The Institutional Context Knowledge Spillover Entrepreneurship

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Abstract

This paper applies the institutional context to knowledge generated in incumbent organizations to explain the inherent difficulty in assessing potential innovations along with the key role played by knowledge spillover entrepreneurship as a conduit for transforming new knowledge to a new firm and innovation. Knowledge is inherently uncertain and constitutes what is characterized as the knowledge filter leading to a diminishing marginal return from the knowledge spillover for incumbent organizations and entrepreneurs. The institutional context can either facilitate or impede the spillover of knowledge from the firm where it was created to the entrepreneurial startup where it is transformed into innovation. Our empirical evidence based on a large, unbalanced panel of 12,118 firms in the United Kingdom (UK) constructed from six consecutive waves of a community innovation survey, and annual business registry survey during 2002-2014. The findings reveal that regional context conducive to entrepreneurship enables a positive relationship between the knowledge spillover and innovative performance, while in regions with weak institutional context for entrepreneurship the relationship is inverted U-shape.

Keywords: knowledge spillover, innovation, region, entrepreneur, institutions

1. Introduction

"More cycles were made in Coventry in the 1890s then in any other city in the world; and during that time, it was referred to as the 'Cycle Capital of the World'". Despite this fact Coventry has never become the Cycling city.
Source: "Gearing Up: From Saddle to Spoke". Online Exhibition, Coventry Transport Museum, 2021

The knowledge spillover of entrepreneurship is the most significant form of action under the condition that entrepreneurs can access knowledge crated in incumbent forms and transform it into innovation by starting a new business (Acs, Braunerhjelm, Audretsch, & Carlsson, 2009).

Thus, the extant literature provides both theoretical (Agarwal, Audretsch, & Sarkar, 2007, 2010) as well as empirical evidence concluding that knowledge spillover is a force underlying and motivating entrepreneurs to start a business by introducing new products to market (Braunerhjelm, Acs, Audretsch, & Carlsson, 2010). However, more recent research by Braunerhjelm, Ding, & Thulin (2018) point out and provide empirical evidence that

knowledge spillover within the organizational boundaries can also result in new product creation. The relationship between the knowledge spillover and innovation is also shaped by the regional institutional context (Fritsch & Franke, 2004; Audretsch and Lehmann, 2005; Fritsch et al. 2019a, 2019b). The literature is remarkably silent on the relative importance of regional institutions in the relationship between knowledge spillover and innovation performance and for intrapreneurship versus entrepreneurship.

The purpose of this paper is to challenge this conclusion by positing that the impact of the knowledge spillover of entrepreneurship on innovation is not ubiquitous, but rather is shaped by the institutional context. Some institution contexts are more conducive to entrepreneurship, while others impede starting a new firm for innovation activity (Levie & Autio, 2011; Welter, Baker, & Wirsching, 2019; McMullen, Ingram, & Adams, 2020). We argue that the ability of both intrapreneurs and entrepreneurs to identify the extent to which knowledge spills over to spur innovation is conditional on the institutional context, such as conducive regional regulation, competitiveness and culture of entrepreneurship where firms operate. We draw on a rich literature to posit that institutional context matters to the ability of entrepreneurs to access and commercialize knowledge (Baumol, 1990; Levie & Autio, 2011; Autio et al. 2014).

This study makes two important contributions to the literature. First, drawing on the knowledge spillover of entrepreneurship *concept* (Acs et al. 2009; Agarwal et al. 2010), we explain the non-linear relationship between the knowledge spillover and innovation performance for entrepreneurs vs intrapreneurs. Second, and more significantly, we use the regional institutional context as an empirical lab that can either facilitate or impede knowledge spillovers by changing an entrepreneur's judgment about the knowledge filter and thus the propensity for entrepreneurship to provide a conduit for the spillover of knowledge. Rather than a ubiquitous response to regional

uncertainty, as has been portrayed by the extant literature, the entrepreneurial response to regional uncertainty in the form of opportunities for the spillover of knowledge is instead influenced by the institutional context.

Although the comparability between our study and previous studies on the knowledge spillover of entrepreneurship and intrapreneurship (Braunerhjelm et al. 2018) as well as between our firm-region level results and prior project-level research (Kobarg, Stumpf-Wollersheim, & Welpe, 2019) is limited, we were able to directly investigate the reasons for these differences, such a regional institutional context provides valuable implications. First, from a conceptual viewpoint, one could argue that there is a non-linear relationship between the level of diversity and the depth of the knowledge spillover and innovation performance. In contrast to prior research (Griliches, 1991; Roper, Love, & Bonner, 2017), we demonstrate that high levels of knowledge spillovers that represent both the depth and the diversity of external knowledge sources may result in the diminishing marginal returns. These are the risk factors explaining the nuanced relationship between the knowledge spillover and innovation performance and how entrepreneurs and intrapreneurs will respond to it.

We use a large-unbalanced panel of 12,118 firms in the United Kingdom (UK) representing three distinctive regions of the UK- the South, Midlands and Wales and the North. Our data is constructed from an innovation survey and annual business registry during 2002-2014 to test the hypotheses that the regional institutions and the extent of knowledge spillover determine entrepreneurial response to transforming incumbent knowledge into innovation.

Our finding suggests that i) entrepreneurs and incumbents embrace knowledge spillover to innovate and ii) knowledge spillovers are greater for start-ups than through intrapreneurship within incumbent firms and iii) the relationship between the knowledge spillover for both entrepreneurs and incumbents is inverted U-shape and is conditional on

regional institutional context. In many countries, there are institutional and competitiveness disparities across regions. In the UK, this is manifested by the 'North-South divide' (Huggins & Izushi, 2008), whereby regions in the south of the nation, in particular London, South East England, and Eastern England, are the nation's core economic drivers, while more northern regions suffer from the lack of entrepreneurial culture and knowledge inputs (Huggins, Thompson, & Prokop, 2019).

2. Theoretical framework

2.1. The Knowledge spillover of entrepreneurship theory

Innovation activity is characterized by the newness and complexity of the knowledge. The ability of entrepreneurs and incumbents to access, adopt and commercialize knowledge is dependent on multiple interfaces and resources inside and outside the organization (Audretsch & Keilbach, 2007; Acs et al. 2009). To perform innovation by establishing a new firm requires entrepreneurs to search and absorb diverse knowledge developments (Jaspers & Van den Ende, 2010) and to rely on novel inputs and resources derived from the recombination of internal knowledge and knowledge spillovers (Audretsch, Belitski & Caiazza, 2021). We expect the knowledge spillover be positively associated with innovation activity as the access to new external knowledge furthers the emergence of new ideas (Griliches, 1991) and increases the probability of the fusion of resources available to the entrepreneur with new ideas and implications for knowledge. Knowledge spillover originates within incumbent organizations (Audretsch & Keilbach, 2007), with some of this knowledge remains uncommercialized. While both entrepreneurs and intrapreneurs extend their learning by accessing knowledge spillovers, the differences between entrepreneurs and intrapreneurs can be explained by from a Knightian view of risk and uncertainty, as

entrepreneurs are better in dealing with uncertainty than intrapreneurs. Knowledge is associated with uncertainty, transaction costs and asymmetry and produced by incumbent firms can be used by entrepreneurs to broaden the knowledge pool, share, and mitigate the uncertainty associated with innovation activity (Eisenhardt & Schoonhoven, 1996).

An increase in knowledge spillover means learning new skills and competences, and greater efficiency in maintaining external links, resulting in a positive externality. Entrepreneurs access external resources via knowledge spillovers acquired mainly through their social relationships and interactions with incumbents (Tsai & Ghoshal, 1998).

