERD refers to the region as a whole. Therefore, in order to estimate the stock of regional knowledge spillovers (from businesses) to which each firm has access to, for each firm, its absorptive capacity (R&D intensity) was multiplied by the amount of BERD in its region. The map in Fig. 2 shows variations BERD across UK regions. It ranges from £243 million



Data source: ONS (2009)

Fig. 2 R&D performed within regional higher education institutions (HERD) and businesses (BERD) (£ million)

(Wales) and £297 million (Northern Ireland) to £3812 million (East of England) and £3758 million (South East). This regional variation in business R&D implies regional variation in access to knowledge spillovers from businesses for firms, depending on their absorptive capacity to take advantage of the spillovers.

- *Access to regional knowledge spillovers (from HEIs)*—knowledge spillovers from regional HEIs such as universities were measured using the 2009 regional R&D data performed within higher education (HERD) (Jaffe 1989; Acs 2002; Abubakar and Mitra 2007; see Fig. 2 for the HERD data). Nonetheless, these data refers to the region as a whole. Thus, in order to estimate the stock of regional knowledge spillovers (from HEIs) a firm has access to, the firm's absorptive capacity (R&D intensity) was multiplied by the amount of HERD in its region. Figure 2 depicts the regional variations HERD across UK regions. It ranges from £156 million (Northern Ireland) and £232 million (Northern East) to £1661 million (London) and £974 million (South East). Again, this regional variation in R&D performed by HEIs suggests regional variation in access to knowledge spillovers from HEIs, depending on firms' absorptive capacity to utilise the spillovers.
- *Robustness check*—the use of two different measures of regional knowledge spillovers (from businesses and HEIs above) adds to the robustness, especially because they have yielded similar and consistent results.

Table 2 shows the descriptive statistics for UK-owned and foreign high-impact firms presents the descriptive statistics that show a comparison between local and foreign high-impact firms on a range of variables related to HIGI, sales growth, employment growth, regional knowledge spillovers, etc. It appears that UK high-impact firms have faster growth rates in comparison to foreign high-impact firms. As argued earlier, this could be because UK firms have greater access to regional knowledge spillovers. As the *t* tests in Table 2 suggest, UK high-impact firms have significantly higher access to regional knowledge spillovers (from businesses) ($p \leq 0.05$) and regional knowledge spillovers (from HEIs) ($p \leq 0.05$), which is likely because they have greater absorptive capacity ($p \leq 0.05$) than foreign high-impact firms, as argued earlier. Thus, in the next section, we will investigate the association between the probability of a firm being a high-impact firm and its access to regional knowledge spillovers for both local and foreign firms.

Findings and discussion

Regional knowledge spillovers and high-impact firms

In this section, we examine the hypotheses developed earlier on similarities and differences in the relationship between regional knowledge spillovers and high-impact growth of UK and foreign firms. In order to test *H1a* and *H1b*, a split on the entire sample was performed, in order to identify firms with high and lower access to regional knowledge spillovers.

Accordingly, to identify firms with higher and lower access to regional knowledge spillovers (from businesses), the sample was split into two. Firms with below the median values are considered to have 'lower access to regional knowledge spillovers (from businesses)' and firms with above the median value are considered to have 'higher access to regional knowledge spillovers (from businesses)'. Similarly, to identify firms with higher and lower access to regional knowledge spillovers (from HEIs), we split the sample into two. Firms with values of this variable below the median are considered to have 'lower access to regional knowledge spillovers (from HEIs)' and those with above the median value are considered to have 'higher access to regional knowledge spillovers (from HEIs)'. *H1a* and *H1b* are then tested below with two different measures of regional knowledge spillovers from businesses and HEIs separately in order to increase the robustness of the findings.

Regional knowledge spillovers (from businesses) and high-impact firms

First, the association between high-impact firms and higher access to knowledge spillovers (from businesses) is examined for both UK and foreign firms. Table 3 presents the results. The results suggest that compared to low-impact firms, high-impact firms are significantly more likely to have higher access to regional spillovers (from businesses) for both UK firms ($p \leq 0.01$; $\chi^2 = 13.97$) and foreign firms ($p \leq 0.1$; $\chi^2 = 3.01$). These results appear to support *H1a*. Also, the association between high-impact firms and access to regional knowledge spillovers (from businesses) appears to be stronger for UK firms (Phi = 0.166) in comparison to foreign firms (Phi = 0.088). Thus, *H1b* also appears to be supported.

