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University Engagement and Productivity in Innovative SMEs: An Empirical Assessment

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University Engagement and Productivity in Innovative SMEs: An Empirical Assessment

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EXECUTIVE SUMMARY

Current debates around the nature of the innovation process increasingly stress its open character, whereby firms utilise knowledge and expertise from outside organisations. From the perspective of Small and Medium Enterprises (SMEs), open innovation allows the leveraging of additional resources which they would not necessarily be able to develop alone. In the context of open innovation, universities are often cited as important sources of external knowledge and key nodes within innovation systems due to their ability to generate and transfer new, cutting edge, knowledge.

The close relationship between firms' innovation and productivity is often cited as evidence that performance and innovativeness are interdependent. Thus, more innovative firms are those that are more productive and vice versa. However, less is known about how productivity levels may determine firm strategy, particularly with regards to the open innovation activities of SMEs. This poses the question, does the productivity of SMEs influence the likelihood that they will collaborate with a university?

This paper, therefore, examines the effect of SME productivity on their propensity to collaborate with universities and their subsequent productivity levels in the period following the collaboration. Using data from the Longitudinal Small Business Survey on 4289 innovative SMEs in the UK, the paper not only tests for the existence of a relationship but also whether they may be linear or non-linear.

The paper presents several important results. Firstly, the productivity of innovative SMEs does not influence their propensity to collaborate with universities. Therefore, collaborating with a university is not driven by the firms' performance but can instead be understood as a process that embraces all innovative SMEs. Secondly, the results suggest that the propensity for SMEs to collaborate with a university is positively influenced by the size of the firms' workforce, exporting, engagement in social networks, and openness. Conversely, family firms and those located in regions with higher levels of R&D expenditure were less likely to collaborate with a university. Furthermore, the propensity to collaborate with universities varies according to the SMEs' sector with SMEs in the transport, retail, and food sector less likely to collaborate with universities that those in the business services and construction and production sectors.

Finally, the analysis suggests that the relationship between initial productivity and the subsequent productivity of innovative SMEs in the years after engaging with a university is curvilinear, or U-shaped. Therefore, we observe higher levels of subsequent productivity for those SMEs whose starting productivity was either high or low. Thus, we conclude that while collaboration with universities has a positive effect on the subsequent productivity of the firms involved, it has the greatest impact on productivity is observed for those firms with either very high or very low starting productivity.

There are several implications of these findings. Firstly, we note that all innovative SMEs can be regarded as potential collaborators regardless of their productivity levels. Therefore, policymakers, academics, businesses, and technology transfer personnel should take a broad approach to the facilitation of these links. Secondly, it may also be appropriate for policymakers to focus their efforts on those innovative SMEs that are less likely to collaborate with universities such as family firms, those with fewer employees, and those that are less open. Thirdly, policymakers in regions with higher levels of expenditure on R&D may need to further encourage SMEs to collaborate with universities as a complementary activity to other linkages they may have. Fourthly, it may be pertinent for universities to work more closely with export promotion personnel in order to seek potential partners as it is these firms that are more likely to engage in university collaboration. Finally, the results suggest that university collaboration can provide a significant boost to SMEs with relatively lower levels of productivity, providing a clear message as to the potential transformational nature of this type of engagement.

Key words: SMEs; university collaboration; open innovation; productivity

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1. INTRODUCTION

Current debates on the nature of the innovation process increasingly stress its 'open' character, suggesting that firms are ever more reliant upon developing and engaging in inter-organisational networks to source knowledge (Chesbrough 2003; Hung & Chou 2013; Chesbrough 2017). From the perspective of Small and Medium-sized Enterprises (SMEs), open innovation allows the firm to leverage additional resources from external sources in order to diversify its offering (Colombo et al. 2014). Indeed, SMEs may be more suited to open innovation practices as their flexibility can enable them use different open innovation practices simultaneously (Spithoven et al. 2013). Although, due to their resource constraints innovative SMEs tend to focus more on inbound activities, i.e. they are more often knowledge seekers, looking to develop external links through which they may procure additional knowledge and expertise (Van de Vrande et al. 2009).

Within the open innovation framework, universities have become recognised as significant sources of external knowledge leading to their portrayal as key nodes within innovation systems (Ghio et al. 2016; Goddard et al. 2014). Indeed, collaborating with universities enables firms to leverage the knowledge and expertise they lack in order to enhance their competitiveness (Bishop et al. 2011). For firms then, collaborating with universities can have a significant impact on R&D, patenting, learning, and scope of their activities (Hagerdoorn et al. 2000; Abreu et al. 2008; Lööf & Broström 2006; Fontana et al. 2006). Therefore, the extant literature suggests a positive chain of causation from university collaboration to SME performance, through first stimulating their innovation activities (Hughes & Kitson 2012; Fontana et al. 2006; Vossen 1999), which, in turn, boosts their overall performance (Humphreys et al. 2005; McAdam & Keogh 2004; Gunday et al. 2011; Freel 2000).

Considering this evidence, the strategic decision for SMEs to collaborate with universities is, potentially, a simple one, given the benefits. However, in reality the engagement of innovative SMEs with universities is lower than for larger firms; as such, they are more prone to developing collaborative links with other actors such as customers and suppliers (Laursen & Salter 2004; Hughes & Kitson 2012; Scandura 2016; Lee et al. 2010). This lack of engagement may result from a deficiency of information regarding the knowledge and expertise possessed by potential university partners as well as their overall trustworthiness, compounded by the fact that SMEs may not possess sufficient resources to accurately assess the credibility of a potential

university partner (Hemmert et al. 2014; Johnston & Huggins 2018).

In order to contribute to the debate around the engagement of innovative SMEs with universities, this paper explores a new direction through examining potential links between their relative productivity and collaboration with universities. Specifically, the paper investigates whether variations in productivity among innovative SMEs both influence their propensity to collaborate with universities and their subsequent productivity levels. While there exists a close relationship between productivity and innovation (Griffith et al. 2006), suggesting that firm performance and innovativeness are interdependent, in an SME context there is still much that is not known regarding potential drivers of productivity or how productivity levels may determine firm strategy, particularly with regards to open innovation (Henley 2018). Indeed, solving 'the productivity puzzle' has been a persistent concern of the UK Government for a number of years (Porter & Ketels 2003; HM Government 2017).