As knowledge spillover increases the diversity of external knowledge, skills to be learned and complementary assets, we propose that knowledge spillover will be positively associated with innovation activity, but that this association will be subject to diminishing returns due to the detrimental aspects of knowledge sourcing resulting in the negative effect on innovation activity.

Entrepreneurs require specific resources and capabilities, such as specific skills as well as diverse social networks in order to pursue market opportunities and extract market profits (Alvarez & Busenitz, 2001). An increase in knowledge spillover requires further investment in internal resources and R&D (Cohen & Levinthal, 1989) and may be limited to continue absorbing and effectively commercializing knowledge spillover. An increase in knowledge spillover will increase firm's operational costs related to access and processing of new knowledge and building relationship and trust to access incumbents' knowledge (Rodrik, 2008; Boudreaux & Nikolaev, 2019; Boudreaux, Nikolaev, & Klein, 2019). Another reason for the negative return to the knowledge spillover is that entrepreneurs become more selective with partner choice (Berliant, Reed, & Wang, 2006) as intuitively, this occurs because the probability of finding other unmatched economic knowledge is higher in the context with

higher knowledge spillovers. Entrepreneurs become "short-sighted," increasing the flows of redundant or obsolete information (Malecki, 2012), creating a knowledge filter, preventing entrepreneurs from penetrating the filter for the ideas to become innovative products (Acs et al. 2009). Due to the institutional context and lack of competitiveness, regions can significantly influence knowledge flow filtration (Audretsch & Lehmann, 2005). These mechanisms decline the access, adoption and commercialization of knowledge spillover by incumbents and entrepreneurs and hinder innovation activity.

The depth of knowledge spillover from diverse sources (e.g., conferences, professional and public associations, patents, technical standards) can disrupt the exchange of new knowledge and results in a nonlinear impact on innovation activity - the positive impact on innovation has a point after which an increase in the knowledge spillover leads to a decrease in innovation activity.

The essential difference between the knowledge spillover of entrepreneurship and intrapreneurship is in the perception of "risk", which usually means a quantity susceptible to measurement and "uncertainly", which is not. In other words, whereas risk is measurable, it can be described by a certain distribution function such as the normal distribution. Incumbent firms can calculate risk to make their decisions. Uncertainty is neither measurable nor quantifiable. Entrepreneurs judge opportunities created by uncertainty and use available knowledge spillovers to generate profits.

Entrepreneurs judge the available knowledge and embrace uncertainty associated with it for the knowledge spillover of entrepreneurship (Audretsch & Keilbach, 2007) to commercialize new knowledge. This action generates new knowledge that is available before in such a combination leading to radical innovation. Information associated with risk and is more embraced by managers in incumbent firms and

intrapreneurs who will aim to calculate and measure risks will delay the process of the knowledge transformation into innovation and will result in a lower level of innovation activity.

We propose the following hypothesis:

H1: The relationship between knowledge spillover and innovation activity will follow an inverted U-shape as knowledge spillovers are greater for entrepreneurship than for intrapreneurship.

2.2. Institutional context and entrepreneurship

Starting from the establishment and operation of a new business, entrepreneurs will face uncertainty when creating and introducing innovation. The uncertainty is associated with the products and services per se and the context where innovation is created (Autio et al., 2014). A body of literature argues that the institutional environment is a determinant of knowledge creation (Aidis, Estrin, & Mickiewicz, 2008; Audretsch, Hülsbeck, & Lehmann, 2012; Bennett & Nikolaev, 2020a, 2020b; Zhu & Zhu, 2017). A weak institutional environment affects entrepreneurial judgment (Knight, 1921, Casson, 2005) and changes the structure of economic incentives that make entrepreneurs embrace uncertainty. Knights (1921) famously argued that uncertainty creates market opportunities, but the institutional environment affects entrepreneurs' ability to establish business and operate it in pursuit of such opportunity. The institutional environment is an exogenous antecedent to the knowledge filter and innovation activity (Bennett & Nikolaev, 2020a). Welter et al. (2019, p. 327) argue that contextualization of knowledge creation activity would better understand the bigger picture. Overall, understanding how and why some agents are more successful at creating and enacting institutional contexts via entrepreneurial action is crucial (McMullen et al., 2020)

and would allow for a more balanced conceptualization of entrepreneurial agency and context.

Institutional environment, including formal institutions such as regulation and laws as well as informal institutions such as entrepreneurial culture, gives acceptance and support to individuals attempting to start their own business (Welter et al. 2019). Regional culture conducive to entrepreneurship is known to facilitate economic competitiveness and resilience of regions overtime (Fritsch et al. 2019a, 2019b). Regional entrepreneurship culture also promotes the willingness of people to take risks and embrace market uncertainty (Knights, 1921, 1933), tolerate failure and experiment with new knowledge (Lindholm-Dahlstrand, Andersson, & Carlsson, 2019), facilitating regional competitiveness (Huggins et al. 2013). In this case, historical factors, traditions and available role models - including peers - may play a significant role (Stuetzer et al. 2016). Local media could also contribute to the development of a supportive entrepreneurship culture by highlighting actual initiatives, existing networks and support programs encouraging productive entrepreneurship (Audretsch & Belitski, 2017).

Regions, therefore, can influence entrepreneurial activities via a shared culture or set of formal and informal rules (Werker & Athreye, 2004). In regions where entrepreneurship is seen as providing valuable rewards, and entrepreneurs are seen as role models, a sustainable entrepreneurial culture can be formed.

Regions with weak institutions are less competitive and lack entrepreneurial dynamism because they lack the key strengths which drive regional economic development (North & Smallbone 2000). If regional institutions are conducive to entrepreneurship, over time regions remain more resilient to economic shocks and more competitive (Huggins et al. 2013; Chowdhury, Audretsch, & Belitski, 2019; Fritsch et

al. 2019b) entrepreneurs may reduce operational and transaction costs related to access and processing of new knowledge and building relationship and trust to access incumbents' knowledge (Kobarg et al. 2019). Entrepreneurs may continue absorbing and effectively commercializing external knowledge, further penetrating the knowledge filter (Audretsch & Keilbach, 2007). As more entrepreneurs can penetrate the filter and convert more knowledge into innovation, the negative part of the inverted U-shape relationship between the knowledge spillover and innovation could be smoothed, resulting in the relationship between knowledge spillover and innovation plateauing. While incumbents calculate risks and insure against it, uncertainty for entrepreneurs paves the way for opportunities to create profit if the market adopts innovation.

The terms on which novel actions are taken and novel institutions are created are set by the culture from which they emerge. For Knight, emergent novelty and innovation are in constant tension with institutional context. While legal rules and institutions create the order, Knight (1999) noticed they also constrain the emergence of new laws, ideas and limit human behavior. Thus, for entrepreneurs who are located in regions where existing formal and informal institutions are conducive to new ideas and innovation activity (Fritsch et al. 2019b), the size of the knowledge filter will be smaller (Audretsch and Lehmann, 2005), as more efficient mechanisms of knowledge spillover are in place, attenuating the transactional managerial and operational costs associated with an increase in knowledge spillover will result in a sustained positive effect on innovation. The positive impact on innovation will have a point after which an increase in the knowledge spillover will no longer lead to a decrease in innovation activity.