Table 3 Descriptive statistics

	Local UK firms vs. foreign firms in UK	Number	Mean	Std. deviation	Sig.
High-impact growth index (HIGI)	Local UK firms	240	1.01	1.22	0.000***
	Foreign firms in UK	83	0.59	0.70	
Employment growth (4 years)	Local UK Firms	240	65.37	66.50	0.011***
	Foreign firms in UK	83	48.25	46.52	
Sales growth (4 years)	Local UK firms	240	110.21	116.75	0.001***
	Foreign firms in UK	83	75.75	60.12	
Firm R&D (£ million)	Local UK firms	240	15.84	50.29	0.603
	Foreign firms in UK	83	13.48	28.90	
Firm R&D growth (4 years)	Local UK firms	240	123,472.01	222,509.56	0.179
	Foreign firms in UK	83	87,429.49	204,812.13	
Absorptive capacity (R&D intensity)	Local UK firms	240	0.32	0.83	0.021**
	Foreign firms in UK	83	0.18	0.27	
Access to regional knowledge spillovers (from business)	Local UK firms	228	806.02	2491.94	0.051**
	Foreign firms in UK	83	439.14	807.78	
Access to regional knowledge spillovers (from HEIs)	Local UK firms	240	301.66	813.09	0.017**
	Foreign firms in UK	83	159.70	251.83	

Source: UK R&D Scoreboard (2009). Test of differences relate only to high-impact firms (those with positive growth in both sales and employment)

t Tests were used to test the significance level of differences between the two groups: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$ (two-tailed)

Regional knowledge spillovers (from HEIs) and high-impact firms

Next, the relationship between high-impact firms and higher access to knowledge spillovers (from HEIs) is examined again for UK and foreign firms. Table 4 shows the results. The findings also suggest that high-impact firms (compared to low-impact firms) have higher access to regional knowledge spillovers (from HEIs) for both UK firms ($p \leq 0.01$; $\chi^2 = 10.51$) and foreign firms ($p \leq 0.1$; $\chi^2 = 3.67$). The results provide additional support for *H1a*. Further, the connection between high-impact firms and access to regional knowledge spillovers (from HEIs) appears to be stronger for UK firms (Phi = 0.144) in comparison to foreign firms (Phi = 0.10). Consequently, this provides additional support for *H1b*.

Sectoral spillovers and high-impact firms

In order to examine *H2a* and *H2b*, we classify sectors 'high/medium-tech' and 'low-tech' based on International Standard Industrial Classification (ISIC) codes identified by OECD (2011). This provides a definition of high-tech, medium-tech and low-tech sectors based on industrial R&D intensity (OECD 2011). Industrial R&D intensity is defined as direct R&D expenditures as a percentage of production (gross output), which is calculated after converting countries' R&D expenditures and production using GDP PPPs (OECD 2011). Table 5

Table 4 Relationship between access to regional knowledge spillovers (from businesses) and high-impact growth of firms

		Local UK firms			Foreign firms in UK		
		Low-impact firm	High-impact firm	Total	Low-impact firm	High-impact firm	Total
Access to regional knowledge spillovers (from businesses)	Lower access to regional knowledge spillovers (from businesses)	61.1% (149)	38.9% (95)	100.0% (244)	82.3% (163)	17.7% (35)	100.0% (198)
	Higher access to regional knowledge spillovers (from businesses)	44.4% (116)	55.6% (145)	100.0% (261)	75.1% (145)	24.9% (48)	100.0% (193)
	Total	52.5% (265)	47.5% (240)	100.0% (505)	78.8% (308)	21.2% (83)	100.0% (391)
	Chi-squared (χ^2)	13.970[a]			3.025[b]		
	Sig.	0.000***			0.085*		
	Degree of freedom	1			1		
	Phi	0.166			0.088		

Numbers in parentheses are total number of firms in each category. Phi values—less than 0.10 = weak; between 0.10 to 0.30 = moderate; greater than 0.30 = strong

χ^2 tests were used to test the significance level: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$ (two-tailed)