Utilising data on UK SMEs from the Longitudinal Small Business Survey (LSBS), the analysis in this paper tests a set of hypotheses which examine three alternative perspectives on the nature of the relationship between productivity and university collaboration among innovative SMEs; 1) a linear relationship, such that increasing productivity is related to an increased propensity to collaborate with universities. Thus, university engagement among SMEs is a direct function of performance. 2) A non-linear U-shaped relationship, where the propensity towards university collaboration is highest among innovative SMEs at either end of the productivity spectrum, i.e. those whose productivity is either relatively weak or relatively strong. 3) A non-linear inverted U-shaped relationship, where the propensity to collaborate with universities among innovative SMEs is lowest for those whose productivity is relatively weak or relatively strong. As such, the analysis presented within this paper provides a clear insight into the open innovation practices of innovative SMEs and whether collaborating with universities is either the domain of lagging, leading or more ‘averagely’ productive firms.

The paper is organised as follows: Section 2 outlines the conceptual and theoretical background as well as the hypotheses under test. This is followed by Section 3, which outlines the data and the analytical techniques used in the analysis, and Section 4 that presented the results. Finally, Section 5 concludes and discusses the implications of the findings.

2. THEORY AND HYPOTHESES

2.1 Conceptual and Theoretical Background

Innovation, while regarded as important for promoting economic development (Fagerberg & Srholec 2008; Fagerberg et al. 2010), is also risky and costly endeavour for firms to engage in as it consumes both time and resources (Christensen 1997). In light of these constraints, the open innovation process, where firms utilise inter-organisational networks in order to procure knowledge from external resources, offers particular advantages for SMEs that may lack the resources to innovate in isolation through offering access to a broad range of knowledge and expertise outside of the firm's boundary (Chesbrough 2003; Enkel et al. 2009; Madrid-Guijarro et al. 2009).

Within the open innovation paradigm, the transfer of knowledge, expertise, and technology from universities is typically regarded as an important source of knowledge for firms (Perkmann et al. 2013; Ankrah et al. 2013; Trippl et al. 2015; Uyarra 2010). Indeed, engaging in the development of university-industry (U-I) links has been demonstrated to enhance firms' capabilities through allowing them to leverage the skills and knowledge that they lacked in order to enhance their competitiveness (Bishop et al. 2011). Furthermore, empirical work on the benefits of U-I links shows that firms may benefit from increased sales, research productivity, patenting, greater levels of learning, and broadening the scope of their activities (Hagerdoorn et al. 2000; Abreu et al. 2008; Lööf & Broström 2006; Fontana et al. 2006). In addition, universities are typically cited as 'safer' actors with which to collaborate (Powell et al. 1996), with their role as a knowledge generator being clearly defined and understood and perceived as less risky partners due to their focus on 'basic' research rather than its commercial application (Miotti & Sachwald 2003). As such, the utilisation of academic knowledge is now considered by both academics and policymakers to be an important input in the development of new ideas within firms (Lambert 2003; Wilson 2012).

Despite the benefits of engaging with universities, non-engagement is high, and significant barriers to collaboration still exist (Hughes & Kitson 2012). Indeed, SMEs are less likely to engage with universities (Laursen & Salter 2004; Giuliani & Arza 2009); although other studies report that firm size is insignificant (Petruzzelli 2011). In addition, the probability of failure has been found to be higher with university partners than for other organisations (Lhuillery & Pfister 2009), while others cite evidence that collaboration with universities has not had a significant effect on the level of R&D or

innovation within firms (Okamuro 2007). Thus, firms may benefit from this type of collaboration, but there is no guarantee that they will be successful. Consequently, considering the potential benefits to SMEs from collaborating with universities, it remains pertinent to understand the factors that underpin their engagement with universities in more detail.

2.2 SME Productivity and University Engagement

The question that motivates this paper concerns the relative productivity of SMEs that collaborate with universities. There exists substantial evidence of a positive relationship between productivity and innovation within SMEs (Crepon et al. 1998; Hall 2011; Hall et al. 2009; Griffith et al. 2006; Baumann & Kritikos 2016; Saunila 2014); thus SMEs that are more productive are, typically, also more innovative.

As collaborating with universities has been characterised as a strategic decision designed to enhance its competitiveness (Mindruta et al. 2016), the act of forming a collaborative link with a university appears to be motivated by both a desire and ability to increase a firm's performance. Accordingly, with this as a starting point, we examine the relationship between productivity and university collaboration among innovative SMEs from two perspectives. Firstly as a sign of innovativeness, the act of collaborating with a university can be interpreted as a sign of the quality of a firm's innovation efforts and depth of its knowledge base (Giuliani & Arza 2009; Powell & Owen-Smith 1998). Conversely, what if the act of engaging with a university was in fact a sign of an inherent weakness in firm's ability to innovate, an admission that the firm does not possess the knowledge and expertise to do so alone? Indeed, while the extant literature acknowledges there may be performance differences among universities, highlighting variations in the quality of the academic partner's knowledge and the research intensity of individual universities (Hewitt-Dundas 2012; Zahringer et al. 2017), there is less consideration of the relative performance of innovative SMEs and their propensity to engage with universities. Considering these arguments, we argue that the productivity of an SME may provide an indicator of its likely engagement with universities. As such, we illustrate three scenarios and present testable hypotheses for each.

Scenario 1: a linear relationship, where the propensity for innovative SMEs to engage with universities increases as their productivity increases. The basis for this approach is evidence that the productivity of an SME has been shown to be underpinned by its

innovativeness (Freel & Robson 2004; Hall et al. 2009). Indeed, the successful capture and exploitation of university knowledge requires that the relevant capabilities exist within the firm and that it also possesses the absorptive capacity to successfully use this knowledge (Agrawal 2001; Cohen & Levinthal 1990; Muscio 2007). In addition, factors that are typically associated with greater performance, such as openness and R&D intensity, have been shown to increase the propensity for firms to collaborate with universities (Bruneel et al. 2010; Laursen & Salter 2004; Laursen et al. 2011). Therefore, among innovative SMEs, those with relatively higher levels of productivity may be more likely to be collaborating with universities. This argument is tested in Hypothesis 1:

Hypothesis 1. There is a positive linear relationship between SME productivity and propensity to engage in university collaboration.