We hypothesize:

H2: Strong institutional context in regions helps to sustain a positive relationship between form's knowledge spillover and innovation with knowledge spillovers are greater for entrepreneurship than for intrapreneurship

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3. Data and method

3.1. Sample

To test our research hypotheses, we use an unbalanced panel dataset that covers the innovation activity of 12,118 UK firms constructed from six consecutive waves of a community innovation survey (UKIS) and Business Structure Database (BSD) known as Business Register during 2002-2014 and annual business registry survey during 2002-2014. The analysis is distributed across three main regions of the UK: South and East, represented by South East and South West region of England (4,055 firms), East of England and Greater London area; Midlands, represented by East and West Midlands and Wales (2,705 firms); North, represented by Yorkshire and Humber, North-East and North-west of England, as well as two countries of Scotland and the Northern Ireland (5,358 firms). We collected and matched UKIS data to the initial year of BSD data for 2002, 2004, 2006, 2008, 2010, and 2012. The UKIS includes innovation input and output data, barriers to innovation, innovation mechanisms, innovation sales, R&D and software expenditure, knowledge collaboration, etc. The BSD variables describe the firm's legal status, ownership (foreign or national firm), alliance information (firm belongs to a larger enterprise network), export, turnover, employment, the industry at 5-digit level, and a firm location the postcode.

The Business Structure Databases had self-employed and micro firms that make 96-97 percent of the sample just by a new firm registration. To avoid including

necessity-driven firms, life-style entrepreneurs, and sole proprietors because they respond to uncertainty and risk in a different way, we exclude all firms that are below than 5 employees.

Given the availability of data, we created three distinctive samples. The first sample includes data on innovation performance for the firms in the South, the second sample includes Midlands and Wales, while the third sample includes the North of England, Scotland and Northern Ireland (see Table 1). Interestingly that the descriptive statistics of our variables of interest do not vary significantly between the three samples.

We start by analyzing three samples by industry distribution (Table 1a). Sectors under-represented are mining and quarrying (0.46%) for the South and 1.14% for the North, utility electricity (<1%) for all samples and education (<2%) for all samples. Industries with the highest share in a sample are high-tech manufacturing (24.21%) for the Midlands, (14.46%) for the South and (18.28%) for the North. Real estate and other business activities are between 10.361% for the Midlands and 14.73% for the South; wholesale, retail trade varies between (14.89%) in Midlands and (16.54%) in the North. Finally, the share of firms in construction is between (8.67%) in the South and (11.72%) in the North. Their financial intermediation is twice as high as in the South (4.59%) compared to (2.52%) in the Midlands and Wales. Basic manufacturing is (7.17%) in the North and half of it (3.93%) in the South.

TABLE 1A ABOUT HERE

Table 1b illustrates the geographical distribution is even across the region within the South, Midlands and the North. Most of the firms in a sample are from the South East of England (28.79%) of the South sample, North-West (23.77%) of the North sample and West Midlands (37.71%) of the Midlands and Wales sample.

TABLE 1B ABOUT HERE

The major differences in the distribution of firms were observed across survey waves 2002-2014. Most of the sample observations come from the first UKIS4 round (2002-2004) –

42.91% in the South and 44.91% in the North samples, while only 5.79% for UKIS9 round 2012-2014 in Midlands and 9.88% in the North samples.

TABLE 1C ABOUT HERE

3.2. Variables

Dependent variable.

We measure innovation using the following question from the UKIS survey: "What is the percentage of the total business turnover of products and services that were new to the market?" The variable varies between zero – which means a firm has zero sales of new to market products to 100 – all sales from new to market products and has been used extensively as a measure of radical innovation (Laursen & Salter, 2006, Leiponen & Helfat, 2010; Snihur, Thomas, & Burgelman, 2018). It is important to notice that the survey asks firms to list the introduction of incremental and radical innovations (OECD/ Eurostat, 2005), and our estimates can differentiate between radical and incremental innovations. The variable we use refers to products and services that were new to the market in line with the definition of innovation in prior research (Santamaría, Nieto, & Barge-Gil, 2009).

Explanatory variables.

Startups. Another explanatory variable we use to identify a startup is firm age. We measure startup as using a binary variable equal to one if a firm is a startup, defined as having a maximum of 4 years since incorporation, has no subsidiaries and is itself a firm and not a subsidiary. The maximum number of employees at the start (year of incorporation) is between 6 and 49. This approach to innovative startups is widespread (Foss & Klein, 2020).

Knowledge spillovers. In the questionnaire, firms rated the importance of externally available information for their innovation process from four sources on a

four-point scale from unimportant (0) to very important (3). We draw on Cassiman & Veugelers (2002) work, who create a knowledge spillover using information sources such as patent information; specialist conferences, meetings, and publications; trade shows, and seminars. Cassiman &Veugelers (2002: 1171) generate a firm-specific measure of incoming spillovers by "aggregating these answers by summing the scores on each of these questions and rescaled the total score to a number between 0 and 1.3".

These external sources of knowledge could be generated by incumbent firms and universities (Audretsch & Link, 2019), but also at the conferences, trade fairs or exhibitions; professional and industry associations; as well as the knowledge found in technical, industry or service standards; scientific journals and trade/technical publication. We rescale the variable between zero and one. These measures are closely related to each other, with correlation coefficients between 0.53 and 0.75. This is why we aggregate and rescale these measures and do not do weighting as we cannot assume that some components (e.gl. information from conferences and events) may be more important than others (e.g., information from industry or service standards; scientific journals). This approach to standardize a construct before running the models to reduce potential problems of multicollinearity (Wooldridge, 2010). The extent to which these sources constitute knowledge spillover may be an issue for debate. However, they do make up important external knowledge inputs that do not involve active collaboration between innovators and incumbent organizations and do not involve a financial reward.

As part of the robustness check, we aggregate the knowledge spillover components with a high degree of internal consistency (Cronbach's Alpha Coefficient = 0.74). Using this construct instead of knowledge spillover in the estimation further does not change the significance of the coefficient. In the model to measure potential non-linear effects between the knowledge spillover and innovation, we take a squared term of knowledge spillover and

interact knowledge spillover in levels and squared with the binary variable startups (entrepreneur).

Our measure captures the exogenous nature of knowledge spillovers, determined by technology and market characteristics of knowledge. While alternative measures of knowledge spillovers have been proposed in the literature (Griliches, 1991; Keller, 2002), e.g. total pool of external knowledge available, investment in R&D, hiring researchers, these studies relied on the indirect measurement of knowledge spillovers require the construction of a pool of potentially available knowledge within each industry region and for each firm in the sample. Prior measures use to examine the benefits of external knowledge by measuring the geographical and technological "proximity" between incumbents and knowledge receiver – an entrepreneur. Our measure is not biased by a geographical distance of knowledge creation and commercialization as we cannot assume that knowledge is geographically constrained (Audretsch & Feldman, 1996). There is a transaction cost to use knowledge. Digital technologies enable to significantly reduce the cost of knowledge transfer by attending the conferences and events, access data, scientific publications, and others with the recent examples of virtual communication tools adopted during the Covid-19 crises.

Control variables.

Uncertainty and risk. Knights (1921) has repeatedly stressed that uncertainty must be taken radically distinct from the more familiar notion of risk. To measure i) risk and ii) uncertainty, we use a proxy for the importance of i) excessive perceived economic risks as constraints on innovation and activities in influencing a decision to innovate (0 – none – 3 very high) and ii) the uncertain demand for innovative goods or services as a constraint on innovation and activities in influencing a decision to innovate (0 – none –

3 very high). Coad, Pellegrino & Savona (2016) used these factors to predict the barriers to innovation and form productivity were found to negatively affect the decision to innovate. Given that entrepreneurs embrace uncertainty (Knight, 1921) in search of profits, we expect to find uncertainty positively associated with innovation for entrepreneurial firms, while the risk is either negative or not significant.