[a] Zero cells (0.0%) have expected count less than 5. The minimum expected count is 115.96

[b] Zero cells (0.0%) have expected count less than 5. The minimum expected count is 40.97

>presents the sectoral classification based on OECD (2011). Based on the OECD measure of industrial R&D intensity, high-tech/medium-tech sectors have higher R&D intensities (4.3) compared to low-tech sectors. Similar, we compared firms in the sectors using firm level measure of R&D and consistent with the above, high-tech/medium-tech sectors (0.28) have significantly higher R&D intensities in comparison to low-tech sectors (0.06) (see Table 5). Thus, our firm level measure of R&D intensity, referred to absorptive capacity (Griffith et al. 2003, 2004; Guellec and van Pottelsberghe de La Potterie 2004), is consistent with the OECD industrial R&D intensity measure.

Accordingly, in order to test *H2a* and *H2b*, firms are classified into high-tech/medium-tech and low-tech sectors. Cross-tabs and chi-squared tests are then used to test the hypotheses. Table 6 presents the results. The results suggest that high-impact firms (compared to low-impact firms) are significantly more likely to be in high-tech/medium-tech sectors for both UK firms ($p \leq 0.01$; $\chi^2 = 10.594$) and foreign firms ($p \leq 0.05$; $\chi^2 = 4.31$). Therefore, the results provide support for *H2a*. Also, the association between high-impact firms and high-tech/medium-tech sectors seems stronger for UK firms (Phi = 0.153) in comparison to foreign firms (Phi = 0.137). Therefore, this provides support for *H2b*.

Firm size and high-impact firms

To test *H3a* and *H3b*, which imply that a negative relationship exists between firm size and high-impact growth for both local and foreign firms, we categorize firms based on their employment sizes. Firms are classified into two categories: those with 'less than 250 employees' and 'large firms' which based on the widely accepted European Commission definition of SMEs and large firms (European Commission 2002, 2011). After that, we then examine the relationship between a firm being a high-impact firm and having 'less than 250' employees for both UK and foreign firms. Table 7 depicts the results. The findings suggest that compared to low-impact firms, high-impact firms are significantly more likely to have 'less than 250 employees' for both UK firms ($p \leq 0.01$; $\chi^2 = 18.221$) and foreign firms ($p \leq 0.01$; $\chi^2 = 8.686$). These results appear to support *H3a*. Additionally, the negative relationship between high-impact firms and small size appears to be stronger for UK firms (Phi = −0.190) in comparison to foreign firms (Phi = −0.151) (Table 8). Therefore, *H3b* also appears to be supported.

Conclusion

Recent theories of firm growth suggest that high-impact firms are important engines of employment generation and growth (Birch 1979, 1989; Evans 1987a, b; Hall 1987; Almus and Nerlinger 1999; Acs and Mueller 2008; Acs et al. 2008; Acs 2013). However, to date, we have very little understanding of whether or not differences exist in factors influencing high-impact growth of local and foreign firms located in the same country. This study examined differences in the influence of regional, sectoral and size related factors in influencing high-impact growth.

Table 5 Relationship between access to regional knowledge spillovers (from HEIs) and high-impact growth of firms

		Local UK firms			Foreign firms in UK		
		Low-impact firm	High-impact firm	Total	Low-impact firm	High-impact firm	Total
Access to regional knowledge spillovers (from HEIs)	Lower access to regional knowledge spillovers (from HEIs)	59.6% (152)	40.4% (103)	100.0% (255)	82.3% (181)	17.7% (39)	100.0% (220)
	Higher access to regional knowledge spillovers (from HEIs)	45.2% (113)	54.8% (137)	100.0% (250)	74.3% (127)	25.7% (44)	100.0% (171)
	Total	52.5% (265)	47.5% (240)	100.0% (505)	78.8% (308)	21.2% (83)	100.0% (391)
	Chi-squared (χ^2)	10.508[a]			3.686[b]		
	Sig.	0.001***			0.055*		
	Degree of freedom	1			1		
	Phi	0.144			0.097		

Numbers in parentheses are total number of firms in each category. Phi values—less than 0.10 = weak; between 0.10 to 0.30 = moderate; greater than 0.30 = strong