Scenario 2: a non-linear U-Shaped relationship, where those innovating SMEs that are most likely to collaborate with universities are those with relatively lower or relatively higher levels of productivity. Therefore collaborating with universities may be the result of the firms' needs and abilities, where the strategic decision to engage with a university is based on the need to address its weaknesses or consolidate its strengths (Mindruta 2013; Mindruta et al. 2016). For example, SMEs with lower productivity levels may be innovating but their lower productivity may be a sign that the firm lacks the resources and capabilities within the firm to do so alone. Therefore, these firms require a university partner in order to obtain the knowledge and expertise necessary to innovate. Conversely, higher levels of productivity within an SME may reflect the fact that the firm does possess the resources, capabilities, and networks to innovate alone and is therefore seeking to consolidate and extend its knowledge base with the external knowledge and expertise from universities (Cassiman & Veugelers 2006; Muscio 2007). This is tested through Hypothesis 2:

Hypothesis 2. There is a 'U-shaped' curvilinear relationship between SME productivity and university collaboration.

Scenario 3: a non-linear inverted U-shaped relationship, where among innovative SMEs those with relatively low and relatively high productivity levels are the least likely to engage with universities. In this scenario, therefore, those innovating SMEs with average levels of productivity are the SMEs that are most likely to collaborate with universities. This is based on the idea that innovative SMEs with lower productivity

levels are less likely to collaborate with universities as their innovation is more basic in nature and not cutting edge enough to involve a university (Griffith et al. 2006). Conversely, innovating SMEs with higher levels of productivity may not engage with universities as they already possess the required resources and capabilities to further improve their competitive position. In addition, they may also be members of extensive innovation networks and be collaborating with actors other than universities (Huggins, Johnston & Thompson 2012). Therefore, in this scenario it may be those SMEs that are near to the median in terms of productivity with the highest propensity to collaborate with universities. This is tested via Hypothesis 3:

Hypothesis 3. There is an inverted 'U'-shaped curvilinear relationship between SME productivity and university collaboration.

2.3 University Engagement and the Subsequent Productivity of SMEs

The second area we explore is the productivity levels for innovating SMEs subsequent to the collaboration. In evaluating the potential impacts of U-I linkages, scholars tend to focus on performance factors such as impacts on sales revenues, R&D activities, and innovative outputs (Soh & Subramanian 2014; Scandura 2016), or process factors such as project management, trust, balancing priorities, and collaborative environment (Perkmann et al. 2011; Schofield 2013; Barnes et al. 2002; Bruneel et al. 2010; Rybnicek & Königsgruber 2018).

The potential benefits to SMEs from university collaboration are broad. Firstly, gaining access to university knowledge has been demonstrated to promote the development of firms' capabilities through leveraging skills, knowledge, and resources into the business that it previously did not possess (Rutten et al. 2003; Huggins, Johnston & Stride 2012; Bishop et al. 2011; Kauffeld-Monz & Fritsch 2013). Thus, engaging in collaborative links with universities enables firms to access knowledge and expertise that they were not previously privy to leaving them better equipped to develop their capabilities and competitiveness (Bishop et al. 2011). Consequently, collaborating with universities has been found to promote increased sales, higher research productivity, greater levels of patenting activity, access to a broader range of external networks, higher levels of learning, and a broadening of the scope of the activities of the participating firms (Hagerdoorn et al. 2000; Abreu et al. 2008; Lööf & Broström 2006; Fontana et al. 2006; Eom & Lee 2010).

While some previous studies have suggested that smaller firms are subject to greater productivity gains from university collaboration than larger firms (Motohashi 2005), the picture is somewhat mixed as other studies report a lack of productivity gains (Eom & Lee 2010). In order to investigate this further, we seek to understand whether the productivity of innovating SMEs collaborating with universities is related to their starting productivity. Furthermore, given the mixed results observed in the extant literature, we posit that this relationship is curvilinear in nature. This is tested via Hypothesis 4:

Hypothesis 4. There is a curvilinear relationship between starting productivity levels and subsequent productivity levels for SMEs collaborating with universities.

3. METHODOLOGY

3.1. Data Sources

This section sets out the data sources and variables used to test the hypotheses developed in Section 2. Firstly, data on SMEs and their characteristics is derived from the Longitudinal Small Business Survey (LSBS) commissioned by the Department for the Business, Energy and Industrial Strategy (BEIS). The LSBS data used covers three annual returns: 2015, 2016, and 2017[1], with the total number of 18,774 firms covered. Its focus is on UK firms and gathers data covering issues pertaining to firm demographics, ownership, performance, location, capabilities, networks, and openness.

The paper focuses on innovative firms, defined here as those that introduced a new product, service or process in the 3 years that precede their survey response. In addition to that, the focus of this paper is on firms that collaborated with universities in the course of this innovation. As this question was only asked in the 2015 edition of the LSBS, the sample of innovative SMEs is limited to 7,750. As the study also focuses on the productivity of such firms, there are further limitations imposed on the data availability (given non-respondents). We define the productivity of firm *i* as its turnover in year *t* divided by employment in the same year:

$$Productivity_{it} = \frac{Turnover_{it}}{Employment_{it}}$$

[1] Detailed information about the survey available in BEIS (2018).

Of the sample of SMEs that were identified as innovating, 4,394 provided turnover data that was required for estimating productivity, falling to 2,626 for 2016, and to 1,541 for 2017.

3.2. Variables

Dependent variables

While university collaboration covers a broad range of interactions from actors within industry and academia (D'Este & Patel 2007; Perkmann & Walsh 2007; Ankrah & AL-Tabbaa 2015), the limitations of the LSBS mean that our dependent variable for Models 1-6 (UC) is binary in nature. Thus, it captures whether a firm reported that it had introduced an innovation in the previous 3 years through a collaboration with a university or other higher education institution. As this question was only asked in the 2015 version of the survey, we use this year as the starting point for our analysis.

Productivity (Prod20xx) denotes firm productivity for particular years. In the regression analysis it is expressed as a natural logarithm. Productivities used are reported in real terms using ONS deflators with 2015 as the base year. In addition, where productivity is utilised as an independent variable it is calculated as above and SqProductivity represents its squared term.