Institutions. Quality of government is associated with corruption, the rule of law, and impartiality and is understood as "a government that acts in an impartial, efficient way, and without corruption—is a crucial factor for explaining the remarkable differences in socio-economic performance across political communities" (Charron, Lapuente, & Annoni, 2019: 1926). The research demonstrated the negative consequences for regions and countries with low government quality (QoG) (Persson & Tabellini, 2005; Holmberg & Rothstein, 2012). The prior research has found that regions with embedded high corruption, partiality, and weak rule of laws have lower economic development levels (Levie & Autio, 2011), greater income inequality and less entrepreneurship (Chowdhury et al. 2019). We use the regional European Quality of Government Index (EQI), which includes the measures of regional governance collected between 2010-2017 and built upon the opinions of respondents in 193 regions from 21 European countries, and we use the UK data available. The EQI index relies on the Quality pillar, Impartiality and Corruption Pillars that were z-score standardized. Given a high correlation between EQI and each Pillar component, we use the EQI in our estimation. Given inconsistent data availability, we used the following approach. For the UK, the level of EQI in 2010 was interpolated for the periods of 2002-2004, 2004-2006, 2006-2008; EQI in 2013 was used for 2008-2010 and 2010-2012; the level of 2017 was used for the period 2012-2014.

Appropriability. To obtain some insight into the role of appropriability methods at the firm level, we draw on the responses to a question in the survey on the degree of importance

to the firm of different methods of protection from 0 – not important to 3 - crucial. The survey question is similar to those used in previous studies of appropriability methods (Lauren & Salter, 2006). Based on the responses, we created a measure of the overall strength of the firm's appropriability strategy by aggregating the five measures of formal and strategic protection (Arora, Athreye, & Huang, 2016) listed in the survey (scored on a 0–3 scale). The six items are patents, copyright, trademarks, secrecy, first entry and complexity. We sum the scores on each of these questions and rescale the total score to a number between 0 and 1 to generate a measure of legal and strategic protection. The set of items appears to have a high degree of internal consistency (Cronbach's Alpha Coefficient = 0.89). Previous research has found a positive relationship between appropriability and firm radical innovation (Laursen & Salter, 2014).

Absorptive capacity. To control for the level of absorptive capacity, we use three variables. First, we use R&D intensity (R&D expenditure divided by total sales) (Cohen & Levinthal, 1989). Second, firm-level software intensity (expenditure for purchasing advanced machinery, equipment and software divided by total sales) (Hall, Lotti, & Mairesse, 2013). Third, the share of employees holding a higher education degree (MSc and above) (Kobarg et al. 2019). An increase in software and R&D intensity and level of education of employees was found to be positively associated with radical innovation (Belderbos, Carree, Lokshin, & Sastre 2015; Audretsch & Belitski, 2020).

Firm age and size. We control for a firm size, measured as a number of employees (expressed in logarithms) and firm age, measured as a number of years since establishment (expressed in logarithms). Both variables are expected to have a non-

linear relationship between innovation as it diminishes with firm growth and age. A number of employees and firm registration year is taken from BSD data.

Knowledge collaboration. To control for the breadth of openness of new firms, we include additional control measures for whether the firm collaborates or not with external partners on knowledge regionally, nationally, and internationally (Leiponen & Helfat, 2010; Hsieh, Ganotakis, Kafouros, & Wang, 2018). The depth of external knowledge collaboration was found to have a positive effect on firm innovation. By including the geographical dimensions of firm knowledge search, we control for the stylized fact that knowledge may be [regionally] concentrated (Malecki, 2010; Decker, Estrin, & Mickiewicz, 2020) and that knowledge flows decay with the distance between knowledge generator and receiver (Audretsch & Feldman, 1996). We also control for the cost of knowledge transmission in collaboration when financial reward may follow, and collaboration may not be "costless across geographic space" (Audretsch & Lehmann, 2005: 1194).

Other control variables. Further, we controlled for firms' exposure to international markets with the binary variable equals to one if a firm export, zero otherwise (i.e., the share of the revenue from markets outside UK>0) (Belderbos et al. 2015). Exporters are likely to be more innovative as the competition is more intense in the international market than in the domestic market. We control for factors that may become impediments of innovation e.g. cost of finance, access to finance, a market competition drawing on Arora et al. (2016), which are expected to have a negative relationship with firm innovation. Further, we controlled for industry differences by including industry dummies in our analyses. Moreover, we controlled for differences between firms that could take place over the analysis period with the first wave (2002-2004 as a reference category). We control for the differences in local environment and innovation ecosystems across different city-regions by including 128 city-regions fixed effects with York city as a reference category. Finally, firms with different legal

statuses (e.g. partnership, limited liability partnership, etc.) (Arora et al. 2016) may acquire different initial incentives to innovate with the listed firm as the reference category. We do not hypothesize any relationship between a firm's legal status and the level of innovation.

Table 2 provides a list of variables used in this study with the summary statistics presented in Table 3.

TABLE 2 ABOUT HERE

TABLE 3 ABOUT HERE

3.3. Method

In our identification strategy, we account for two types of dependent variables and build two models to identify the hypothesized relationships. First model accounts for the censored nature of our dependent variable "Innovative sales" and we use Tobit models (Amemiya, 1985). In econometric form the model has dependent variable $y_{itdc\,mk}$ (firm's innovation sales, % and product innovator, yes or no) as a function of a set of explanatory variables start-up and knowledge spillover S_{it}:

$$y_{it} = \beta_0 + \beta_1 S_{it} + \beta_2 S_{it}^2 + \beta_3 \varphi_{it} S_{it} + \beta_{4_i} z_{it} + \delta_r + \tau_t + u_{it} \quad (1)$$

We can also call it structural equation to emphasize that we were interested in β_1-β_3 that demonstrate the relationship between knowledge spillover and innovation for entrepreneurs and intrapreneurs (managers in incumbent firms). The vector φ_{it} is a startup, the vector S_{it} is a knowledge spillover measure. The vector z_{it} is a list of exogenous control variables and not correlated with u_{it} - an error term. δ_r, τ_t are industry and year fixed effects. Our knowledge spillover variable S_{it} is exogenous and is unlikely to be correlated with u_{it} (Wooldridge, 2009: 517).

We estimate equation 1 using a multivariate Tobit model for each of three samples - the South, Midlands and Wales and the North, including Scotland and Northern Ireland (Wooldridge, 2010). First, we implement several control variables that could, against the background of the literature, account for unobserved heterogeneity. Second, employing the Tobit regression exclusively, we deem unobserved heterogeneity not to be a major concern (Kobarg et al. 2019).

4. Results

The results of the hypotheses testing are presented in Table 4. First, we estimated an innovation production function using the Tobit model for the firms located in the South of the UK (Table 4, spec. 1-2), the Midlands and Wales (Table 4, spec. 3-4), and finally for firms located in the North of the UK (Table 4, spec. 5-6). We calculated a likelihood-ratio test comparing the panel Tobit model with the pooled OLS with the test supporting the use of Tobit estimation should be used.

TABLE 4 ABOUT HERE

The coefficients in Table 4 present the marginal effect of the independent variables on firm innovation. Robust standard errors are estimated for these coefficients. Regressions (1), (3) and (5) include only control variables as well as the knowledge spillover and entrepreneur identified, while regressions (2), (4) and (6) adds other control variables for knowledge collaboration regional institutional quality and absorptive capacity of a firm as well as the interaction between knowledge spillover and entrepreneur.

The overall predictive power of the estimated regressions (2), (4) and (6) (1) and (2) in Table 4 is higher than in regression regressions (1), (3) and (5) when we control for the

quality of institutions (Charron, Lapuente, & Rothstein, 2013; Charron, Lapuente, & Annoni, 2019), knowledge collaboration (Kobarg et al. 2019; Hsieh et al. 2018) and absorptive capacity (Cohen & Levinthal, 1989). Interestingly, the coefficient of risk and uncertainty is positive and significant across firms located in all three parts of the UK, demonstrating that firms come across risk and uncertainty when innovating new products and services. In economic terms, we interpret our results as one unit increase in the level of uncertainty (from low to a medium level, or from none to a low level), increases innovation sales by 3.55 in the South, while only by 1.56 percent in the Midlands and Wales (specifications 2 and 4, Table 4). The changes are not statistically significant with and without control for knowledge collaboration, institutions and absorptive capacity.