χ^2 tests were used to test the significance level: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$ (two-tailed)

[a] Zero cells (0.0%) have expected count less than 5. The minimum expected count is 118.81

[b] Zero cells (0.0%) have expected count less than 5. The minimum expected count is 36.30

Table 6 High-tech, medium-tech and low-tech sectors

Sectors	Industrial R&D intensity[a] (OECD calculation)	Firm-level R&D intensity[b] (authors' calculation)
High-tech Aircraft and spacecraft (353); pharmaceuticals (2423); office, accounting and computing machinery (30); radio, TV and communications equipment (32); medical, precision and optical instruments (33)	4.3	0.28
Medium-high-tech Electrical machinery and apparatus, n.e.c. (31); motor vehicles, trailers and semi-trailers (34); chemicals excluding pharmaceuticals (24 excl. 2423); railroad equipment and transport equipment, n.e.c. (352 + 359); machinery and equipment, n.e.c. (29)		
Medium-low-tech Building and repairing of ships and boats (351); rubber and plastics products (25); coke, refined petroleum products and nuclear fuel (23); other non-metallic mineral products (26); basic metals and fabricated metal products (27–28)		
Low-tech Manufacturing, n.e.c. recycling (36–37); wood, pulp, paper, paper products, printing and publishing (20–22); food products, beverages and tobacco (15–16); textiles, textile products, leather and footwear (17–19)	0.3	0.06

Source: OECD (2011)

[a] R&D intensity defined as direct R&D expenditures as a percentage of production (gross output), calculated after converting countries' R&D expenditures and production using GDP PPPs. The average R&D intensity or high-tech and medium-tech sectors put together is calculated as 4.3. This is because the individual R&D intensities for the sectors is high-tech (9.3), medium-high-tech (3.0) and medium-low-tech (0.3)

[b] R&D intensity is our key measure of absorptive capacity in this study (see 'Data and methods' section) and is measured as R&D spending over total sales (Griffith et al. 2003, 2004; Guellec and van Pottelsberghe de La Potterie 2004)

Original findings

First, firms' capacity to access regional knowledge spillovers—from businesses and HEIs—lie at the heart of high-impact growth for UK firms, but to a lesser degree for foreign firms. In other words, regional resources play a more crucial role in influencing the high-impact growth of UK firms compared to foreign firms. This is likely because foreign firms are less dependent on resources located in a host country (Caves 1996; Nachum and Keeble 2003; Osabutey et al. 2014) as their inadequacies are often supplemented by their access to resources from their parent companies (Keeble and Nachum 2003). For example, anecdotal evidence collected by *Forbes* (Forbes 2015) suggest that foreign firms coming into high-tech regions like Silicon Valley face greater challenges

Table 7 Relationship between sector and high-impact growth

		Local UK firms			Foreign firms in UK		
		Low-impact firm	High-impact firm	Total	Low-impact firm	High-impact firm	Total
Sector	Low-tech	64.7% (88)	35.3% (48)	100.0% (136)	89.2% (58)	10.8% (7)	100.0% (65)
	High/medium-tech	48.3% (168)	51.7% (180)	100.0% (348)	77.8% (228)	22.2% (65)	100.0% (293)
	Total	52.9% (256)	47.1% (228)	100.0% (484)	79.9% (286)	20.1% (72)	100.0% (358)
	Chi-squared (χ^2)	10.594[a]			4.314[b]		
	Sig.	0.001***			0.038**		
	Degree of freedom	1			1		
	Phi	0.153			0.137		

Numbers in parentheses are total number of firms in each category. Sectors were classified as 'high/medium-tech' and 'low-tech' based on ISIC codes identified by OECD (2011). Phi values—less than 0.10 = weak; between 0.10 to 0.30 = moderate; greater than 0.30 = strong

χ^2 tests were used to test the significance level: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$ (two-tailed)

[a] Zero cells (0.0%) have expected count less than 5. The minimum expected count is 64.07

[b] Zero cells (0.0%) have expected count less than 5. The minimum expected count is 13.07