Independent variables

In order to provide a holistic examination of the propensity for SMEs to engage with universities, we also consider their capabilities and openness as these are also highlighted within the extant literature as important factors in the development of U-I links. Firstly, the capabilities of the firm reflect a larger knowledge base with which to utilise for innovative activities; thus, greater capabilities typically promote innovativeness and also increase the propensity for SMEs to develop U-I linkages (Giuliani & Arza 2009). We therefore include a variable comprised of a set of five ordinal-type measures focussed on: a) people and management, b) developing and implementing a business plan and strategy, c) developing and introducing new products or services, d) accessing external finance, e) operational management. These are measured on a scale of 1-5, with 5 representing the higher level of capabilities.

Secondly, the openness of a firm, i.e. its receptiveness to developing external networks and creating linkages with external organisations also has a positive influence on the

propensity to engage in collaborative links with universities (Zeng et al. 2010; Fontana et al. 2006; Laursen et al. 2011). Therefore, we developed a variable that captures the number of partners each SME reports collaborating with on its innovations, expressed as a proportion of the number of types of partners a firm collaborated with from the following: a) other businesses within firm's enterprise group, b) suppliers of equipment, materials, services or software, c) clients or customers from the private sector, d) clients or customers from the public sector, e) competitors or other businesses in the firm's industry, f) consultants, commercial labs or private R&D institutes, g) universities or other higher education institutions, h) government or public research institutes.

Finally, in order to assess the influence of the SMEs' networks (Huggins et al. 2012), a set of dummies that capture different types of networks a firm engaged with were used. These captured a broad range of networking through a) social media business networks, b) local chambers of commerce, c) formal business networks, d) informal business networks, e) other types of networks. The reference category in each case is if the firm did not participate in a specific network type.

Control Variables

In order to provide a robust test of our hypotheses several control variables were used in the model. The values of these variables are those that were reported in the 2015 survey. Firstly, as the resource base of firms has been linked to performance (Wernerfelt 1984; Barney 1991) we control for differences through including variables for firm size, measured as the number of employees, the total number of sites the firm operates from, the number of directors, and age, captured on an ordinal scale from 0-9 as no continuous variable was available in the 2015 version of the LSBS.

Beyond firm size, a set of control variables were used to capture other characteristics of the SMEs. Firstly, legal status was included as a dummy taking a value of 1 if the firm was registered as a limited company or 0 otherwise. Secondly, as the extant literature suggests that different sectors have varying propensities to engage with universities (D'Este & Patel 2007; Johnston & Huggins 2016; Lawton Smith & Bagchi-Sen 2006; Giuliani & Arza 2009) a set of three dummies that control for the firm's sector were included. These took the value of 1 if the firm operated within a given sector or 0 otherwise. The firms were assigned into broad sectoral groups as follows: 1) production and construction, 2) transport, retail and food, 3) business services. The reference category in each case is other sectors. Thirdly, given that substantial

evidence that exporters are more innovative in general (Roper & Love 2002; Love & Roper 2015), a dummy variable controlling for a firm's exporting activity was included, taking the value of 1 if the firm exported goods or services, or 0 otherwise. Fourth, as family businesses have been found to follow different innovation strategies to non-family owned businesses as well as organisation of the process (Massis et al. 2015) a dummy variable controlling for the character/ownership of the firm was included. This took a value of 1 if the firm is a family business and 0 otherwise.

As prior evidence also suggests that the performance and innovation characteristics of female led firms differ (Mari et al. 2016; Fuentes-Fuentes et al. 2015; Blake & Hanson 2005), we included a dummy variable taking the value of 1 if over 50% of the firm is owned by women and 0 otherwise to account for this. Along with gender, there is also evidence to suggest that firms led by ethnic minority owners may influence the performance of a firm (Nathan & Lee 2013; Wang & Altinay 2012). Therefore, a dummy taking value of 1 if the firm belongs to an ethnic minority business owner and 0 otherwise was included.

Location characteristics

We also control for the location characteristics of the firms. For this, we firstly utilised data captured in the LSBS on whether the SMEs were based in urban areas through including a dummy taking value of 1 if the firm is based in an urban area and 0 otherwise. The LSBS also lists the broader region (Government Office or NUTS 1) for each SME, allowing us to control for their wider socio-economic characteristics in the analysis. In order to do so, regional data on gross value added (GVA) per capita, government expenditure on research and development (GERD) per capita, regional employment levels, and industrial structure was obtained from the Office for National Statistics (ONS) and matched to each SME. While the first three are self-explanatory, our industrial specialisation measure requires further explanation. This was adopted from Fotopoulos (2014) and Huggins and Thompson (2017), and calculates the industrial specialisation of a region across 14 sectors in comparison to the rest of the country. A similar regional-level approach was used in Prokop et al. (2019), where a detailed description of the variable construction is available.

Table 1: Descriptive statistics

	Mean	Standard Deviation
UC (0/1)	0.134	
Prod2015	131561.52	354025.72
Size	36.68	45.41
No. of sites	2.20	10.56
Age	8.08	1.54
Legal status (0/1)	0.825	
Sector: production and construction (0/1)	0.234	
Sector: transport retail and food sectors (0/1)	0.232	
Sector: business services (0/1)	0.323	
Exporter (0/1)	0.340	
Family business (0/1)	0.561	
No. of directors and partners	7.25	246.21
Women-led (0/1)	0.177	
MEG-led (0/1)	0.049	
Urban-based (0/1)	0.750	
GVA per capita	26088.27	7926.57
Employment	3033.72	1136.71
GERD per capita	512.17	202.15
Industrial Specialisation	0.07	0.04
People management	4.07	0.75
Developing and implementing a business plan and strategy	3.87	0.87
Developing and introducing new products or services	3.83	0.90
Accessing external finance	3.39	1.26
Operational improvement	3.95	0.82
Social media	0.619	
Local Chamber of Commerce	0.293	
Formal business network	0.428	
Informal business network	0.352	
Other	0.023	
Openness	0.21	0.14

3.3. Analytical approach

Two statistical techniques were employed in this study. First, bivariate tests of difference were used to inspect the relationships between the variables and whether the firm collaborated with a university to introduce its innovation. The tests inspect a number of key variables describing the following firm characteristics: productivity, openness, capabilities, networks, and regional economic environment. Given that the diagnostic tests established that these variables were not normally distributed, non-parametric Mann-Whitney U-tests were employed. The results are reported in Appendix 1.