The direction of the signs of the two coefficients of knowledge spillover indicates that the positive relationship decreases or becomes negative with increasing values of knowledge spillover, thus indicating an inverted U-shaped relationship. Tests of the location of the turning point and the steepness of the slopes further affirm the presence of an inverted U-shaped relationship between knowledge spillover and innovation performance, supporting H1.

Figure 1a-1c illustrates the predictive margins of the direct effect of knowledge spillover and entrepreneur on innovation performance across three UK regions associated with different levels of economic development and competitiveness: The South, Midlands and Wales and the North.

INSERT FIGURE 1 ABOUT HERE

While we support H1 on the inverted U-shape relationship knowledge spillover and innovation performance, the differences between entrepreneurs and incumbent firms are statistically significant for the South and the North of the UK (see Figure 1A and 1C), while there are no differences in the relationship between knowledge spillover and innovation performance between intra- and entrepreneurs in Midlands and Wales (see Figure 1B). The interaction coefficient of start-ups and knowledge spillover is positive and significant for the South (β=12.92, $p<0.01$), while it is insignificant for the North due to the inverted U-shaped effect (Figure 1C). In the North of the UK, a lack of entrepreneurship tradition and large-scale manufacturing has long been identified as a weakness in the regional economies, with persistently low entrepreneurial activity rates resulting in a deficit of entrepreneurial culture and mindset.

Thus, H1 is confirmed in terms of the U-shape, but partly confirmed on the statement that entrepreneurs are always better at using knowledge to establish new businesses and innovate, as we do not find that entrepreneurship and intrapreneurs behave differently in Midlands and Wales.

Regions such as North East England, Yorkshire and the Humber, Scotland and Northern Ireland are significantly uncompetitive in comparison with their southern neighbors and based on a composite index of competitiveness across the UK's regions, only the three regions of the 'Greater South East' are found to be performing above the UK competitiveness average (Huggins 2003; Huggins et al. 2019). South of the UK have performed above the UK average since 1997, and the disparities between the leading and lagging nations are persistent (Huggins et al. 2013) with the negative effect significantly reducing innovation as knowledge spillover increases (Figure 1C). Greater availability of resources, higher rates of entrepreneurial activity, and increased demand affect entrepreneurial pursuit and subsequent behaviors in the South (Huggins et al. 2013; Fritsch et al. 2019), as in the case in the South of

UK with more competitive regions can i) sustain the positive effect of the knowledge spillover (Figure 1A) and ii) entrepreneurs have on average higher innovation performance than incumbents in the South, supporting H2.

Fig. 1C shows the curvilinear relationship between values of knowledge spillover and the predicted values of innovation performance. The turning point of this curve is calculated at a value of 0.6 for the North and 0.65 from the South. For the South, the relationship demonstrates the diminishing returns to knowledge spillover and it finally plateaus. For Midlands while we find that the linear and the squared term of the knowledge spillover are insignificant, the relationship follows the diminishing marginal returns as in the depth of knowledge collaboration with external stakeholders in the recent study Kobarg et al. (2019). Unlike Kobarg's study we identified the differences in the turning point across regions with different institutional contexts. For example, for Midlands, the turning point indicates that diminishing returns from an increased knowledge spillover occur relatively early than the South and the North of the UK. Further inspection of the curve reveals that the predicted values for innovation performance indicate innovation performance is, in fact, increasing as innovation sales are potentially lower for firms who access the rate of 0.60 of knowledge spillover or more than firms with knowledge spillover less than 0.60. At the same time, firms with the level of knowledge spillover of 0.90 are not different in innovation performance with firms at 0.60, indicating the diminishing and finally zero marginal returns to knowledge spillover. Wales and Midlands have been traditionally viewed as having a less entrepreneurial economy than other UK areas (Huggins et al. 2019). The story of the Midlands could be described by in the example given at the *"*Gearing Up: From Saddle to Spoke" online Exhibition at the Coventry Transport Museum, 2021 which says *"More cycles were made in Coventry in the 1890s then in any other city in the*

world; and during that time, it was referred to as the 'Cycle Capital of the World'". Despite this fact Coventry has never become a cycling city. Large scale manufacturing has prevented people from starting their own business, with Midlands and Wales have developed as a manufacturing and resource-based region for the rest of the country.

While diminishing marginal returns to knowledge spillover is not the best scenario possible, at least for firms in the South and Midlands, there is no negative effect as in the case of the North region.

On a conceptual level, our findings indicate a high sensitivity of firm innovation to overly excessive knowledge spillover. In regions with the highest institutional quality located in the South of England, London and East of England, the technological focus and the resource constraints of innovation projects are leveraged by support infrastructure and entrepreneurial culture (Welter et al. 2019; McMullen et al. 2020). Further research is required to identify the specific reasons for this sensitivity within each region.

Our finding supports Knight (1999) on the role that institutional context matters for uncertainty and risk terms where novel actions and novel institutions are created. Stronger institutional conditions and competitive regions are expected to affect individual behaviors of entrepreneurs creating tensions and uncertainties but also creating opportunities used by entrepreneurs to achieve greater profits.

5. Discussion

The decision to become an innovative entrepreneur is influenced by the internal characteristics of a firm as well as the regional context (Fritsch & Franke, 2004; Fritsch et al. 2019a,). It is therefore critical to understand how regional competitiveness (Huggins & Izushi 2008; Audretsch et al. 2012 2012) and institutions (Aidis, Estrin, & Mickiewicz, 2008; Decker et al. 2020) can affect the distribution of innovative entrepreneurs across the country

and lead an individual to access external knowledge for innovation. This study aimed to investigate the relationship between knowledge spillover and innovation performance for entrepreneurs and intrapreneurs with regional competitiveness and resources affect this relationship, a relationship previously examined only at the firm level. Thus, this study complements and extends prior open innovation and regional economics literature by analyzing how the regional competitiveness and culture shapes the relationship between knowledge spillover and innovation for new ventures who introduce innovations and incumbent firms.

We found that innovation performance follows an inverted U-shaped relationship with knowledge spillover in contrast to what we knew before of the knowledge spillover as a positive externality (Griliches, 1991; Block, Thurik, & Zhou, 2013; Roper et al. 2017; Audretsch et al. 2021); whereas firms' innovation performance follows an inverted U-shaped relationship with knowledge spillover and the effect is stronger for entrepreneurs than entrepreneurs. This effect is consistent for the south and the north of the UK, while in the Midlands and Wales, a lack of entrepreneurial culture prevents new firms from engaging in innovation activity based on new knowledge. In the South, the institutional context is stronger, such as sharing infrastructure, skills and capabilities, availability of finance and support structures, supply and demand matching, legitimacy and culture of entrepreneurship and small business, and greater diversity (Rosenthal and Strange, 2004; Huggins et al. 2019). Increased knowledge flows between economic agents in the South of UK foster positive externalities and diversity of ideas (Caragliu, de Dominicis, & de Groot, 2016), creating new combinations of knowledge (Hsieh et al. 2018).

Beyond the relevance of these results, they provide further interesting insights when compared to the prior research on the knowledge spillover of entrepreneurship and intrapreneurship.

These differences are related to the mindset of entrepreneurs, such as the role of entrepreneurial judgment and regional context. First, the entrepreneurial judgment is different from that of incumbents (Foss & Klein, 2015) because entrepreneurs are believed to have an above-average level of willingness to act on entrepreneurial opportunity, created by the uncertainty of future profits (Knight, 1921; Kihlstrom & Laffont, 1979), accruing from higher innovation rates and higher returns to knowledge spillovers.