Table 8 Relationship between firm size and high-impact growth

		Local UK firms			Foreign firms in UK		
		Low-impact firm	High-impact firm	Total	Low-impact firm	High-impact firm	Total
Firm size	Less than 250 employees	40.4% (78)	59.6% (115)	100.0% (193)	69.8% (88)	30.2% (38)	100.0% (126)
	Large firms	59.9% (187)	40.1% (125)	100.0% (312)	83.0% (220)	17.0% (45)	100.0% (265)
	Total	52.5% (265)	47.5% (240)	100.0% (505)	78.8% (308)	21.2% (83)	100.0% (391)
	Chi-squared (χ^2)	18.221[a]			8.868[b]		
	Sig.	0.000***			0.003***		
	Degree of freedom	1			1		
	Phi	−0.190			−0.151		

Numbers in parentheses are total number of firms in each category. Phi values—less than 0.10 = weak; between 0.10 to 0.30 = moderate; greater than 0.30 = strong

Chi-squared tests were used to test the significance level: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$ (two-tailed)

[a] Zero cells (0.0%) have expected count less than 5. The minimum expected count is 91.72

[b] Zero cells (0.0%) have expected count less than 5. The minimum expected count is 26.75

in acquiring local knowledge and finance in the region (due to lack of familiarity with the local people).

Secondly, UK high-impact firms were found to be more likely to be in high-tech/medium-tech sectors (which have more regional knowledge spillovers) in comparison to foreign firms. This suggests that high-impact growth of foreign firms is less dependent on being in high-tech/medium-tech sectors and regional knowledge spillovers. This could be because of the access to resources they have from parent companies (Keeble and Nachum 2003). Therefore, unlike UK firms, for foreign firms, being in high-tech sector seems to play a less important role in determining whether or not they experience high-impact growth.

Thirdly, we found that the high-impact growth of foreign firms appears to be less associated with small size (and therefore relatively more dependent on large firm size), in comparison to UK firms, which is more associated with small size. Hence, the finding that small firms grow faster than large firms (Birch 1979, 1989; Evans 1987a, b; Hall 1987; Almus and Nerlinger 1999) is more linked to UK firms and in comparison to foreign firms. Large size is important for the growth of foreign firms likely because of costs arising from unfamiliarity with the environment (Buckley and Casson 1976; Caves 1996; Nachum and Keeble 2003; Guler and Guillen 2010) as these disadvantages can be offset by their firm-specific advantages such as their large size (Horst 1972; Kinoshita 1998). For example, according to *The Guardian* (Guardian 2014), even though the number of micro-sized foreign firms in the UK decreased by 10% between 2009 and 2012, yet the contribution of foreign firms to UK gross value added increased by 19%. This they explained is because of an increase in the number of larger sized foreign-owned businesses, which have greater tendency to contribute more significantly to the economy (Guardian 2014).

Implications for policy

In encouraging high-impact growth of UK and foreign firms, policy makers should take into account specific differences in the region-, sector- and firm-specific factors (size). A blanket strategy may not be very effective in fostering the high-impact growth of local and foreign firms in UK. The first implication is that policy makers need to understand that foreign firms benefit less regional knowledge spillovers compared to local firms. Hence, initiatives that could help foreign firms integrate more and utilise the local resources more effectively could help the performance of foreign firms. Secondly, policy makers need to understand that foreign firms are less dependent on being in high-tech sectors for their performance. This implies that UK regions that lack strong high-tech sectors, can still try to attract foreign firms in low-tech sectors, as they require less regional spillovers to generate high-impact growth. Thirdly, for foreign firms, high-impact growth is less dependent on being small sized. This implies that policy makers need to appreciate the potential of large foreign firms in generating high-impact growth and design effective initiatives for supporting them.

Limitations and implications for future research

Researchers are often criticised for not making clear the environments to which their theories apply. The present analysis is concerned only with firms that have significant R&D activities, especially since the sample was drawn from R&D Scoreboard data. Therefore, the results of the analysis on local firms are applicable only to local firms

that engage in R&D, while the findings on foreign firms are mainly applicable foreign firms that conduct R&D. Hence, future studies could consider using other sources of data beyond the R&D Scoreboard data to see the extent to which the findings hold. Also, this study is limited to high-impact growth, i.e. growth in both employment and sales, and it does not therefore consider other growth and firm performance measures. Thus, future studies could consider other growth performance measures, such as profitability.

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