Second, the regression analyses the hypothesised relationships between SMEs' collaborative innovation with universities and productivity. Whilst a panel technique would be more desirable given the longitudinal character of the LSBS, the question

pertaining to university collaboration was only asked in the first run of the survey. This inconsistency in questionnaire deployment across different runs of the survey imposes limitations on the sample size and consequently dictates a non-panel-based statistical approach. After inspecting the models for collinearity issues, regional employment, GVA per capita, and industrial specialisation were identified as problematic, recording high values for variance inflation factors (above 10). To overcome this, we enter regional employment and GVA per capita in separate models, which overcomes the issue by bringing down the VIF values for the variables to conventionally acceptable levels (i.e. all were below 4).

The first part of the analysis uses a logit model (1) to assess the probability that firm i innovated through a collaboration with university by observing its level of productivity. The models take the following form:

$$(1)\ UC_{it} = \alpha + \beta_1 FC_{it} + \beta_2 RC_{it} + \beta_3 Prod_{it} + \varepsilon_i$$

where, UC_i captures whether firm i collaborated with a university on innovation or not, α is a constant parameter, β represents model coefficients, FC_i denotes firm controls, RC_i its regional characteristics, whilst $Prod_i$ the productivity of firm i. Finally, ε_i captures the variance unaccounted for by the model.

The next Model (2) examines the probability of firms innovating through collaboration with universities by examining their capabilities, openness, and networks. The models employed take the following logit form:

$$(2)\ UC_i = \alpha + \beta_1 FC_i + \beta_2 RC_i + \beta_3 Prod_i + \beta_4 Cap_i + \beta_5 Open_i + \beta_6 Net_i + \varepsilon_i$$

where Cap_i denotes a set of capabilities of firm i, $Open_i$ measures its openness, whilst Net_i depicts its networks.

The second set of models (3) and (4) employ OLS regressions to test whether future productivity of SMEs that collaborated with universities is related to initial productivity levels. This is examined in two scenarios. The first scenario (3) depicts a 1-year lagged productivity, with the dependent variable being the 2016 productivity:

$$(3)\ Prod_{i,t} = \alpha + \beta_1 FC_{i,t-1} + \beta_2 RC_{i,t-1} + \beta_3 Prod_{i,t-1} + \varepsilon_i$$

where $Prod_{i,t}$ denotes the productivity of firm i in year $t = 2016$, $FC_{i,t-1}$ are firm

controls in year $t-1$, $RC_{i,t-1}$ are regional characteristics in year $t-1$, and $Prod_{i,t-1}$ represents productivity in year $t-1$.

The second scenario (4) models a 2-year lagged productivity, with the dependent variable being the productivity reported in 2017:

$$(4)\ Prod_{i,t} = \alpha + \beta_1 FC_{i,t-2} + \beta_2 RC_{i,t-2} + \beta_3 Prod_{i,t-2} + \varepsilon_i$$

where $Prod_{i,t}$ denotes the productivity of firm i in year $t = 2017$, $FC_{i,t-2}$ are firm controls in year $t-2$, $RC_{i,t-2}$ are regional characteristics in year $t-2$, and $Prod_{i,t-2}$ represents productivity in year $t-2$.

4. RESULTS

In total, 13.55% of the innovating SMEs in the survey reported that they had collaborated with universities or higher education institutions. Table 4.1 provides a comparison with other sources of collaboration, highlighting the fact that innovative SMEs are less likely to collaborate with universities than other potential partners such as suppliers (57.99%) or private sector customers (42.19%).

Table 3: SMEs' Collaborative Partners.

Partner in Collaboration	Proportion of firms
Suppliers of equipment, materials, services or software	57.99%
Clients or customers from the private sector	42.19%
Clients or customers from the public sector	27.44%
Other businesses within enterprise group	27.08%
Competitors or other businesses in the same industry	21.24%
Consultants, commercial labs or private R&D institutes	19.38%
Universities or other higher education institutions	13.55%
Government or public research institutes	6.60%

N=4406 (Source: LSBS 2015)

We first examine the results from the logistic regression model regarding innovating SMEs' propensity to collaborate with universities. The results, presented in Table 4, show that no linear relationship between SME productivity levels and university collaboration exists (Models 1 and 2). Adding a squared term for productivity to account for non-linearity (Models 3 and 4) again shows no statistically significant result. Consequently, we reject hypotheses 1-3 as there is no relationship between the

productivity levels of innovating SMEs and their propensity to collaborate with universities.

While productivity levels are not related to the propensity of innovating SMEs to collaborate with universities, several other variables were found to be statistically significant. The estimated coefficients for the firm's size, its legal status, the sector in which it operates, whether it exports its output and whether it was a family-owned business were all found to have an impact on university engagement. We find evidence that employment levels within the firm are positively related to university collaboration, thus innovating SMEs with higher numbers of employees are more likely to collaborate with a university.

In addition, the analysis suggests that innovating SMEs registered as limited companies are more likely to collaborate with universities than other legal forms; while we also find evidence that the propensity to collaborate varies according to sector. Furthermore, the positive coefficient on the exporting variable suggests that SMEs that are both innovators and exporters are more likely to be involved in university collaboration. Conversely, the negative coefficient on the family-owned business variable suggests that this type of innovative SME is less likely to collaborate with universities.

In terms of location, our results suggest that the propensity to collaborate with a university is more common for SMEs residing in regions with lower levels of GERD per capita. We find no evidence that other regional characteristics such as GVA per capita, employment levels or industrial specialisation influence the propensity of SMEs to collaborate with universities.

Models 5 and 6 then expand the initial models to examine the broader characteristics of innovating SMEs in terms of capabilities and openness. Here we find that the coefficients on the variables that capture the capabilities of the firm are not statistically significant, thus do not influence the propensity to collaborate with a university. In contrast, the results suggest that both the SMEs' engagement through social networks and overall openness towards networking have a positive effect on its propensity to collaborate with a university. Thus, the openness of innovating SMEs has a positive effect on university collaboration. However, as the quadratic term is not significant, the relationship is linear.

Table 4: Logit regressions of innovation collaboration with universities.