Second, the differences between the effect of the knowledge spillover on innovation activity is indeed a derivative of the regional competitiveness and culture where firms operate. The diminishing marginal returns to knowledge spillover and the similar ability of firm managers and entrepreneurs to innovate new products and services are conditional on the quality of regional institutions and in particular, entrepreneurship culture and mindset. A comparison between three distinctive parts of the UK showed that the relationships differ between the regional levels, thereby underlining the importance of an investigation at the regional level.

Our study extends the prior research on the knowledge spillover of entrepreneurship and intrapreneurship in three important ways. First, regarding innovation performance, our firm-level analyses show a curvilinear relationship of knowledge spillover, which has also been found for the knowledge collaboration breadth by Kobarg et al. (2019). Compared to this study, the knowledge spillover would also follow the same pattern; however it is more sensitive to institutional context than knowledge collaboration or other forms of outward open innovation, drawing an important distinction for entrepreneurship policy. Second, unlike knowledge collaboration, which takes place with domestic and international partners,

knowledge spillovers are highly dependent on the availability of localized tacit knowledge and its diversity (Audretsch & Feldman, 1996), and therefore the relationship between knowledge spillover and innovation performance vary with the regional institutional context and may differ from positive, to diminishing and negative. This finding explains the difference between knowledge spillovers and knowledge collaboration at both the firm and regional level. Further research needs to pay more attention to these distinctive differences when explaining the effect of the knowledge spillovers and knowledge flows with a financial reward on innovation. Third, our firm-region level results indicate that such a relationship is only present for the knowledge spillover of entrepreneurship but also intrapreneurship, expanding what we know about it from Braunerhjelm et al. (2018).

Implications for managers and entrepreneurs

Entrepreneurs and intrapreneurs should interpret these findings as a caution towards excessive knowledge spillover and an emphasis on the importance of the careful selection of external knowledge (e.g. conferences, publications, patents, professional and trade associations, etc.).While we found that both the linear and the squared term of knowledge spillover are significant, the effect varies between entrepreneurs and intrapreneurs who perceive uncertainty differently (Knight, 1921) as well as the regional competitiveness (e.g. the “North-South” divide). In addition to knowledge collaboration with regional, national and international partners, knowledge spillovers appear to influence the radical innovation performance in both incumbent and entrepreneurial firms, while regional competitiveness explains the difference in the relationship. Further tests of the turning point location and slopes confirm the presence of an inverted U-shaped relationship with regional development and entrepreneurship

policy should focus on firm-level and regional characteristics that can be responsible for reducing the negative effect of the knowledge spillover while it gets excessive.

Our research findings indicate that startups with access to knowledge spillovers will have a greater propensity to transform knowledge into innovative activity than do incumbents. However, an incumbent firm may also benefit by knowledge spillovers. Our study also suggests that incumbents may not completely control the knowledge created through their own investment due to the knowledge inexcludability (Audretsch & Keilbach, 2007). They do not reduce their knowledge investments as more knowledge spills over to entrepreneurs.

Implications for policy

Innovation policies typically focus on spurring innovation in incumbent firms. However, the results of this study suggest that the entrepreneurs tend to exhibit higher innovative activity at the same levels of knowledge spillovers. Rather, entrepreneurship in the form of a new firm startup is a more effective response to incumbent knowledge. AS the effects vary across regional context in the UK, we suggest that policy might be better advised to focus on policy instruments conducive to regional entrepreneurial ecosystems and availability of finance as a conduit for knowledge spillovers rather than prioritizing instruments attempting to spur intrapreneurship within incumbent firms and a focus in the South of the UK.

While both managers and policymakers see knowledge spillover as a positive externality, firms in the North of the UK are still unable to sustain the efficient transformation of knowledge spillover into innovative performance. The further policy will examine how leveling -up in the knowledge spillover of entrepreneurship could be achieved. The answer may not be by improving the regional infrastructure and connecting the North and the South, but in developing informal regional institutions, such as a culture of entrepreneurship and

small business midset, providing region-based financial support and capabilities, investing in skills and digital competencies aiming to facilitate positive returns to available knowledge spillovers for firms in the North.

6. Conclusions

Our study applies the knowledge spillover of entrepreneurship concept to knowledge generated in incumbent organizations to explain the differences between entrepreneurs and incumbents in a way they innovate. Unlike incumbent organizations that are more averse to uncertainty and the use of external knowledge, entrepreneurs see knowledge spillover as an entrepreneurial opportunity by leveraging external knowledge in order to innovate. While the extant literature is ambivalent about the relative efficacy between entrepreneurship and intrapreneurship as a conduit of knowledge spillovers, we find compelling evidence suggesting that the efficiency of entrepreneurs is higher, and the innovation outcome is also shaped by the underlying regional knowledge context. We theoretically posited and empirically demonstrated that entrepreneurs embrace knowledge spillovers to innovative activity by founding a new firm.

The first major advancement of this study to the knowledge spillover of entrepreneurship and institutional research is in providing the first theoretical synthesis of Acs's et al. (2009) concepts of the knowledge spillover of entrepreneurship with the role of regional competitiveness and innovation in explaining the non-linear relationship between knowledge spillover and innovation performance. The second contribution is to identify that the entrepreneurial response to a context where

knowledge is highly uncertain is greater than is the intrapreneurial response within incumbent firms.

Limitations and Further research

The main limitations of this study are as follows. First, due to the UK Innovation Survey's anonymous nature, no additional sources for information on external partners and sources of knowledge could be added, along with the location of knowledge (regional, national, overseas). These could have been used to supplement our knowledge with new evidence.

Second, this research focuses specifically on knowledge spillover entrepreneurship and the entrepreneurial response by commercializing knowledge in a context of high uncertainty. Further research would be well advised to consider different types of knowledge (e.g., tacit and explicit; basic and applied) (Audretsch and Link, 2019) and how entrepreneurship scholars following Knight see entrepreneurship as the conduit of knowledge into business profit. Data limitations made it difficult to identify the effort of the entrepreneur to access external knowledge or prior experience of dealing with each specific type of knowledge. Further advancement in the microeconomic foundations requires discussing knowledge spillovers role in the optimal market allocation of resources between knowledge creation and its commercialization.

The major assumption in the KSTE is that entrepreneurs endogenously create the set of entrepreneurial opportunities and that they all can observe and use the knowledge created by incumbents. Corporations and universities are a major source of knowledge creation; however, these incumbents produce heterogeneous quality knowledge and operate in different institutional contexts with different knowledge spillovers. Future research may investigate the role of specific knowledge creators and knowledge spillover mechanisms and

test the assumption that incremental innovations are based more on information, while radical innovations require knowledge.

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Table 1a: Data representation by sector divisions across three regions of the UK

Sector divisions	South		Midlands and Wales		North (incl. Scotland and NI)	
	# obs.	%	# obs.	%	# obs.	%
1 – Mining and Quarrying	45	0.46	34	0.58	110	1.14
2 - Manufacturing basic	383	3.93	373	6.36	695	7.17
3 - High-tech manufacturing	1411	14.46	1421	24.21	1771	18.28
4 – Utility	68	0.70	52	0.89	71	0.73
5 – Construction	846	8.67	612	10.43	1135	11.72
6 - Wholesale, retail trade	1584	16.24	874	14.89	1602	16.54
7 - Transport, storage	501	5.14	371	6.32	572	5.90

8 - Hotels and restaurants	635	6.51	265	4.52	576	5.95
9 – ICT	873	8.95	338	5.76	464	4.79
10 - Financial intermediation	448	4.59	148	2.52	281	2.90
11 - Real estate and other business activities	1437	14.73	605	10.31	1160	11.97
12 - Public admin, defence	1174	12.03	375	6.39	891	9.20
13 – Education	185	1.90	76	1.29	160	1.65
16 - Other community, social activity	165	1.69	165	2.81	200	2.06
Total	**9755**	**100.00**	**5869**	**100.00**	**9688**	**100 .00**

Source: Office for National Statistics. (2017a). *UK Innovation Survey, 1994-2016: Secure Access*. [data collection]. *6th Edition.* UK Data Service. SN: 6699, http://doi.org/10.5255/UKDA-SN-6699-6 (hereinafter UKIS- UK Innovation survey)

Table 1b: Geographical split across three regions of the UK

UK region	South		Midlands and Wales		North (incl. Scotland and NI)	
	# obs.	%	# obs.	%	# obs.	%
North East					1395	14.40
North West					2303	23.77
Yorkshire and Humber					2068	21.35
East Midlands			2032	34.62		
West Midlands			2213	37.71		
Eastern England	2265	23.22				
London	2556	26.20				
South East	2808	28.79				
South West	2129	21.82				
Wales			1624	27.67		
Scotland					1966	20.29
Northern Ireland					1956	20.19
Total	**9755**	**100.00**	**5869**	**100.00**	**9688**	**100 .00**

Source: Office for National Statistics. (2017a). *UK Innovation Survey, 1994-2016: Secure Access*. [data collection]. *6th Edition.* UK Data Service. SN: 6699, http://doi.org/10.5255/UKDA-SN-6699-6 (hereinafter UKIS- UK Innovation survey)

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Table 1c: Data representation by the survey periods across three regions of the UK

	South and East	Midlands and Wales	North, Scotland and NI

Survey year	Firms	%	Firms	%	Firms	%
UKIS4 (2005)	4186	42.91	2801	47.73	4351	44.91
UKIS5 (2007)	1027	10.53	591	10.07	1257	12.97
UKIS6 (2009)	1530	15.68	1398	23.82	1120	11.56
UKIS7 (2011)	1057	10.84	486	8.28	1108	11.44
UKIS8 (2013)	980	10.05	340	5.79	957	9.88
UKIS9 (2015)	975	9.99	253	4.31	895	9.24
Total	**9755**	**100.00**	**5869**	**100.00**	**9688**	**100 .00**

Source: Office for National Statistics. (2017a). *UK Innovation Survey, 1994-2016: Secure Access*. [data collection]. *6th Edition.* UK Data Service. SN: 6699, http://doi.org/10.5255/UKDA-SN-6699-6 (hereinafter UKIS- UK Innovation survey)

Office for National Statistics. (2017b). *Business Structure Database, 1997-2017: Secure Access*. [data collection]. *9th Edition.* UK Data Service. SN: 6697, http://doi.org/10.5255/UKDA-SN-6697-9 (hereinafter BSD- Business Structure Database)

Table 2: Description of variables

Variable (source)	Definition
Innovative sales (UKIS)	Dependent variable: % of firm's total turnover from goods and services that were new to the market (%)
Independent variables	
Knowledge spillovers (UKIS)	Sum of scores (0 to 3) of how important to innovation activities was information from: conferences, trade fairs or exhibitions; professional and industry associations; technical, industry or service standards; scientific journals and trade/technical publication (rescaled between zero and one). The individual variables are described below.
Associations (UKIS)	**Knowledge spillovers component:** how important to innovation activities was information from: professional and industry associations (0 – not applicable to 3 – high)
Standards (UKIS)	**Knowledge spillovers component:** how important to innovation activities was information from: technical, industry or service standards (0 – not applicable to 3 – high)
Conferences (UKIS)	**Knowledge spillovers component:** how important to innovation activities was information from: conferences, trade fairs or exhibitions (0 – not applicable to 3 – high)
Publications (UKIS)	**Knowledge spillovers component:** how important to innovation activities was information from: scientific journals and trade/technical publications (0 – not applicable to 3 – high)
Start-ups (BSD)	Binary variable equal one if a firm is from 0-3 years old since establishment has maximum (50 employees at establishment) and is not part of an enterprise group, including no units at establishment, zero otherwise
Uncertainty (UKIS)	How important has been the uncertain demand for innovative goods or services as constraint to innovation and activities in influencing a decision to innovate (0 – none – 3 very high)?
Risk (UKIS)	How important has been an excessive perceived economic risk as constraints to innovation and activities in influencing a decision to innovate (0 – none – 3 very high)?
Control variables	
EQI	The regional European Quality of Government Index (EQI) which includes corruption, impartiality and rule of law pillars (Charron et al. 2013, 2020).
Collaboration regional (UKIS)	Binary variable=1 if firm collaborates on innovation regionally with at least one partner: enterprise group, suppliers; customers; competitors; consultants, commercial labs; universities; government and public research institutes, zero otherwise
Collaboration national (UKIS)	Binary variable=1 if firm collaborates on innovation nationally with at least one partner: enterprise group, suppliers; customers; competitors; consultants, commercial labs; universities; government and public research institutes, zero otherwise

Collaboration international (UKIS)	Binary variable=1 if firm collaborates on innovation in Europe and other world with at least one partner: enterprise group, suppliers; customers; competitors; consultants, commercial labs; universities; government and public research institutes, zero otherwise
Age (BSD)	Age of a firm (years since the establishment)
Employment (BSD)	Number of full-time employees (>5), in logarithms
Scientist (UKIS)	The proportion of employees that hold a degree or higher qualification in science and engineering at BA / BSc, MA / PhD, PGCE levels
Exporter (UKIS)	Binary variable=1 if a firm sells its products in foreign markets, 0 otherwise
Survival 2017 year (BSD)	Binary variable=1 if a firm survived as an independent unit or as a part of a group until year 2017, 0 otherwise
Foreign (BSD)	Binary variable=1 if a firm has headquarters abroad, 0 otherwise
Reporting units (BSD)	Number of local units (subsidiaries within the enterprise group, both in the country and abroad)
R&D intensity (UKIS)	The amount of expenditure for internal Research and Development (000s), to total sales (000s pound sterling)
Appropriability (UKIS)	The degree of effectiveness of various legal and strategic methods for maintaining or increasing the competitiveness of product and process innovations rescaled from zero to one using the data on: patents, copyright, trademarks, secrecy, first entry (0 – not applicable or important to 3 – high)?
Software (UKIS)	The amount of expenditure for purchasing advanced machinery, equipment and software (000s) to total sales (000s pound sterling)

Source: UKIS- UK Innovation survey; BSD- Business Structure Database.

Table 3: Summary statistics for variables used in this study across three regions of the UK.

Region	South and East =9755 obs.		Midlands and Wales		North, Scotland and NI	
Variables	Mean	SD	Mean	SD	Mean	SD
Innovative sales	4.29	13.51	3.79	11.50	3.57	11.75
Knowledge spillover	0.26	0.27	0.26	0.26	0.27	0.27
Uncertainty	0.86	1.00	0.87	0.99	0.88	1.00
Risk	0.51	0.74	0.51	0.74	0.52	0.75
EQI	0.60	0.33	0.66	0.27	0.80	0.25
Start-ups	0.08	0.28	0.08	0.28	0.08	0.28
Age	17.17	9.94	17.66	10.02	18.07	10.15
Employment	4.13	1.62	3.90	1.40	3.91	1.40
Scientist	7.68	18.14	5.25	13.52	6.18	5.90
Exporter	0.35	0.47	0.34	0.47	0.33	0.47
Survival 2017 year	0.56	0.49	0.59	0.49	0.59	0.49
Foreign	0.44	0.49	0.41	0.49	0.41	0.49
Reporting units	1.38	2.34	1.48	2.90	1.40	2.56
Collaboration regional	0.13	0.33	0.13	0.34	0.13	0.34
Collaboration national	0.18	0.38	0.17	0.36	0.15	0.36
Collaboration international	0.12	0.33	0.10	0.30	0.09	0.29
R&D intensity	0.012	0.05	0.008	0.03	0.009	0.04
Appropriability	0.08	0.15	0.08	0.15	0.07	0.14
Software	0.01	0.04	0.01	0.04	0.01	0.04

Note: Number of observations: 13,712.
Source: UKIS- UK Innovation survey; BSD- Business Structure Database.