	Model 1			Model 2			Model 3			Model 4			Model 5			Model 6		
	B	S.E.	p	B	S.E.	p	B	S.E.	p	B	S.E.	p	B	S.E.	p	B	S.E.	p
Prod2015	-0.029	(0.038)		-0.029	(0.038)		-0.028	(0.047)		-0.028	(0.047)		-0.085	(0.071)		-0.084	(0.071)	
sqProd2015							0.000	(0.013)		0.000	(0.013)		-0.033	(0.025)		-0.033	(0.025)	
Emp	0.003	(0.001)	***	0.003	(0.001)	***	0.003	(0.001)	***	0.003	(0.001)	***	0.003	(0.001)	**	0.003	(0.001)	**
Sites	0.001	(0.004)		0.001	(0.004)		0.001	(0.004)		0.001	(0.004)		-0.005	(0.010)		-0.005	(0.010)	
Age	-0.013	(0.032)		-0.013	(0.032)		-0.013	(0.032)		-0.013	(0.032)		0.079	(0.049)		0.078	(0.049)	
Status	0.379	(0.136)	***	0.379	(0.136)	***	0.379	(0.136)	***	0.379	(0.136)	***	0.147	(0.199)		0.147	(0.199)	
Sector: prod/con	-0.531	(0.147)	***	-0.531	(0.147)	***	-0.532	(0.149)	***	-0.531	(0.149)	***	-0.247	(0.222)		-0.248	(0.222)	
Sector: tran/ret/food	-1.086	(0.163)	***	-1.086	(0.163)	***	-1.087	(0.164)	***	-1.087	(0.164)	***	-0.715	(0.237)	***	-0.717	(0.237)	***
Sector: busserv	-0.523	(0.131)	***	-0.523	(0.131)	***	-0.523	(0.132)	***	-0.524	(0.132)	***	-0.306	(0.193)		-0.306	(0.193)	
Exporter	0.381	(0.105)	***	0.381	(0.105)	***	0.381	(0.106)	***	0.381	(0.106)	***	0.425	(0.157)	***	0.426	(0.157)	***
FamBus	-0.487	(0.098)	***	-0.486	(0.098)	***	-0.487	(0.098)	***	-0.486	(0.098)	***	-0.339	(0.146)	**	-0.337	(0.146)	**
Directors	0.000	(0.000)		0.000	(0.000)		0.000	(0.000)		0.000	(0.000)		-0.014	(0.018)		-0.014	(0.018)	
Wom	0.026	(0.123)		0.026	(0.123)		0.026	(0.123)		0.027	(0.123)		-0.033	(0.187)		-0.033	(0.187)	
MEG	0.325	(0.209)		0.325	(0.209)		0.325	(0.209)		0.325	(0.209)		0.269	(0.287)		0.273	(0.287)	
Urb	0.004	(0.113)		0.004	(0.113)		0.004	(0.113)		0.004	(0.113)		0.114	(0.167)		0.119	(0.167)	
Reg GVA 2015	0.000	(0.000)					0.000	(0.000)					0.000	(0.000)				
Reg Emp 2015				0.000	(0.000)					0.000	(0.000)					0.000	(0.000)	
GERD 2015	-0.001	(0.000)	**	-0.001	(0.000)	**	-0.001	(0.000)	**	-0.001	(0.000)	**	-0.001	(0.000)	**	-0.001	(0.000)	**
IndSpec 2015	-0.737	(1.943)		-1.115	(1.395)		-0.738	(1.944)		-1.116	(1.396)		-2.412	(3.003)		-3.307	(2.078)	
Cap 1: Peopman													-0.077	(0.117)		-0.078	(0.117)	
Cap 2: plan and strategy													0.050	(0.096)		0.050	(0.096)	
Cap 3: new prod/ser													-0.051	(0.084)		-0.051	(0.084)	
Cap 4: fin													0.009	(0.063)		0.009	(0.063)	
Cap 5: Ops													-0.036	(0.096)		-0.036	(0.096)	
Social media													0.355	(0.152)	**	0.356	(0.152)	**
Chamber													-0.115	(0.148)		-0.116	(0.148)	
Fnet													0.230	(0.140)	*	0.230	(0.140)	*
Inet													0.034	(0.139)		0.034	(0.139)	
Other													0.293	(0.390)		0.294	(0.390)	
Openness													10.720	(0.887)	***	10.723	(0.888)	***
sqCap1													-0.044	(0.056)		-0.044	(0.056)	
sqCap2													0.086	(0.065)		0.086	(0.065)	
sqCap3													-0.105	(0.077)		-0.105	(0.077)	
sqCap4													-0.015	(0.073)		-0.016	(0.073)	
sqCap5													-0.051	(0.068)		-0.051	(0.068)	
sqOpenness													-0.033	(0.054)		-0.033	(0.054)	
Constant	-0.876	(0.502)	*	-0.886	(0.502)	*	-0.882	(0.574)		-0.891	(0.574)		-3.386	(1.059)	***	-3.411	(1.060)	***
Observations	4289			4289			4289			4289			2849			2849		
DF	18			18			19			19			35			35		
H-L test	7.374			6.739			7.375			7.423			10.243			11.085		
-2LL	3222.625			3222.646			3222.624			3222.646			1546.071			1545.936		
Nagelkerke R Square	0.068			0.068			0.068			0.068			0.412			0.412		

* significant at the 10% level; **significant at the 5% level; *** significant at the 1% level

The remainder of this section presents the results of the OLS regression models assessing the factors underpinning the subsequent productivity levels within innovating SMEs. The results, presented in Table 5, show estimates for a 1-year lag on productivity using data from 2016 as the dependent variable (Models 5 and 6), and estimates for a 2-year lag on productivity, using data from 2017 as the dependent variable (Models 7 and 8). All models show a significant and positive effect of starting productivity on the SMEs' subsequent productivity in the years following their collaboration with a university. Importantly, the coefficients on the quadratic variables are also positive and significant, indicating the existence of a curvilinear, U-shaped, relationship. Consequently, Hypothesis 4 is confirmed.

Thus, while the subsequent productivity levels of innovative SMEs engaging with universities is positively influenced by its initial productivity, the curvilinear relationship suggests that higher levels of subsequent productivity are observed among those SMEs where starting productivity was either relatively low or high. As such, this evidence suggests that for those innovative SMEs engaging in collaborative links with universities, subsequent productivity is higher for those that had either relatively low or relatively high productivity at the outset. Thus, collaboration with universities appears to have a transformative effect on SMEs with relatively lower initial levels of productivity and a maintenance effect for SMEs with relatively higher levels of initial productivity.