Table 4 –Tobit estimation of the knowledge spillover of entrepreneurship. Dependent variable: Innovation sales % to total sales

Region	South and East		Midlands and Wales		North, Scotland and NI	
Specification	(1)	(2)	(3)	(4)	(3)	(4)
Knowledge spillover β_1	79.76*** (5.31)	56.75*** (5.18)	69.42*** (5.91)	45.64*** (5.99)	72.55*** (5.33)	55.86*** (5.19)
Knowledge spillover squared	-54.68** (6.79)	-49.56 (5.79)	-45.95** (6.11)	-37.65*** (6.80)	-52.35** (6.10)	-52.74*** (6.00)
Uncertainty	3.45*** (.53)	3.55*** (.50)	2.31*** (.60)	1.56*** (.60)	2.83*** (.53)	2.26*** (.51)
Risk	2.97*** (.65)	1.36** (.63)	2.28*** (.73)	0.66 (.73)	3.45*** (.55)	1.62** (.63)
Collaboration regional		6.04*** (1.21)		3.41*** (1.39)		5.06*** (1.22)
Collaboration national		8.04*** (1.25)		7.71*** (1.45)		10.59*** (1.28)
Collaboration international		3.10** (1.35)		3.09** (1.61)		1.86 (1.47)
R&D intensity		61.31*** (7.19)		66.52*** (9.09)		56.88*** (7.73)
Appropriability		38.50*** (3.31)		31.99*** (3.03)		36.91*** (3.14)
Software		27.91*** (9.47)		54.35*** (9.95)		33.19*** (8.15)
Knowledge spillover x startups β_1 (H1/H2)		12.92*** (5.55)		10.95 (6.73)		6.01 (5.33)
EQI		0.87 (1.38)		1.31 (1.90)		0.23 (1.86)
Start-ups β_2	2.18 (2.16)	2.34 (2.76)	-6.99 (7.88)	-4.49* (2.61)	1.62 (2.21)	-4.49* (2.61)
Age	-0.99*** (.25)	-0.65*** (.23)	1.01*** (.27)	-0.41** (.29)	-0.60** (.25)	-0.03 (.24)
Age squared	0.01** (.00)	0.01** (.00)	0.02** (.00)	0.01 (.00)	0.01* (.00)	0.01 (.01)
Employment	-0.33 (.36)	-0.95*** (.33)	-1.05** (.25)	-1.31*** (.45)	0.11 (.40)	-0.93*** (.39)
Scientist	0.37*** (.02)	0.15*** (.02)	0.27*** (.03)	0.10*** (.03)	0.32*** (.06)	0.11*** (.02)
Exporter	15.19*** (1.06)	8.65*** (1.02)	15.69*** (1.20)	9.14*** (1.20)	11.94*** (1.07)	5.52*** (1.00)
Survival 2017 year	1.10 (.99)	0.25 (.94)	0.06 (1.10)	-1.44 (1.08)	2.37** (1.00)	0.62 (0.96)
Foreign	-2.94** (1.16)	-2.29** (1.12)	-2.90** (1.26)	-2.77** (1.29)	-3.47*** (1.00)	-1.38** (1.12)
Reporting units	0.17 (.18)	0.02 (.15)	-0.05 (.15)	-0.09 (.18)	-0.23 (.15)	-0.06 (.15)
Constant	-43.57** (4.07)	-42.50** (7.87)	-54.37** (9.45)	-52.62** (9.01)	-47.75** (5.20)	-46.37** (5.24)
N	9755	9755	5869	5869	9688	9688
Left censored	7250	7250	4529	4529	7686	7686
LR(chi2)	2290.15	3364.45	1255.02	1993.02	1783.12	2817.25
Pseudo R2	.081	.118	.071	.119	.061	.122

Note: reference category for legal status is Company (limited liability company), industry (mining), region (North East of England).
Robust standard errors are in parenthesis. The coefficients of the tobit regressions are the marginal effect of the independent variable on the probability of Knowledge spillover, knowledge collaboration, ceteris paribus. For dummy variables, it is the effect of a discrete change from 0 to 1.
Significance level: * p<0.05; ** p<0.01, *** p<0.001
S**ource:** UKIS- UK Innovation survey; BSD- Business Structure Database.

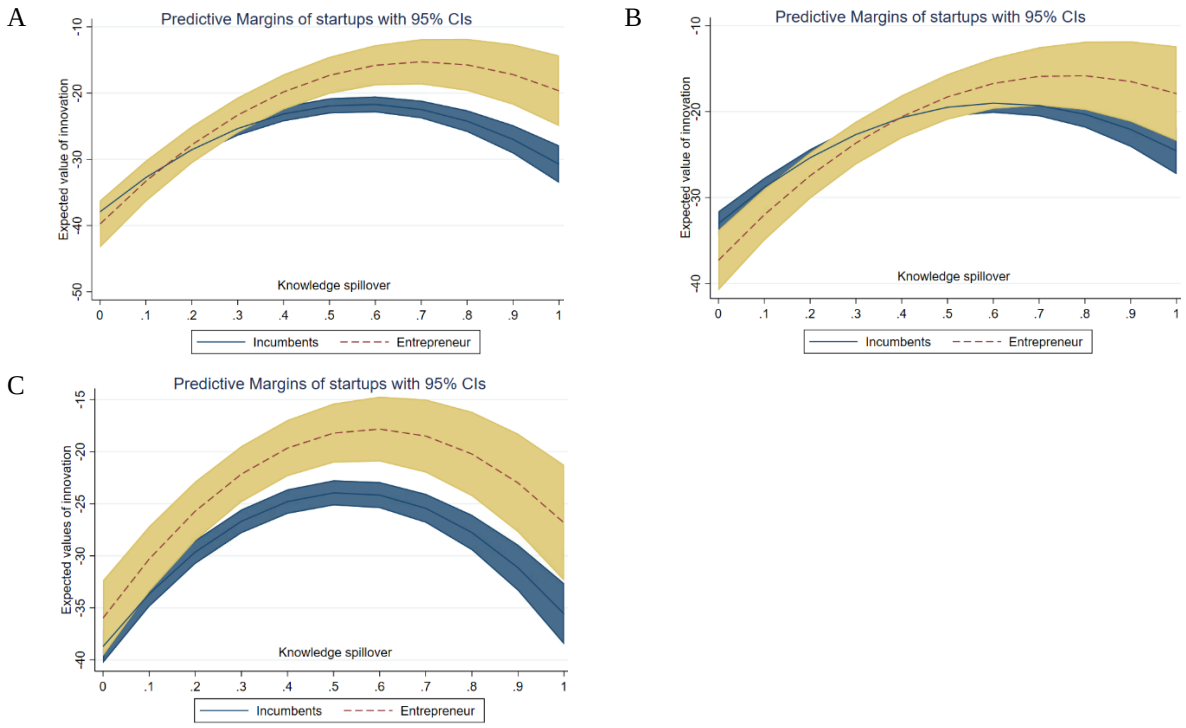

Figure 1: Knowledge spillover of entrepreneurship in the South (A), Midlands and Wales (B) and the North (North of England, Scotland and Northern Ireland) (C)
S**ource:** UKIS- UK Innovation survey; BSD- Business Structure Database.