In addition, there is also evidence that the subsequent productivity of SMEs collaborating with universities is not uniform and varies according to their broad industrial sector. However, this appears to be a short-term effect as it is only observed over the course of one year (Models 5 & 6). Finally, in the longer term, higher levels of productivity within SMEs that have collaborated with a university is also positively influenced by whether the firm is an exporter.

Table 5: OLS regressions of productivity with 1-year lag (2016) – models 5 and 6, and 2-year lag (2017) – models 7 and 8.

	Model 5			Model 6			Model 7			Model 8		
	B	S.E.	p	B	S.E.	p	B	S.E.	p	B	S.E.	p
Productivity2015	0.887	(0.027)	***	0.888	(0.027)	***	0.907	(0.049)	***	0.906	(0.049)	***
sqProductivity2015	0.063	(0.028)	**	0.063	(0.028)	**	0.116	(0.052)	**	0.115	(0.052)	**
Size	0.000	(0.002)		0.000	(0.002)		-0.001	(0.002)		-0.001	(0.002)	
No. of sites	0.001	(0.000)	*	0.001	(0.000)	*	0.000	(0.001)		0.000	(0.001)	
Age	0.000	(0.016)		0.000	(0.016)		0.009	(0.027)		0.009	(0.027)	
Legal status dummy	-0.069	(0.061)		-0.069	(0.061)		0.213	(0.116)	*	0.211	(0.116)	*
Sector: production and construction	0.230	(0.068)	***	0.226	(0.068)	***	0.011	(0.113)		0.010	(0.112)	
Sector: transport retail and food sectors	0.190	(0.083)	**	0.189	(0.083)	**	0.223	(0.132)	*	0.222	(0.131)	*
Sector: business services	0.151	(0.060)	**	0.150	(0.060)	**	-0.049	(0.102)		-0.049	(0.102)	
Exporter	0.020	(0.048)		0.019	(0.048)		0.237	(0.081)	***	0.239	(0.080)	***
Family business	-0.056	(0.046)		-0.056	(0.046)		0.064	(0.074)		0.066	(0.074)	
No. of directors and partners	0.000	(0.007)		0.000	(0.007)		-0.012	(0.013)		-0.012	(0.013)	
Women-led	0.003	(0.057)		0.003	(0.058)		0.001	(0.095)		-0.000	(0.095)	
MEG-led	-0.230	(0.120)	*	-0.229	(0.120)	*	-0.000	(0.248)		0.003	(0.247)	
Urban-based	-0.036	(0.051)		-0.035	(0.051)		-0.007	(0.084)		-0.004	(0.084)	
Regional characteristics												
GVA per capita 2015	0.000	(0.000)					0.000	(0.000)				
Employment in thousands 2015				0.000	(0.000)					0.000	(0.000)	
GERD per capita all performance sectors 2015	0.000	(0.000)		0.000	(0.000)		0.000	(0.000)		0.000	(0.000)	
Industrial Specialisation 2015	-0.389	(0.922)		0.038	(0.644)		2.780	(1.600)	*	1.816	(1.082)	*
Constant	0.571	(0.432)		0.574	(0.433)		1.252	(0.777)		1.260	(0.774)	
N	258			258			154			154		
DF	18			18			18			18		
R Square	0.888			0.887			0.861			0.862		
Adjusted R Square	0.879			0.879			0.843			0.843		

* significant at the 10% level; **significant at the 5% level; *** significant at the 1% level

5. DISCUSSION AND CONCLUSIONS

The focus of this paper was twofold: 1) to assess whether the productivity of innovative SMEs provided a reliable indicator of their propensity to collaborate with universities in the course of its innovative activities; and 2) to assess the relationship between initial levels of productivity and subsequent productivity levels for innovative SMEs collaborating with universities.

Using data from the Longitudinal Small Business Survey (LSBS), our empirical analysis tested several hypotheses related to these questions. The paper, therefore, makes several contributions. Firstly, we find that productivity is not a determinant of collaboration with universities for innovative SMEs; thus, collaborating with a university is not driven by the firms' relative performance. As such, it is not the case the collaboration with universities is the domain of either relatively weak or relatively strong firms, it is a process that embraces all innovative SMEs regardless of performance.

The second contribution of the paper is that the analysis suggests that the propensity for SMEs to collaborate with universities is affected instead by the characteristics of the firm and its location. We find that higher levels of employment within the firm, exporting activity, engagement in social networks, and openness all have a positive influence on the propensity to collaborate with a university. Conversely, family firms and those located in regions with higher levels of R&D expenditure were less likely to collaborate with a university. Finally, the propensity to collaborate with universities varies according to the SMEs' sector.

The paper's third contribution focuses on the linear/non-linear nature of the relationships between productivity and university collaboration, and the rejection of all three hypotheses concerning each potential relationship. The SMEs' capabilities had no effect (linear or non-linear) on their propensity to collaborate with universities. Finally, while the openness of the firms had a significant effect, we found no evidence to suggest this is a curvilinear relationship; thus, there is no optimum level of openness for innovative SMEs.

The paper's fourth contribution focuses on the subsequent productivity of innovative SMEs in the years after engaging with a university, where we find evidence of a curvilinear, U-shaped, relationship between the initial productivity of the firms and their productivity in the following two years. Thus, for those innovative SMEs that have

collaborated with universities in the previous three years we see higher subsequent productivity for those firms that started out with either relatively high or relatively low productivity. Therefore, we conclude that for SMEs, university collaboration maintains the high productivity of high performing firms and transforms the productivity of lower performing firms, and accordingly Hypothesis 4 is accepted.

This result suggests that the potential gains from collaborating with universities may be more nuanced than previously envisaged; for SMEs with relatively lower productivity the knowledge and expertise leveraged from their university partner has a greater marginal effect. The lower productivity levels may reflect a lack of knowledge resources within the firm; therefore, university collaboration is a greater learning experience for these firms and induces a larger change in productivity. As such, we suggest that among innovative SMEs, lower relative productivity reflects a capacity to learn from their university partner and absorb their knowledge and expertise effectively in order to boost performance.

In the case of SMEs with higher relative productivity, university collaboration allows them to maintain their performance levels through augmenting their knowledge resources. Thus, higher levels of productivity among innovative SMEs may reflect an ability to effectively utilise knowledge from their university partners in order to maintain their competitive position.

Indeed, the results make a clear contribution to the extant literature, which highlights the fact that collaborating with a university enables firms to leverage the knowledge and expertise they lack in order to enhance their competitiveness (Bishop et al. 2011). Accordingly, these results suggest that the gains from this process may be uneven and are dependent on the initial competitiveness of the firm. However, it is also clear that there are no performance losses associated with SMEs engaging with universities; university engagement has a positive effect on subsequent SME performance.

The result that characteristics such as size, in terms of employment, and openness both have a significant and positive effect on university collaboration reaffirms previous evidence in the extant literature (Laursen & Salter 2004; Laursen et al. 2011; Lawton Smith & Bagchi-Sen 2006; Johnston & Huggins 2016). The paper also highlights additional evidence of the close relationship between exporting and innovation (Love & Roper 2015). Therefore, it may be that exporting is a significant push factor for these innovative SMEs towards the development of new products and services due to facing

increased competition, which drives them to collaborate with universities.

The characteristics of the innovative SMEs' location reveal interesting effects on their collaboration with universities. The extant literature suggests that more dynamic regions tend to be more innovative and possess denser networks (Huggins et al. 2014), factors that promote collaboration between firms and universities (Huggins et al. 2008). However, the results suggest that the economic performance of the firms' region has little effect on its behaviour, evidenced by the fact that both coefficients on the GVA per capita and employment variables are insignificant. The only regional variable that influenced the propensity to engage with universities was the level of GERD, and this had a negative effect. Thus, innovative SMEs located in regions where expenditure on R&D is relatively lower are more likely to collaborate with universities. This suggests that engagement with universities may act as a substitute for other knowledge creating organisations. Indeed, the fact that a greater proportion of innovative SMEs typically collaborate with other actors such as suppliers and customers than universities gives credence to this argument.

The implications of these results for policymakers suggest that the development of collaborative linkages between innovative SMEs and universities is not about focussing on those that are more productive but taking a broad approach to include all innovators. Furthermore, it may be more useful for policymakers to focus their efforts on those SMEs that innovate but are less likely to collaborate with universities such as family firms, those with fewer employees, and those that are less open. Furthermore, policymakers in regions with higher levels of GERD may need to further encourage SMEs to collaborate with universities, providing a complement to other sources of knowledge they may utilise.

For technology transfer officers within universities the result that innovative SMEs collaborate with universities regardless of performance suggests that in order to find partners it is advisable to examine all innovative SMEs. In addition, it may be pertinent for universities to work more closely with export promotion personnel in order to seek potential partners as it is these firms that are more likely to engage in university collaboration. However, as the results suggest that engagement with universities among innovative SMEs is still lower than for other actors, there is still work to be done to encourage greater levels of interaction between SMEs and universities. The results highlight the existence of clear performance gains for SMEs with lower relative productivity, a result that can be used to showcase the transformational role

universities can play for firms. In addition, tackling the potential barriers to collaboration that may exist through putting in place a framework that facilitates effective collaboration between SMEs and universities given their differing motivations and focus, plus or providing information as to the potential benefits to SMEs from this type of collaboration would appear to be a sensible first step (Siegel et al. 2003; O'Reilly & Cunningham 2017; Hewitt-Dundas & Roper 2017). Indeed, as prior collaboration with universities has been shown to promote the formation of U-I links, it may be the case that once the initial barriers are overcome then innovative SMEs will form lasting relationships with universities (Hewitt-Dundas et al. 2019).

Finally, while the findings presented in this paper make several contributions to the extant literature, several limitations must be noted. Firstly, as the dataset only records whether a SME has collaborated with a university or otherwise we do not have the specific details of their university partner, the nature of the interaction, the spatial reach of the relationship, and the governance of the relationship, factors that have been shown to be important determinants of U-I links (Lee & Cavusgil 2006; Bishop et al. 2011; Hewitt-Dundas 2012; D'Este et al. 2013; Abramovsky & Simpson 2011). Indeed, while we have presented new insights into the performance of SMEs and their collaboration with universities we acknowledge that as U-I linkages encompass a broad variety of links (D'Este & Patel 2007; Perkmann et al. 2013) and their formation is a complex process (Johnston & Huggins 2018) more research should be pursued in terms of whether the productivity of innovative SMEs influences the type of collaborations they undertake with universities, the types of university they partner with, and the spatial scope of such linkages. Finally, further research into the mechanisms through which university engagement influences productivity changes within SMEs is required in order to more clearly understand the processes through which this occurs.

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APPENDIX

Table A1: Bivariate tests of innovative firms and their university collaboration activity

Variable	University collaboration Mean/% Yes	University collaboration Mean/% No	Test coefficient		N	Test
Productivity 2015	115246.02	136875.20	1074482.00		4394	U-test
Productivity 2016	103165.15	126129.93	366772.50	***	2626	U-test
Productivity 2017	111496.05	136087.62	128114.00	***	1541	U-test
Openness	0.38	0.18	1047511.50	***	7750	U-test
Capabilities						
People management	4.17	4.15	2082923.50		5957	U-test
Developing and implementing a business plan and strategy	3.96	3.85	3111347.50	***	7647	U-test
Developing and introducing new products or services	3.96	3.86	2971526.00	***	7400	U-test
Accessing external finance	3.45	3.30	1794242.50	***	5689	U-test
Operational improvement	4.02	3.99	3177534.50		7543	U-test
Networks						
Social media	49.46%	9.02%	57.17	***	6982	Chi-square
Local Chamber of Commerce	19.13%	3.71%	20.83	***	6982	Chi-square
Formal business network	31.14%	6.69%	87.49	***	6982	Chi-square
Informal business network	28.86%	5.61%	38.07	***	6982	Chi-square
Other	1.85%	0.34%	1.10		6982	Chi-square
Regional characteristics						
GVA per capita	26160.71	26102.64	3344824.00		7750	U-test
GERD per capita all performance sectors	496.20	515.05	3242854.00	**	7750	U-test
Employment	3014.22	3045.80	3333328.00		7750	U-test
Industrial Specialisation	0.070	0.068	3232199.00	**	7750	U-test

significant at the 5% level; * significant at the 1% level

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